HIGH SPEED GROUND TRANSPORTATION ALTERNATIVES STUDY

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U.S. DEPARTMENT OF TRANSPORTATION
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16. Abstract

A comprehensive analysis is provided of the economic, technological, and institutional factors involved in implementing Improved Passenger Train service and High Speed Tracked Levitated Vehicle Systems in the United States. The study concludes that the potential benefits and markets are sufficient to warrant Federal activity in Research & Development for both. Of special note is the evaluation of system viability and benefits under future situations involving serious petroleum fuel shortages.

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ABSTRACT

The High Speed Ground Alternatives Study was undertaken in response to a request by the Under Secretary of Transportation for a comprehensive analysis of the economic, technological and institutional factors involved in implementing Improved Passenger Train service and high speed Tracked Levitated Vehicle Systems in the United States. The study concludes that the potential benefits and markets are sufficient to warrant Federal activity in Research and Development for both. Of special note is the evaluation of system viability and benefits under future situations involving serious petroleum fuel shortages.

FOREWORD

The High Speed Ground Transportation (HSGT) Alternatives Study was performed under the sponsorship and direction of the Office of the Assistant Secretary for Policy and International Affairs. Study development was closely coordinated with the Federal Railroad Administration; the Office of the Assistant Secretary for Research and Technology; and the OST Office of Planning and Program Review. In addition, valuable comments on preliminary drafts were received from the Federal Highway Administration; the Federal Aviation Administrati and the OST Office of Budget. The Federal Railroad Administration directed a related effort which resulted in site-specific estimates of investment costs for upgrading track and facilities for Improved Passenger Train service.

Overall study direction was provided by M. Miller, D. Igo and N. Ebersole of the Strategic Planning Division, Office of Assistant Secretary for Policy and International Affairs. The FRA effort was the responsibility of M. Klein, E. Ward, K. Lawson, and S. Ditmeyer.

Contractors who participated in this study are: The MITRE Corporation, under contract to the Strategic Planning Division; Peat, Marwick, Mitchell & Co.; Resource Management Corporation; and SYSTAN, Inc., all under sub-contract to MITRE; and PanTechnology Consulting Corporation, under contract to the Federal Railroad Administration. PMM&Co. prepared Chapter IV, "Identification of Potential Markets" and Appendix A, "Demand Projection Methodology"; RMC provided generalized estimates of unit costs for the alternative transportation systems; and SYSTAN contributed Chapter VI, "Institutional Factors."

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CHAPTER I

SUMMARY

A. INTRODUCTION

The High Speed Ground Alternatives Study was undertaken in response to a request by the Under Secretary of Transportation for a comprehensive analysis of the economic, technological and institutional factors involved in implementing Improved Passenger Train service and high speed Tracked Levitated Vehicle Systems in the United States. Subsequent chapters of this report present the detailed analysis, and the appendices describe the methodologies used to develop demand estimates and cost-revenue comparisons. This summary chapter encapsulates the findings of the study.

In brief, the HSGT Alternatives Study concludes:

- o For the expected future situations, the potential benefits and markets are sufficient to warrant Federal activity in Research and Development for both Improved Passenger Train and Tracked Levitated Vehicles.

    - oo The Improved Passenger Train provides the basis for growth of AMTRAK
    - oo Tracked Levitated Vehicles are a promising option for the longer term future.

- o The unresolved issues and uncertainties of projection make it essential that final implementation decisions for any route be based on research and development results plus on-site cost analysis and cost-benefit comparisons with competitive new modes.

oo Investment in the current R&D programs is needed to reduce the risks of major investment decisions in the future.

These conclusions are discussed in more detail at the end of this chapter; and limitations in scope, unresolved issues and remaining uncertainties are also presented.

B. SYSTEMS DEFINITIONS

Both High Speed Ground Transportation (HSGT) Alternatives involve new system concept definitions essential to analysis.

Improved Passenger Train (IPT)

The IPT concept is aimed at revitalization of past investments in conventional rail routes by the introduction of:

- o attractive, comfortable and reliable equipment
- o operating on schedules to give convenient, frequent service
- o at speeds competitive with air in the 50 to 200 mile trip range
- o with little adverse environmental impact.

Technically, the IPT concept is an optimum mix of moderate upgrading of existing rail rights-of-way with new self-powered, non-electrified vehicles. The IPT will offer greater comfort and convenience than conventional rail, at speeds 30 to 50% higher on curves and up to 150 mph on the straightaway. The performance will be achieved with new light-weight cars featuring advanced suspension systems and high power-to-weight propulsion. The average terminal-to-terminal speed will depend on the particular routes, their curvature and other restrictions. However, the IPT will always offer a marked improvement over existing rail service and a better competitive position with respect to highway and air than AMTRAK now enjoys. Improvements of this nature will be essential to the increase needed to reach a sufficiently high volume of patronage to make AMTRAK a commercial success.

Interest in upgrading rail systems is strong outside the United States. New high speed trains are either operational or under development in France, England, Canada, Italy and Germany[1] with speeds as high as 300 kmh (186 m.p.h.). Because of differences in condition and configuration of the route system right-of-way, designs developed abroad may not be optimal for the United States. Therefore, the IPT program is designed to take advantage of foreign innovations where applicable, but to seek a technology mix best suited for U.S. needs.

Tracked Levitated Vehicles (TLV)

The generic term, tracked levitated vehicles, applies to the concept of very high speed service using non-contacting support technology. The objective of the TLV program is to provide an additional future option for the national transportation system, with speed competitive with air up to 400 miles. The intercity TLV system concept features speeds up to 300 m.p.h.[2] combined with a very smooth ride. Vehicles are all electric power and have low noise and pollution impact. The service will be frequent and convenient as well as attractive from speed and comfort standpoints.

TLV uses a wholly new dedicated guideway but its non-contacting feature may offer savings in guideway construction tolerance and maintenance costs at high speed, compared with new guideway for conventional

[1]The Japanese New Tokaido rail line differs from the IPT concept since it uses an all new high-investment right-of-way.

[2]The technological speed limit for TLV is well in excess of the 300 mph used for analysis. The final optimum speed may be higher or lower depending on the route, The R&D program results, and the economics of power consumed by aerodynamic drag which rises as the third power of speed.

wheel-rail systems. The very high speeds for TLV require a relatively straight route which employs wholly new rights-of-way or elevated construction over existing rail rights-of-way where applicable.

The technologies for TLV include:

Tracked Air Cushion Vehicle (TACV) is one of the technologies in the TLV program. Early work was done by the French Societe de l'Aerotrain which now has two prototype vehicles in operation at speeds of 120 and 178 m.p.h., with a commercial operation planned. British Tracked Hovercraft, Ltd. has an experimental model TACV capable of 150 to 200 m.p.h. The United States intercity TACV research vehicle (TACRV) is capable of 300 m.p.h. and is beginning test at the High Speed Ground Test Center (HSGTC).

The TACV designs all use pressurized air cushions enclosed in flexible skirts for support and lateral guidance. Guideway designs differ among the three countries. The United States TACRV uses a wide U-shaped cross section shown in NASA tests to give good cross-wind support. The guideway is of reinforced concrete and advanced construction methods promise new economies compared with the present test track. The operational TACV will use a linear induction motor (LIM) for propulsion with wayside power pickup. The LIM and power collection systems also will be tested at the HSGTC.

Magnetic Levitation (MAGLEV) is being studied by Japan, Germany, and Canada, as well as by the Ford Motor Co. and Stanford Research Institute under contract to the Federal Railroad Administration. The technology development effort is in an early stage, with two major concepts under study:

- o repulsion based on the repulsion forces between like magnetic poles in vehicle and guideway, and
- o attraction based on the attractive forces between electromagnets and steel rails.

Repulsion systems are inherently stable and allow a relatively large gap between vehicle and guideway. Superconducting coils in the vehicle allow high current flow at low resistance losses. Guideway form and vehicle secondary suspension could be the same as for the TACV. Attraction systems require dynamic current control for stability plus active secondary suspension to compensate for the very small gap between magnet and rail. The magnets suspend the vehicle from beneath rails and could be compatible with the U.S. TACV guideway shape.

The TLV concepts are generally comparable in performance potential and price. The TLV R&D program will generate the information to permit a rational choice among the concepts for implementation. For this study, analysis is based on the TACV for which the best data are available.

Relationship of IPT and TLV Systems

In many respects IPT and TLV are complementary rather than competitive systems. IPT is a near term technology suitable for early implementation with moderate development and test; TLV is a longer term option which will result from advanced development effort. The timing of availability of the technologies matches the growth of demand levels to support their implementation since the lower cost IPT requires lower patronage for viability than TLV. In fact, TLV could serve as a follow-on to IPT in corridors where the successful upgrading of rail results in heavy loads on capacity.

C. SYSTEMS ECONOMIC ANALYSIS

Viability of IPT and TLV is measured by estimating the revenue and cost streams over the expected life of a system and discounting both back to a common base year, to calculate Net Present Value (NPV). The process involves many uncertainties, not the least of which is the projection of transportation demand for future corridors, and the complex response of demand to the services and prices of HSGT and the competitive conventional modes. A second major uncertainty is the future energy situation, in particular the scarcity and cost of petroleum fuels and the growth of electric generation capacity. By 1985 the price of petroleum fuel could go up by a factor of three and by 1995 nuclear electric power generating capacity could begin to catch up to demand.

The HSGT Alternative Study approached these problems by using a three-stage procedure:

1) Gross estimation of demand nationwide and relative ranking of potential corridors by HSGT patronage level
2) Detailed analysis of four corridors spaced through the ranking list, including re-estimation of demand from local survey data[3] and site-specific cost estimates
3) Sensitivity analysis of reasonable variations in major factors affecting viability.

[3] For example, the California Corridor projections were based on recent California Division of Highway surveys, CAB interstate air data and State Public Utilities Commission intrastate air data, Western Greyhound and AMTRAK records, rather than a generalized national demand model as in Stage 1. See Appendix A for details of both Stage 1 and Stage 2 demand estimation methodologies.

The measure of viability is the NPV, which can be positive, negative or zero. The result of the NPV calculation is a dollar amount essentially[4] equal to:

- o the sum of discounted operating revenues over system life
- o less the sum of the discounted investment and operating cost over system life.

The significance of a zero NPV for a project is that the effective yield over the life of the project is the same as if the initial investment were put at compound interest at the discount rate. Thus, the zero NPV case includes return on investment and is, in fact, a profitable system. Under conditions of increasing demand, however, zero NPV need not imply profitability in the first year of operations.

The measure used for comparison of viability among the corridors is NPV divided by the discounted initial investment. This "viability index" has the value of being normalized for different sizes of investment, being independent of the base year to which discounting is done, and giving an indication for a non-viable (negative NPV) system of the fraction of the initial investment the revenues cannot cover.[5]

IPT Viability

Potentially viable corridors for IPT are shown in Figure 1-1 with their relative ranking. Corridors selected for detailed analysis were Los Angeles-San Diego (3), Chicago-Detroit (10) and Seattle-Portland (17).

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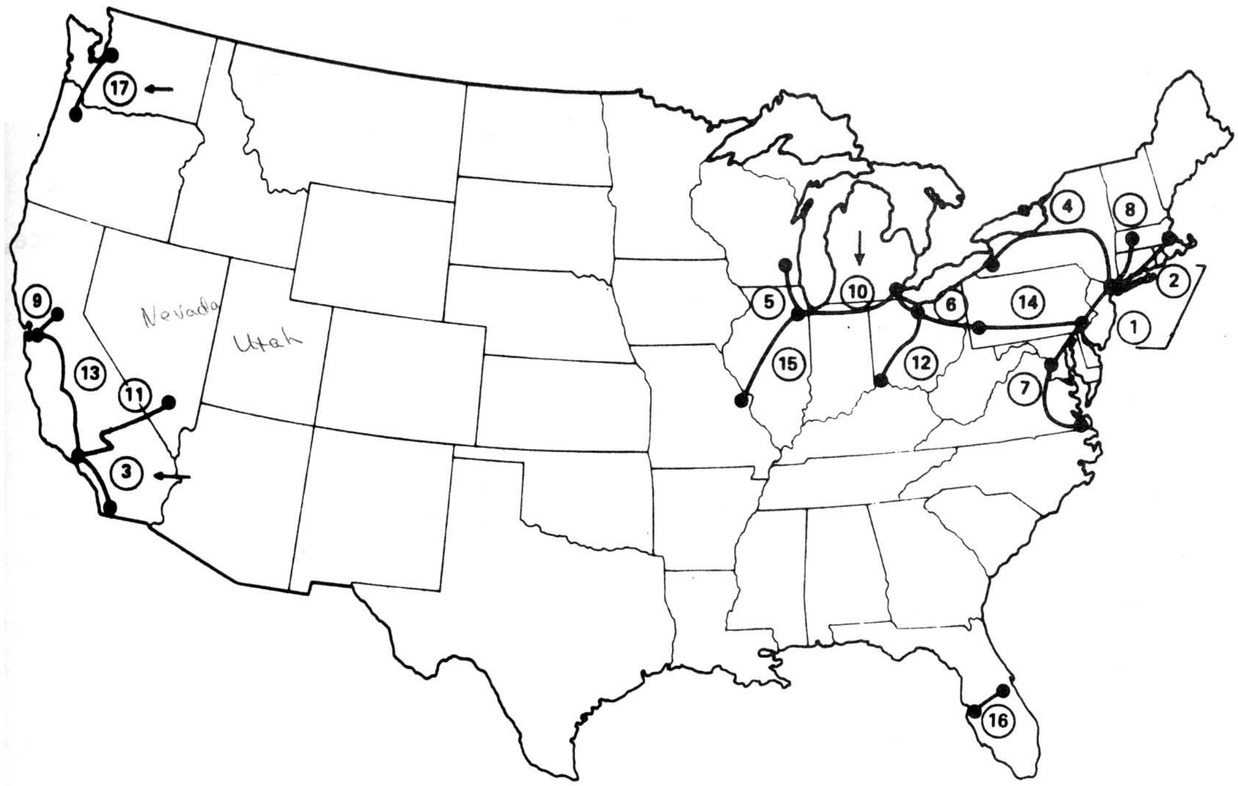
[4]See Appendix B for details.

[5]For example, a viability index of -.23 indicates that 23 percent of the initial investment is not covered and that an initial grant of that amount would make it viable. A viability index less than -1.00 indicates a system which cannot cover operating costs with revenues.

RANKED POTENTIAL IPT CORRIDORS



CORRIDOR RANKING

(From Market Potential Analysis)

IMPROVED RAIL SYSTEMS

1. New York-Washington
2. New York-Boston

IPT CANDIDATES

→3. Los Angeles-San Diego
4. New York-Buffalo
5. Chicago-Milwaukee
6. Pittsburgh-Detroit
7. Washington-Norfolk/Newport News
8. Springfield/Hartford-New York
9. San Francisco-Sacramento
→10. Chicago-Detroit
11. Los Angeles-Las Vegas
12. Cleveland-Cincinnati
13. Los Angeles-San Francisco
14. Pittsburgh-Philadelphia
15. Chicago-St. Louis
16. Tampa-Orlando
→17. Seattle-Portland

FIGURE 1-1

Improved rail service in the Washington-New York-Boston corridor was analyzed in detail in the earlier Northeast Corridor Study. Estimates of viability for the selected corridors allow an implied estimate of viability for the remainder of the list. Thus, by implication, if corridors (3) and (10) were strongly viable, then corridors (4) through (9) would stand a good chance of being viable also. The implied estimate, however, is an approximation good only to the extent that the general techniques used to develop the ranking agree with the actual demand and site specific costs for the other corridors.

Figure 1-2 illustrates the use of the viability index for the IPT in the potential corridors. The indications of the economic analysis of the IPT base case[6] are:

- IPT will be viable in 1975 in the San Diego-Los Angeles corridor with standard fares and standard (low) fuel prices.
- Chicago-Detroit and Portland-Seattle have negative NPV for 1975 and 1985 base cases.
- Of the six corridors ranked between Los Angeles-San Diego and Chicago-Detroit, three (New York-Buffalo, Chicago-Milwaukee and possibly Pittsburgh-Detroit) appear to have a good chance for viability. This finding, however is subject to the uncertainties of the ranking process.

The indications from the sensitivity investigations for IPT include the following:

---

6 "Standard" fare, current fuel price, 10 percent discount rate, and low "modal constant" (see p. 1-13 footnote).

IPT

NET PRESENT VALUES (NPV)

(Standard Fare: $1.72 + $0.086/Mi)
(Discount Rate: 10%)

Corridor	Fuel Price Factor	Discounted Investment* 1975 ($M)	Discounted Investment* 1985 ($M)	Discounted Op Costs* 1975 ($M)	Discounted Op Costs* 1985 ($M)	Discounted Revenues* 1975 ($M)	Discounted Revenues* 1985 ($M)	NPV Ops Begin* 1975 ($M)	NPV Ops Begin* 1985 ($M)
	x1.0	59	23	74	32	55	29	-78	-26
Chi-Det	x3.0	59	23	98	44	107	55	-50	-12
	x1.0	23	9	49	21	30	17	-42	-13
Port-Sea	x3.0	23	9	61	28	58	33	-26	- 4
L.A.-S.D.	x1.0	22	8	112	60	190	110	56	42
	x3.0	22	8	179	100	338	197	137	89
(Low Fare)**	x3.0	22	8	267	151	322	187	33	28

* Discounted at 10% to 1975 whether Operations Begin 1975 or 1985

** (Low Fare = $1.25 + $0.05/Mi)

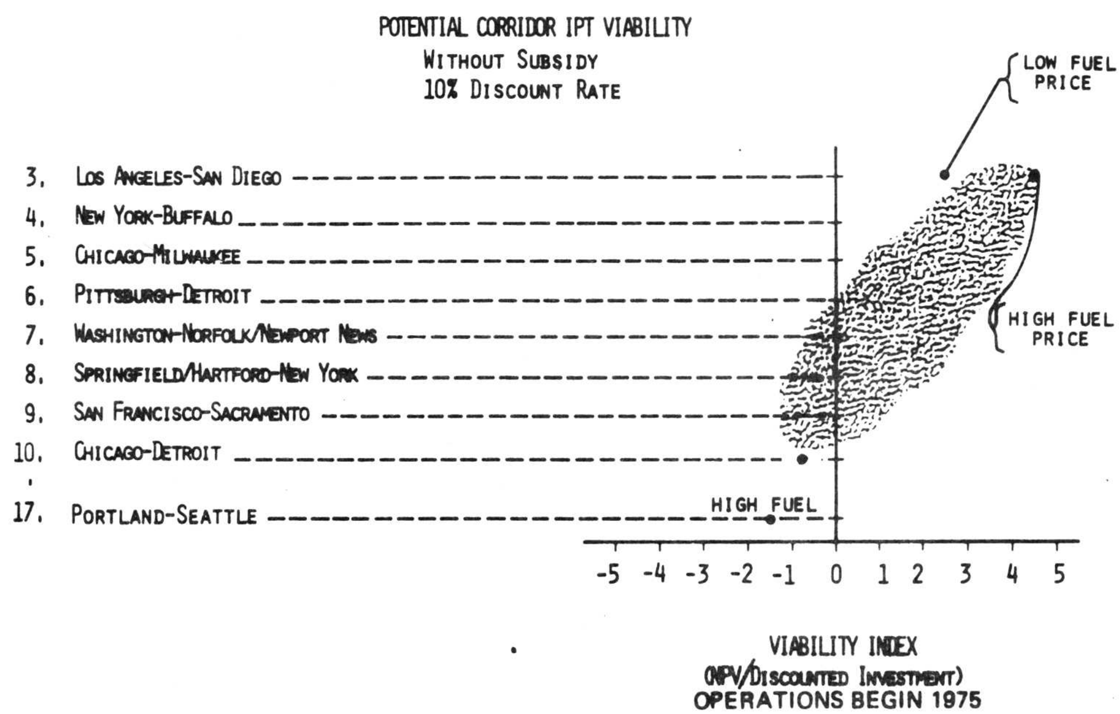


FIGURE 1-2

- The "high" (factor of 3) fuel price enhances the relative attractiveness of IPT[7] in many corridors.
- The introduction of a very low fare, competitive with PSA air fare, in the Los Angeles-San Diego Corridor yields a positive NPV, under high-fuel price conditions. The fare tested ($1.25 + .05 per mile) is only slightly in excess of operating cost so that very high demand is required to pay capital costs.
- Reasonable variations in the "modal attractiveness factor"[8] used in demand estimation do not change NPV to positive in any corridor tested for operations beginning in 1975, except for the case of low fare and low fuel price in the Los Angeles-San Diego Corridor.
- If, in addition to high fuel prices and a high modal constant the discount rate is reduced from 10 to 6 percent, IPT systems in the Chicago-Detroit corridor and in Portland-Seattle could be nearly viable in 1975 (viable in 1985 with 10% discount rate). The use of a lower discount rate might reflect the fact that there are non-fare box benefits resulting from the system which have not been quantified, but which might be judged to make the total social return equal to the 10 percent level prescribed by OMB.
- Direct subsidy in the form of forgiveness of part of the fixed investment can make many of the corridors have positive NPV for the remainder of the investment. The possibilities for such subsidy include:

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7 Fuel constitutes somewhat less than 5 percent of the ticket price on the IPT at the expected demand level. Thus, a factor of 3 increase fuel price means roughly a 10 percent raise in fare. For auto, the major component of perceived cost is fuel: hence a tripling of fuel would more than double perceived cost of intercity auto travel.

8 This factor is a demand model parameter which accounts for "attractiveness" (other than frequency, time and cost considerations) of one mode over another. If, for a particular O-D pair, the frequency, time and cost of two modes were exactly the same, the mode with the greater "modal constant" or "modal attractiveness factor", would generate more demand.

Corridor & Situation	Fixed Cost (Million)	Subsidy for NPV = 0
1975 CHI-DET @ High Fuel Price	59	84% of Fixed Cost
1985 CHI-DET @ High Fuel Price	59	52% of Fixed Cost
1975 PORT-SEAT High Fuel Price	23	114% of Fixed Cost
1985 PORT-SEAT High Fuel Price	23	50% of Fixed Cost

TLV Viability

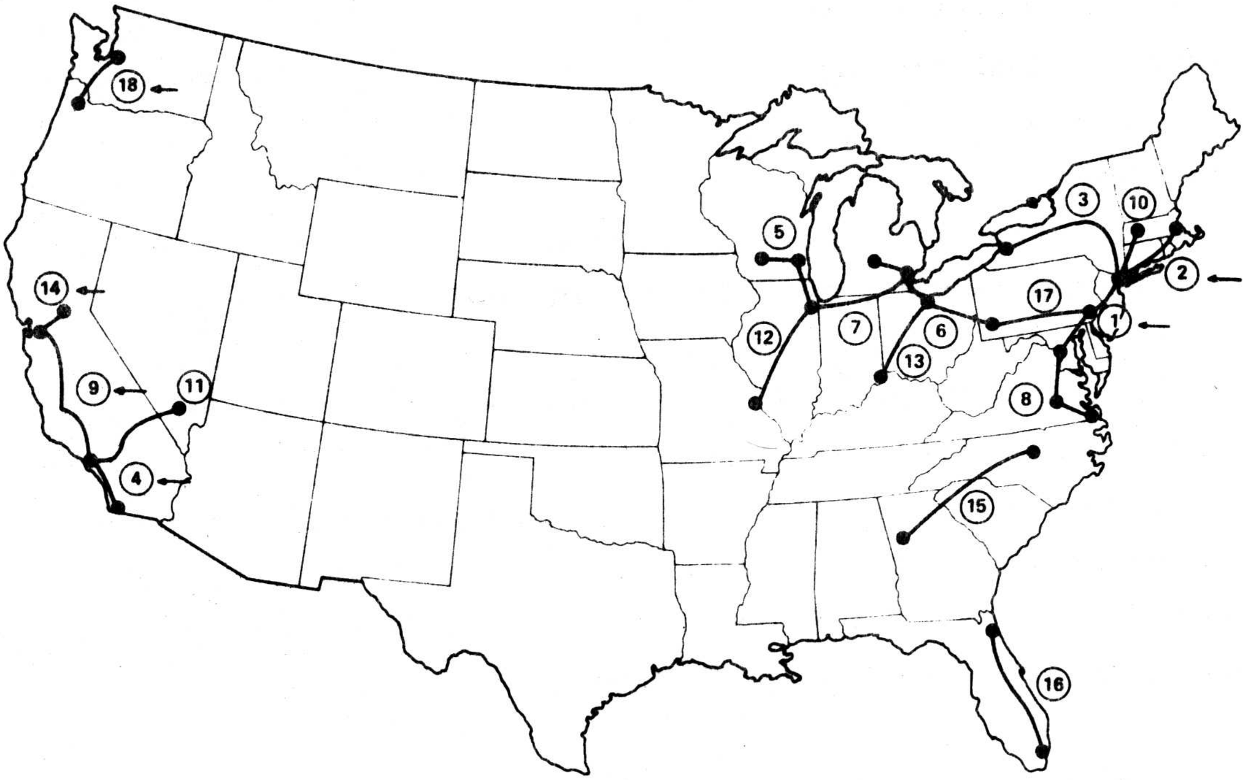
Potential corridors for TLV were estimated for 1985-95 as shown in Figure 1-3. The corridor rankings are similar but not identical to those for IPT. In general, the longer distance routes tended to move up in ranking for TLV compared to IPT. New York-Buffalo moved ahead of San Diego-Los Angeles; Los Angeles-San Francisco moved up from 13th to 9th and Jacksonville-Miami moved into the standings at 16th in place of Tampa-Orlando. The corridors selected for detailed analyses were Washington-Boston (1 & 2), San Diego-Los Angeles (4), San Diego-Sacramento (4 & 9 & 14), Seattle-Portland (18).

The economic analyses for the Washington-Boston TLV were limited to re-examination of investment and costs: demand estimates were taken from the NEC studies for 1985 as a base and projected in line with the expected patronage growth for 1995. As for IPT, the demand estimates for Portland-Seattle and for the California Corridor were based on recent survey data (1965-70) projected out to 1985 and 1995 in line with expected income and population growth (see Appendix A). The choice of the combined San Diego-Los Angeles-San Francisco-Sacramento as a single corridor allowed a new analysis of a long TLV route. In the demand estimation procedure, the individual origin-destination demands were generated and then summed over the route.

The findings of the economic analyses for TLV are illustrated in Figure 1-4. Results of the "base case"[9] examination are as follows:

[9]The "base case" includes the following assumptions: standard fare; low fuel price; and 10 percent discount rate.

RANKED POTENTIAL TLV CORRIDORS



CORRIDOR RANKING

(From Market Potential Analysis)

TLV SYSTEM

→1. New York-Washington	10. Springfield/Hartford-New York
→2. New York-Boston	11. Los Angeles-Las Vegas
3. New York-Buffalo	12. Chicago-St. Louis
→4. Los Angeles-San Diego	13. Cleveland-Cincinnati
5. Chicago-Milwaukee-Madison	→14. San Francisco-Sacramento
6. Pittsburgh-Detroit-Lansing	15. Durham-Atlanta
7. Chicago-Detroit	16. Jacksonsville-Miami
8. Washington-Norfolk/Newport News	17. Philadelphia-Pittsburgh
→9. Los Angeles-San Francisco	→18. Seattle-Portland

FIGURE 1-3

TLV

NET PRESENT VALUES (NPV)

Corridor	Fuel Price Factor	Discount Rate	Discounted Investment* 1985 ($M)	Discounted Investment* 1995 ($M)	Discounted Op. Costs* 1985 ($M)	Discounted Op. Costs* 1995 ($M)	Discounted Revenues* 1985 ($M)	Discounted Revenues* 1995 ($M)	NPV Ops Begin 1985 ($M)	NPV Ops Begin 1995 ($M)
Northeast										
(40M Pax/Yr)	x1.0	10%	1550	598	964	496	2960	1540	446	446
(30M Pax/Yr)	x1.0	6%	1940	1080	1530	1150	4770	3610	1300	1380
Port-Sea	x3.0	10%	483	186	67	31	128	65	-422	-152
L.A.-S.D.	x1.0	10%	347	134	110	56	298	161	-159	-29
	x3.0	10%	347	134	206	110	622	337	69	93
Intermediate Fare**	x1.0	6%	440	246	309	233	578	452	-171	-27
	x3.0	10%	347	134	163	88	297	166	213	-56
San Diego-Sacramento	x1.0	10%	1770	681	420	209	1060	562	-1130	-328
	x3.0	10%	1770	681	696	358	1960	1040	-506	1
	x3.0	6%	2240	1250	1450	1089	4200	3240	510	901

*Discounted to 1975 whether Operations Begin 1985 or 1995

**Intermediate Fare $2.51 + $0.057/Mi; standard fare $3.44 + $0.097/Mi.

POTENTIAL CORRIDOR TLV VIABILITY
WITHOUT SUBSIDY
10% DISCOUNT RATE

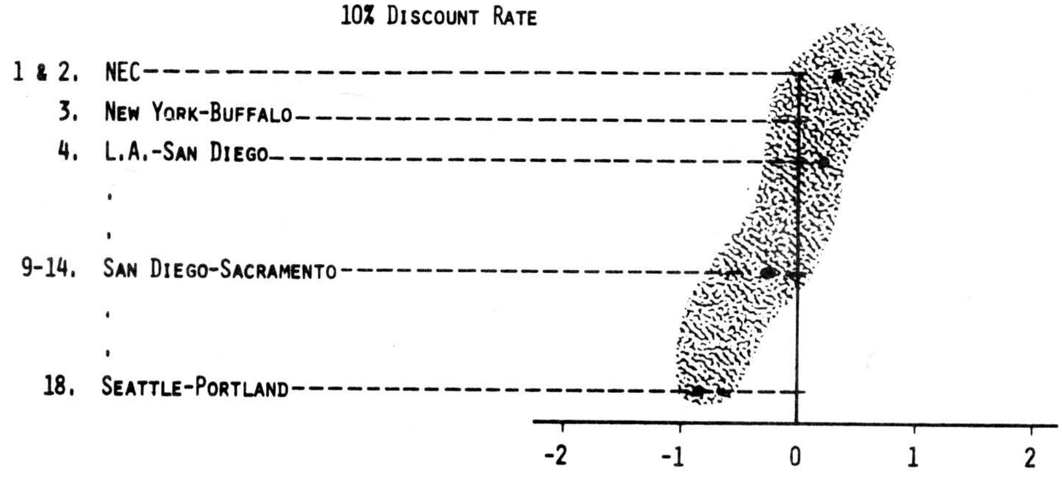


FIGURE 1-4

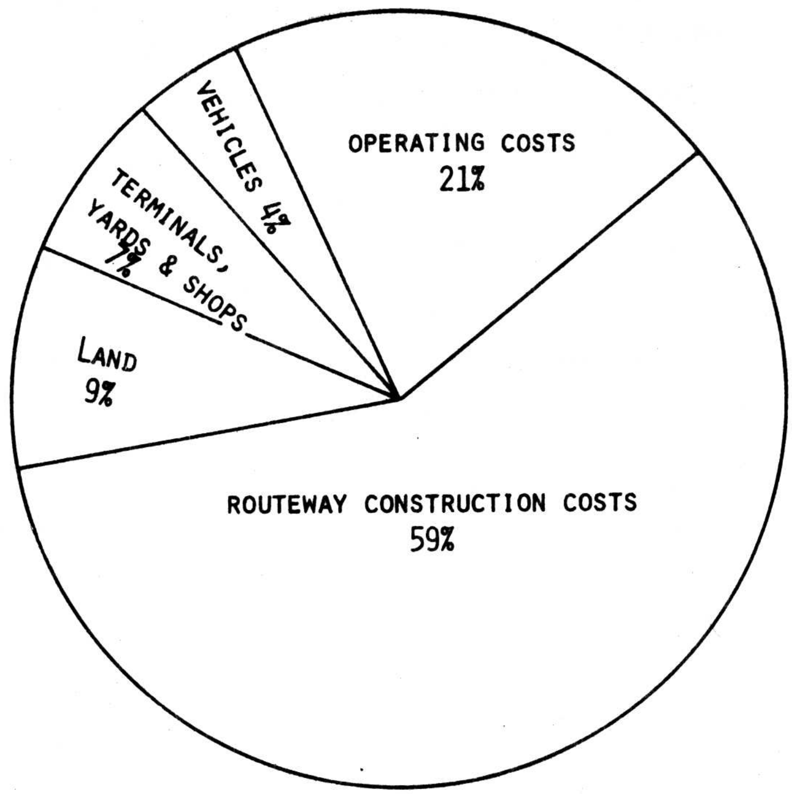
- TLV is viable in the Northeast Corridor with implementation in 1985.
- Since New York-Buffalo ranked second to the NEC, it may be viable for 1985 implementation (although it was not studied in detail).
- San Diego-Los Angeles is not viable through 1995 implementation at standard fare and low fuel price.
- The entire San Diego-Sacramento corridor has a negative NPV through 1995 implementation.
- Seattle-Portland would have negative NPV through 1995 implementation.

Sensitivity analyses indicate the following:

- Net present value for TLV in the Northeast Corridor would become slightly negative if the demand realized were to be only 30 million rather than the expected 40 million per year. However, even at the lower demand level, results are positive given a delay in implementation; a mild fuel price rise; a slightly lower discount rate; or a small subsidy.
- Under the high fuel price situation, the TLV in the San Diego-Los Angeles corridor would be viable in 1985 with a standard fare and by 1995 with fare competitive to PSA air fare.
- The California Corridor (San Diego-Sacramento) would have a positive NPV in 1985 with only a slight decrease in the 10 percent discount rate or a small subsidy, and high fuel prices.
- The eight intervening corridors (5 through 8) and (10 through 13) have implied possible viability sufficient to warrant more detailed analysis.

The concept of a government subsidy indicates that external benefits not included in the fare-box revenue stream should be added to the overall present value calculation. If such external benefits exist, they could be accounted for either by assistance in the initial fixed investment or by yearly assistance to reduce deficits. The presentation here of computations at lower discount rate or for a decrease in fixed investment is an attempt to show the magnitude of additional external benefit which might be required as justification.

On the following page are listed some examples of TLV subsidy possibilities. Shown also is a typical distribution of the costs associated with a TLV system (Figure 1-5).



DISTRIBUTION OF REVENUE
AT BREAKEVEN DEMAND
FOR TLV IN NEC

FIGURE 1-5

TLV SUBSIDY POSSIBILITIES

CORRIDOR & SITUATION	INITIAL FIXED INVESTMENT* (Billions)	SUBSIDY FOR NPV=0
1985 S.D.-Sac. at HIGH FUEL PRICE	3.394	29% of Initial Fixed Investment
1985 Port-Sea. at HIGH FUEL PRICE	.929	87% of Initial Fixed Investment
1995 Port-Sea. at HIGH FUEL PRICE	.929	81% of Initial Fixed Investment

*Initial Fixed Investment is the investment for constructing the fixed plant, i.e.: excluding vehicle investment, operating costs, and maintenance costs.

D. TOTAL BENEFIT & COST CONTRIBUTION

Both IPT and TLV will be fare-box viable for some Corridors and both appear to be technically feasible with appropriate research and development. Because R&D and implementation involve allocation and risk of public resources, consideration must include their total costs and benefits to society. While the analysis of externalities cannot be made in a rigorously numerical form, a number of factors appear which, on balance, enhance the desirability and viability of high speed ground travel.

Energy Consideration

The developing national (and international) energy crisis has been the subject of much recent study and discussion. The expectations are that both petroleum and electrical energy will be in short supply in the near future with possible longer term shifts to substitute fuels and especially to extensive nuclear generation of electricity. The price rise effects of petroleum shortage have already been shown to enhance the fare-box viability of both IPT and TLV. On the broader basis of overall consumption of scarce energy resources:

- o IPT, at 150 miles per hour, consumes less energy per seat-mile than the compact auto or diesel bus at 60 mph.

- o TLV, at 300 miles per hour, consumes less energy per seat mile than conventional aircraft (DC-9-30) and achieves competitive short-haul trip times.

- o Most importantly, TLV uses centrally generated electrical energy which in the longer term future may become more plentiful from nuclear sources, while petroleum fuels will remain scarce.[10]

Congestion Consideration

If the existing modes are able to find satisfactory solutions to the fuel shortage problem, then congestion of facilities will arise as a problem. Most particularly, air terminal congestion in major airports of the most dense corridors is predicted for the late 1980's despite various capacity improvement measures, unless new airports can be built. IPT and TLV offer congestion relief options along the very dense routes.

Land Use Considerations

A major impediment to most transportation system expansion is a public reluctance to devote more land to transportation use. IPT offers a major advantage by using right-of-way already dedicated and should have a negligible impact in terms of disruption and relocation of existing activities.

TLV, to the extent that it requires new land for right-of-way and terminals, will encounter serious problems in acquisition of scarce urban land. Because it requires a continuous, relatively straight route, TLV also offers potential problems in rural land acquisition. There are several mitigating factors, however:

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[10] However, over the long term future substitute fuels may become available. Hydrogen-fueled vehicles may constitute the majority of urban fleet systems, and hydrogen may fuel non-electric intercity ground transportation in the post-2000 period (see Chapter VII).

- The actual right-of-way width needed for TLV is narrow - about 100 feet - and the resulting practical capacity is high - up to 12,000 passengers per hour (total of both directions) at 300 mph as compared to about 7,200 at 60 mph for a four-lane highway.
- The TLV guideway can be elevated to provide positive separation from adjoining land and offers minimum restriction to passage.
- As will be discussed next, TLV has low noise and pollution impacts on adjacent land.

Environmental Considerations

Noise and air pollution are two environmental impacts which must be considered as societal costs for any transportation system. Both IPT and TLV have favorable environmental characteristics relative to other modes. Figure 1-6 summarizes the noise and pollution impacts for the various modes. For the two HSGT modes:

- IPT, based on measurements for the current Metroliners and the Japanese New Tokaido Line, should have noise comparable to freeway auto and truck traffic. However, because IPT uses existing rights-of-way, surrounding land use patterns are already adjusted to railroad noise and no additional adverse impact is likely.
- TLV, at 300 miles per hour, will be no more noisy than existing freight trains, if current R&D is successful. By elimination of compressor and air cushion noise, the MAGLEV promises to be somewhat less noisy than the TACV. In examination of Figure 1-6, it should be noted that TLV noise level at 50 feet would be roughly equivalent to a quiet aircraft at 500 feet.

- IPT is far lower in output of air pollution emissions per seat mile than any auto (at 1975) standards), diesel bus or aircraft.
- Because TLV is electric powered, the emissions associated with its operation are those of the generating plant. If the generation were all nuclear, then no chemical pollutants would be emitted. Figure 1-6 shows an output based on the assumption that electric power supply is 50% nuclear and 50% from clean fossil fuel plants. The emission level is relatively high in nitrogen and sulphur oxides, from the fossil fuel plants. This can be expected to decrease with continued R&D and with further introduction of nuclear plants. In any event, the emission is located at the generator and will not be an impediment to land use along the right-of-way.

Institutional Considerations

One of the principal institutions now concerned with implementation of high speed ground transportation is AMTRAK. The problems of revitalizing rail passenger service are many and are not all concerned with speed. Clean terminals and equipment; courteous, helpful personnel; convenient, frequent schedules and comfortable ride are all required to bring rail up to an attractive service level. Given these factors, however, competition also involves the ability of rail to transport people rapidly between major cities. Despite refurbishing of the fixed plant and retraining of personnel, AMTRAK must acquire new rolling stock to revitalize the industry. The marginal benefits of IPT performance in terms of passenger attractiveness will justify its marginal cost over new conventional trains for use in high density corridors. Thus improved passenger trains are important to the growth of AMTRAK.

EXTERNAL NOISE LEVELS FOR VARIOUS TRANSPORTATION MODES

	MODE	SPEED	dB(A)	PNdB	COMMENTS
Highway	Auto	60	70	84-88	
	Freeway Traffic	50-70	76	90	
	Diesel Truck		90	101-104	
Rail	Freight	40		93-110	
	Metroliner	107	92	92	
	NTL	124	87-92		
TLV	UTACV	150	73		DOT Specification
	Aerotrain	90	79-82		LIM Vehicle
		150	97-99		Propeller Vehicle
	TACV	300	83-98	96-111	Projected
Air	CTOL	Takeoff		138	At 500 ft.*
	V/STOL	Takeoff		88-105	At 500 ft.*

*All Other Estimates for 50 feet.

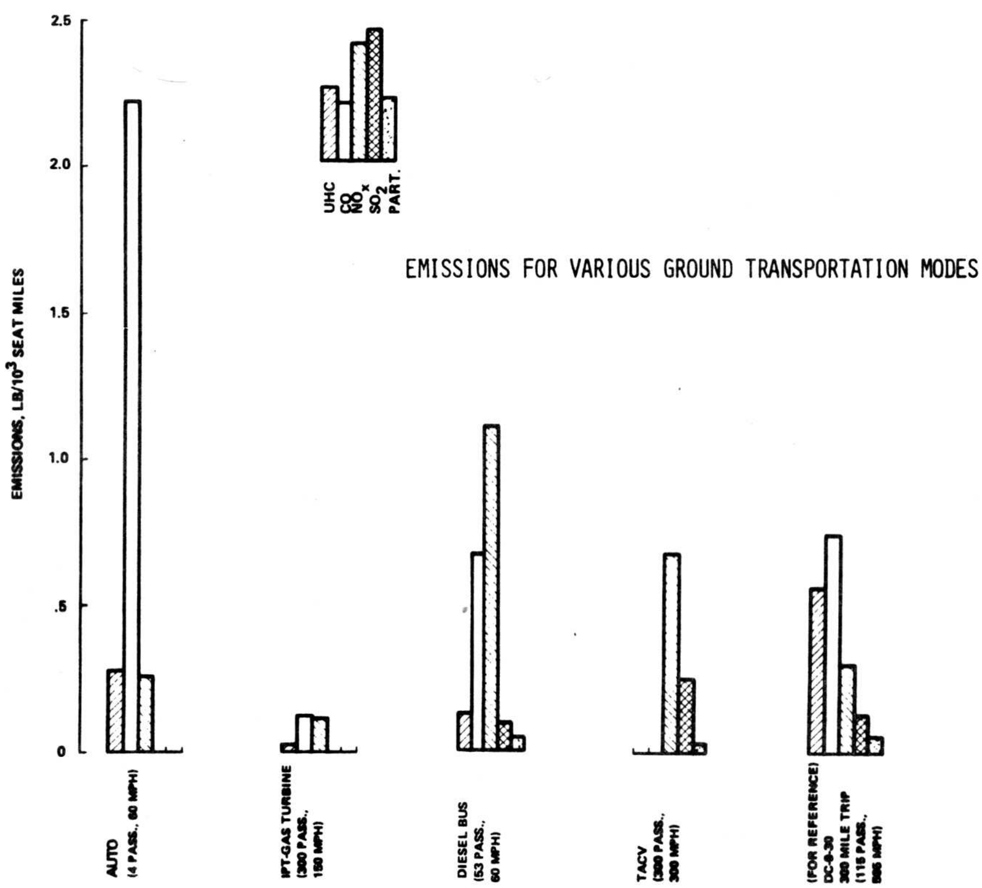

FIGURE 1-6

While the optimal organization for operation of TLV has not been determined, implementation of TLV only where complementary to the rail system is essential. Thus, close ties with AMTRAK are highly desirable for TLV implementation and operation. Similarly, because TLV is a powerful transportation mode for future high density short-haul routes, its implementation should be considered on national, as well as local or regional levels. Thus, close connections with DOT and with the quasi-public AMTRAK are desirable for the implementation phases.

E. UNRESOLVED ISSUES

Because analysis of implementation of IPT and TLV deals with future demand and other social and economic conditions, a number of uncertainties exist and will continue to exist. However, several of the issues which have not been resolved by this study are subject to better - if not complete - resolution with continued effort:

Site-Specific Issues

Costs of implementation of either IPT or TLV along specific routes could be estimated with greater confidence from on-site studies, especially for those corridors not studied in detail here. In addition, possible freight-passenger interference on IPT and the expected performance of TLV on elevated guideways over existing rights-of-way require investigation. The problem of acquiring land for new TLV right-of-way needs to be addressed in the specific corridors where viability appears possible.

Demand Estimation Issues

Despite considerable effort on the Northeast Corridor Study and other projects, the reliability of demand projection and estimation techniques is lower than desirable for implementation decisions involving large investment in future systems markedly different from systems for which data on historical and current experience are available. Also, the data base for demand for present modes is in need of expansion and validation. The effects of future changes in automobile technology and costs should be documented as well as the effects of improved access to common carriers. Most particularly, the amount of demand diversion and induced new demand for a radically improved service needs to be tested via carefully controlled surveys, demonstration, and experiments.

Energy Issues

While most authorities agree that a severe energy problem exists, the timing of future shortages and of technical or other solutions remains uncertain. A full assessment of the status of research and development on new fuels, new engines and power sources was beyond the scope of this study. Because the timing of developments in energy availability has such a major impact on the desirability and viability of all forms of transportation, it is essential that further transportation planning be based on the best possible prediction of the energy situation, and on the directions of emerging national energy policy initiatives.

Technology Issues

The R&D programs for IPT and especially TLV are aimed at resolving the technological issues which create uncertainty in planning for implementation. For IPT, the major issue is to find the optimum compromise between vehicle performance and route upgrading, as they affect the costs and viability of the system. For TLV, a basic issue involves the balancing of suspension against performance and guideway cost. The data on which to base an IPT decision and to decide between the TACV and MAGLEV concepts can only be gained by continued research and testing.

F. CONCLUSIONS

Based on the analyses and considerations of this study, it appears that both IPT and TLV have a good likelihood of viability in some major high density U.S. corridors over the next twenty years. Both HSGT systems offer benefits as valuable options to meet future demand under contingencies posed by energy crisis and congestion of alternative modes. However, especially for IPT, the contingencies are not essential for system viability in some corridors. The environmental impacts of both IPT and TLV are favorable to their acceptance.

In summary, the IPT would aid AMTRAK's growth prospects by improving the use of the past investment in right-of-way and facilities. The new investment required is low in comparison to the service and capacity increases to be gained. The improved passenger train is a low consumer of energy per seat mile, with correspondingly low environmental pollution and noise. The R&D program involves relatively low cost and low technological risk; in return it will greatly reduce uncertainty concerning future rail vehicle procurement.

TLV is an additional option for our future national transportation system which could provide a safe, comfortable ride at aircraft speeds. TLV is a potential substitute for high density short haul air in the event of either energy or congestion contingencies. The results of the current R&D program are needed to aid in future multi-billion dollar implementation decisions.

The unresolved issues are of sufficient importance to preclude specific recommendations for implementation based on this study. Rather, implementation decisions must be reached on the basis of continued R&D effort, site-specific studies, cost benefit comparisons with other possible new modes, and demonstration and test results. In this regard, the investment in current programs and analyses is necessary to minimize the risks of possible major future investments.

CHAPTER II

EVALUATION METHODOLOGY

A. ISSUES AND APPROACH

Comparative evaluation of IPT and TLV involves three areas which need to be discussed at the outset: first, the definition of benefits derived from transportation in general; second, the definition of criteria for evaluation of research and development efforts as opposed to system implementation; and third, the relevant applications of the IPT and TLV modes themselves. The ensuing discussion will lead from the general to the particular and finally to the evaluation methodology adopted for this report.

Benefits of Transportation

A basic difficulty in assigning a benefit to the process of passenger transportation is that, for the traveler, the value of the trip is generally associated with the destination and his transactions there rather than with transportation as such. For a given trip to a particular destination at a particular cost in time, money and other resources, the trip will be "purchased" by that segment of the population for whom that destination meets a need, for whom the value of the trip exceeds the perceived cost, and for whom no other destination meets the need better at lower cost.

Traditionally in the United States, the traveler pays for his transportation more or less in proportion to the service rendered, either in fares on common carriers or in gasoline taxes and tolls on highways. It is therefore germane to any evaluation of transportation service to estimate the degree to which user payments will cover its costs. However, insistence that the user pays for <u>all</u> the costs departs from our recent tradition.

In reality the traveler almost never pays the full cost of his trip, neither is he the sole recipient of its benefit. Society has long recognized the benefit of travel and the responsibility of government to foster the development of good transportation. The United States has extensive passenger transportation facilities and systems, each of which is regulated to some degree by the government, and most of which were, and still are, supported to some degree by government funds. The rationale for government support must be that the overall benefit to society outweighs the cost of the support.

"Fare box" viability thus must be taken to mean that revenues can cover costs after adjustment is made for the amount that society is willing to pay to support the service. Presumably the societal support is geared to the net societal benefit.

The full benefit or disbenefit of a transportation system change is extremely difficult to measure. Improvements in transportation yield a benefit to society, but it is becoming increasingly recognized that the costs of transportation in terms of expenditure of land, clean air and other resources can offset much or all of the benefit. As the resources become more scarce, the same amount of land required for or pollution produced by transportation will be perceived as an increasing cost. Thus a transportation change which would have produced an apparent <u>net</u> societal benefit ten years ago may be recognized as producing a net disbenefit ten years hence.

Research & Development versus Implementation

The decision to implement a transportation system and to incur construction and operating costs must be based on a firm knowledge of the system characteristics and on the place and situation in which it will operate. The imminent IPT and TLV decisions, however, are those to commit the funds for research and/or development which can lead to a later implementation decision.

The research and development efforts which lead to a system capable of implementation usually involve only a small fraction of the total cost of investment in implementation of the system. The R&D efforts necessarily take place at an earlier point in time, when neither costs nor benefits nor even the place and conditions of implementation can be reliably estimated. In fact, one of the products of R&D must be the firm data on which implementation decisions can be based. It is not possible in the early phases of research to base a decision on R&D funding on the detailed criteria and procedures for implementation.

Research and development, nevertheless, involves the allocation of resources which cannot be done in an arbitrary manner without consideration of the prospects of benefit or cost. The criteria for resource allocation must take into account the probabilistic nature of the future and of the outcomes of the various programs which would affect the future. Certainly no research and development funds should be expended on systems which could not be beneficially implemented under any circumstances. On the other hand, a criterion which demanded demonstration of a net benefit under all future circumstances for systems which at present can only be defined in vague outline would stifle all research.

The following three criteria appear reasonable for use in determining the appropriateness of research and/or development efforts associated with HSGT. The first two of the criteria probably would influence a decision as to whether or not to implement a system in a specific location at a particular time.

1. The system should have a prospect of being fare-box viable to the extent that revenues should cover the money costs of operation and maintenance of the system, and part or all of the cost of implementation of the system under some reasonable set of future circumstances. The amount of any subsidy provided to cover implementation of a system would be a measure of the additional net benefit to society expected to accrue from operation of the system.

2. No insurmountable obstacles to future implementation in terms of physical or institutional constraints should exist under the relevant circumstances.

3. The disbenefit of having failed to make preparation for some contingency which required the system, subsidized if necessary, should be large enough to justify the R&D cost as insurance.

The "insurance" criterion has been applied in the past to justify military expenditures where the cost of unpreparedness was considered to be very high. While national survival might not be at stake, the availability of good transportation has become so ingrained in our economic and social life patterns that general deterioriation in transportation could cause major disruptions. Thus the expenditure of present resources on R&D to insure against future transportation contingencies could be justified.

Relevant Applications of IPT and TLV

While both are called high speed ground modes, direct comparison of benefits between IPT and TLV is not generally appropriate. In terms of time period, IPT is near future while TLV is perhaps a decade away before it could be an implemented system. In terms of market, the IPT with its average speed of 60 to 90 mph would be expected to be competitive to other modes for trips up to about 150 miles. The TLV, with average speeds ranging from 200 to 240 mph, should have a competitive advantage over other modes for trips up to about 300 miles. In terms of present status, IPT is primarily a developmental concept, while TLV requires research effort to determine basic technological trade-off relationships needed for development. The expected development cost to bring IPT to the implementation stage is considerably lower than the total research and development cost to bring TLV to the implementation point.

The evaluation treats IPT and TLV separately in determining whether either is appropriate for research and/or development effort now. Because IPT could be ready for implementation much sooner, its evaluation touches more on the implementation criteria and must consider more site-specific estimates of costs, patronage and benefits. TLV is evaluated more on a contingency basis befitting a research effort. Thus while the mechanics of the analysis are much the same for both, the emphasis differs in evaluation of those analyses.

Evaluation Criteria

The complete set of factors considered as criteria in assessing the two HSGT alternatives (with emphasis on implementation, or investment, criteria) is given below in Table 2-1. The items included in the table constitute in effect a checklist of considerations, all of which have been taken into account to some degree. In view of the uneveness of available data and the difficulty of quantification, not all of the criteria have been assessed to the same level of detail.

TABLE 2-1

EVALUATION FACTORS

SYSTEM CHARACTERISTICS

SYSTEM COST	SYSTEM PERFORMANCE (As affecting demand and revenue)
Research & Development	Capacity
Fixed Investment (including ROW acquisition, guideway cost, signaling, control, protection of interface between ROW and surroundings, terminals)	Safety
Rolling Stock	Reliability
Operating Costs (including maintenance and administration)	Flexibility
	Comfort and Ride Quality
	Convenience (including Frequency of Service)
	Door to Door Travel Times
	Sensitivity to Number of Stops
	Dependence on Urban Transit

COST-REVENUE ANALYSIS

Net Present Value over its expected life for relevant circumstances
Break-even vs. Predicted Demand

EXTERNAL COSTS AND BENEFITS

EXTERNAL COSTS	RESOURCE LIMITATIONS
Noise	Energy Consumption
Air Pollution	Land Requirements and Availability
Relocation and Disruption	
Aesthetics	

SOCIOECONOMIC IMPACTS	INSTITUTIONAL IMPACTS
Enhanced Mobility of Population	Societal Attitudes
Land Use	Private Financing
Flexibility	Public Financing
	Management Structure
	Political Jurisdictional Factors
	Labor Relations

B. GENERAL ORGANIZATION OF THE ANALYSIS

The analysis of the IPT and TLV systems in terms of the evaluation criteria listed above is developed in the remaining chapters of this report, as described below.

Chapter III describes the alternative systems in terms of their principal performance characteristics of speed, ride quality, safety, and capacity. Technological issues which require further refinement or substantiation are discussed, along with the trade-offs that have major impact on continuing HSGT development and implementation plans. These include particularly means of suspension for TLV, power requirements, and energy consumption.

Chapter IV characterizes the intercity travel market in the United States today in terms of historical ridership and travel forecasts. A national HSGT network is developed to include a number of travel corridors that appear to have potential for successful HSGT operation. Travel corridors are constructed from the network, and these corridors are ranked in terms of estimated traffic density (estimated passenger-miles per route-mile) for the years 1975, 1985, and 1995. Demand was estimated using a mathematical model similar to the Northeast Corridor Demand Model. The results of this analysis can be regarded as adequate for ranking the corridors, even though the data used do not represent precise estimates of absolute demand levels.

A small number of high-, medium-, and low-ranked corridors were selected for more detailed analysis. Improved historical demand data were collected for these corridors, and cost-revenue analyses were conducted for IPT (in 1975 and 1985) and for TLV (in 1985 and 1995) in the selected corridors. Results are reported in Chapter V. Two of the corridors chosen represent high-ranked markets: the Northeast Corridor between Washington and Boston (TLV), and the California strip from San Diego to Los Angeles (for IPT) and northward to San Francisco and Sacramento (for TLV). The Portland-Seattle corridor (both IPT and TLV) exemplifies a low-ranked market, whereas Chicago to Detroit via Toledo (IPT only) is ranked at medium density. A detailed examination of the potential of both of the alternatives is presented in terms of cost-revenue projections. The Net Present Value of each HSGT alternative in each corridor is computed, based on the predicted demand. Break-even demand is also computed for specific years.

Chapter VI reports the possible impact of major institutional factors which could affect the desirability of both TLV and IPT. These include public attitude, land use impact, land availability, financial considerations, management structure, and labor relations. The significance of each as a possible constraint on eventual implementation is assessed.

Of the contingencies which affect the role of HSGT R&D and of HSGT systems, the principal one treated in Chapter VII concerns energy. In particular, the danger of sharply-curtailed petroleum fuel supplies from traditional sources leading to significant increase in user costs is addressed. In addressing the capability of HSGT to assume the load of modes strongly affected by fuel shortage, estimates of passenger demand were computed using assumptions that the relative price of petroleum fuel would increase over the time periods considered. The significance of possible air congestion to HSGT is also investigated but to a lesser extent than the energy contingency.

Chapter VIII presents an overall summary evaluation of both IPT and TLV. Costs and benefits are summarized in terms of economic viability, contingencies and external costs.

CHAPTER III

SYSTEM CHARACTERISTICS AND TECHNOLOGICAL ISSUES

This chapter describes several possible HSGT modes and discusses technical factors involved in their development and application. General system characteristics are quantified so that the implementation of HSGT modes in applicable potential markets may be evaluated in terms of economic and institutional factors.

A. HSGT SYSTEM CONCEPTS

Background

To be viable, a new or improved passenger transport system requires attractive characteristics - competitive travel time; a safe, comfortable ride; a convenient, reliable schedule with satisfactory access time, interfaces, and network connectivity; and suitable passenger amenities - at a price commensurate with the provided services and with the capacity to handle a growth in its service demand. In addition, the transportation system must be acceptable to the community - it must present a minimum disturbance to the environment in terms of noise, air pollution, and community safety; it must not greatly disrupt existing land use patterns; and it must make efficient use of energy resources.

In developing the attributes of the HSGT modes, many features of attractiveness and passenger convenience - e.g., on-board conveniences and services, physical comforts, neat and attractive appearance, internal environmental control (noise and air conditioning), communication links, reliability and on-time performance, convenient schedules, and ease of access - can be provided by good design practice and operating procedures. Advanced technology must be applied to develop the desired system service characteristics - speed, capacity, ride quality, and passenger safety - to control the community impact factors - noise, pollutants, energy consumption, and community safety - and to obtain affordable costs - investment capital and operating expenses. These are the basic descriptors which quantify the system.

The level of technological advancement incorporated in a candidate for high speed ground transportation applications could start from existing railroads and go the extreme of employing unconventional concepts of supporting loads that lead to "new from the ground up" systems. All levels of technology are, in fact, being considered by the Federal Railroad Administration Office of Research, Development, and Demonstrations (FRA/ORD&D). Metroliners are in current operation in the Northeast Corridor; Improved Passenger Train (IPT) service is a concept that requires advances in railroad technology; and the Tracked Levitated Vehicle (TLV) systems - a generic class that includes the Tracked Air Cushion Vehicle (TACV) and the Magnetically Levitated Vehicle (MAGLEV) are new technology applications requiring substantial research and development.

One basic difference between the advanced IPT and the new TLV is the level of advanced technology (the amount of research) which must be applied to reach an operational stage. The IPT is based on extensions of a familiar load carrying mechanism and existing transportation networks - steel wheel and rail on existing routes and roadbeds. There is little technical uncertainty associated with this system. Research is required only to fill gaps in available knowledge or to optimize the vehicle/roadbed configuration.

The TLV is based on new concepts for non-contacting means of supporting and guiding vehicles. Elimination of mechanical contact offers new freedom for increased speed. Design and implementation of an operational transportation system utilizing a new concept, however, requires research programs and tests at several levels of system development to establish its feasibility. Potential routes must also be studied and evaluated from the viewpoint of their suitability and feasibility of acquisition.

Basis for Establishing System Concepts

The distinguishing technology level between IPT and TLV brings another important difference for this study--the data source used to develop each concept. The IPT is much closer to existing hardware and state-of-the-art technology than is TLV. The IPT routes are established on existing rail lines, and IPT cost estimates can be based partially on applicable historical sources. The TLV systems, on the other hand, are conceptual. Application of air cushion and magnetic levitation principles to operating vehicles is in the research or developmental hardware stage, the actual performance capability of the system at high speeds is yet unproven, and the cost estimates require that data from past experience be transferred to new applications and extrapolated into the future.

The highest level of planning for high speed ground transportation systems in the U.S. is contained in the NECTP Study.[1] The improved rail systems in that study have performance characteristics that are indicative of those of the IPT. Additional background applicable to the IPT can be derived from available data and descriptions of other new passenger train operation. The NECTP study also considered the

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[1] Recommendations for Northeast Corridor Transportation, Final Report, Volume 2, September 1971, Office of System Analysis and Information, Department of Transportation, available from National Technical Information Service, PB-205-242.

TACV system which is representative of the TLV class, particularly with regard to performance characteristics. Background for the TACV is contained in a system engineering study[2] and additional data can be derived from the U.S., British, and French research and development programs. MAGLEV concepts are less developed, although prototype hardware is operating in Germany (ferromagnetic--attraction concept) and Japan (superconducting--repulsion concept). In general, subsystem research and development ideas have yet to be integrated into the system concepts required for a complete MAGLEV system description.

Further information on the status of research and development related to IPT and TLV systems is presented in Section C of this chapter.

IPT System Description

The IPT concept offers a relatively inexpensive and timely means for introducing fast, efficient train service between selected cities of the U.S., taking full advantage of existing facilities and programmed improvements. IPT trains are envisioned to be completely new in design, with engineering advances to permit cruise speeds of 150 miles per hour. The IPT would operate at least 30 percent faster than conventional trains around curves and would have a high power-to-weight ratio for acceleration to full speed on tangent track. The present indication is that such power-to-weight ratio will be best achieved with moderate increases in power over present trains and significant decreases in car weight. Acceptable ride quality will require advanced suspension systems; both ride and speed, however, cannot be made completely independent of the condition of the track.

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[2] TRW Systems Group, "HSGT Systems Engineering Study," Tracked Air Cushion Vehicles, PB-195-030. May 1970, available from NTIS.

New rights-of-way or roadbeds are not considered in the IPT concept. The high speed performance capabilities would result from vehicle design, rather than from costly changes to the track alignment. Only minor changes in alignment and curve easements would be made. The track would be upgraded to all welded rail, the signalling and communications would be improved for high speed operation, and all grade crossings would be protected or eliminated.

The IPT concept hardware is not defined in detail at this point, but rather will evolve as technical requirements become finalized and the subsystems are developed. The trains would be self-powered. Several options concerning on-board propulsion exist, with possible choices including improved gas turbines or diesel engines and electrical, hydraulic and mechanical drives. Similarly, the overall train configuration is open to consideration, although passenger accommodations and interior design would be attractive and provide maximum comfort and convenience. Entrance and movement within the train would be convenient and designed for the whole range of passenger needs. Safety and maintainability will be considered throughout the IPT development.

TLV System Description

The TLV is a promising concept for very high-speed ground transportation. Either air pressure or magnetic force levitates the TLV and eliminates mechanical contact between the vehicle and the guideway. The same phenomenon provides directional guidance--a function normally provided in railroads by the tapered and flanged steel wheel. The TLV, which could operate in the 150 mph speed range as does the French Aerotrain, is inherently suitable for higher speeds. This study considers a maximum cruise speed of 300 mph.

Three TLV concepts are considered in this study: one TACV and two MAGLEVs. The TACV forces air between the vehicle and the guideway with sufficient pressure to support and guide the vehicle. The air for the cushions is supplied by compressors driven by rotary electric motors. The MAGLEVs use either magnetic repulsion or attraction principles. The first MAGLEV concept utilizes the opposition of like magnetic poles to provide levitation. The on-board magnetic field is supplied by superconducting magnets, cryogenic devices cooled with liquid helium. The vehicle accelerates on a low-speed wheel suspension until sufficient lift is generated between the on-board magnets and the field induced in flat aluminum plates mounted on the guideway. The second MAGLEV concept makes use of the attraction between an on-board electromagnet and elevated steel rails. Sensors and electronic circuits are used to maintain a constant gap between the vehicle magnets and the guideway rails.

The vehicle configuration for any TLV could be similar to the TACV concept[3] in which the vehicle is modularized, with a passenger compartment adjoined at either end by equipment bays containing the propulsion and support/guidance equipment. These vehicles can operate singly or in trains. In order to quantify power requirements, system capacity, etc., for the cost/revenue predictions of this study, a typical vehicle size has been assumed -- 100 seat capacity, 100,000 lb. gross weight, and 125 ft. length.

The guideway design is a critical portion of the system design because of interaction with the vehicle support and guidance functions. Considerable emphasis also must be given to elevated guideway design in order to minimize routing constraints and physical interferences.

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[3] TRW Systems Group, op. cit.

It could well be that when requirements for stiffness and minimization of environmental effects such as cross-wind interaction and noise shielding are considered, the MAGLEV guideway design may not vary greatly from the U-shaped cross-section considered for the TACV.[4]

The TLV would use linear electric motors, another concept currently in the R&D phase, for propulsion. This method is ideally suited to the TLV because it functions with no mechanical contact between the vehicle and the guideway. The electrical power for propulsion and levitation would be supplied to the vehicle from a stiff rail power distribution system located along side the guideway. On-board equipment would condition the power for the linear motors and other electrical equipment.

[4]TRW Systems Group, op. cit.

B. HSGT TECHNOLOGICAL FACTORS

Some factors which determine the technical characteristics of HSGT systems will be discussed. The general performance characteristics -- speed, ride quality and system capacity -- describe the technical aspects of system operation. The power and energy requirements have major impacts on vehicle and system design. Environmental impacts result from noise and air pollutant emissions. Safety requires additional design considerations. Other technological factors which may create impacts or involve important tradeoffs in system development include TLV suspension characteristics, IPT track investment costs, TLV guideway costs, and the factors required in TLV operation to meet the projected demand.

Speed

Speed capability is the primary distinction between IPT service and a TLV system. IPT is limited by using the steel wheel and rail on existing rail routes and operating with mixed passenger/freight traffic. The TLV concept is based on non-contacting support and guidance from a new guideway system, providing freedom to attain greatly increased speed.

The IPT is based on a 150 mph cruising speed. This goal is fully realizable and within the state-of-the-art, based on performance of the Metroliner (qualified at 164 mph, formerly operated at 125 mph) and Turbotrain (170 mph in testing, 120 mph in operation) in the United States, the Japanese New Tokaido Line and several Trans-European Express trains (130 mph), the English APT (155 mph predicted) and the French TGV (190 mph in tests). The upper range of speed practical with a steel wheel/steel rail support system is not yet known, but is generally considered to be between 200 mph and 250 mph. The phenomena which limit the speed include vibration and adhesion (for traction and braking). A lower limit generally occurs when a high speed train is implemented on existing routes - speed restrictions due to route curvature. The IPT concept incorporates advanced suspension to alleviate these speed limitations - inward banking on curves and improved isolation from track-induced vibrational disturbances. The goal of this improved suspension is an increase of 30% to 50% in speed on curves and a 50% increase in speed over well-maintained track with a ride quality equivalent to well-maintained conventional systems.

The TLV concept, on the other hand, is based on non-contacting support and guidance, and is free from the constraints of existing railroad track structure and the limitations imposed by wheel/rail contact. Consequently, the speed limitations for vehicles operating at atmospheric pressure become a matter of power and energy requirements. A practical limit, which is competitive to short-haul air travel time, is 300 mph. At this speed, curve restrictions of existing rights-of-way would badly reduce cruise capability; consequently, TLV systems are generally associated with new route locations. Two factors, however, allow consideration for the TLV maintaining a higher speed for a given radius curve by going to a higher bank angle - these are positive lateral guidance with greater lateral force capability (no excessive flange force) and exclusive single speed operation (no mix of fast passenger service with slow freight trains).

One further characteristic that results from the higher cruise speed is the increased acceleration capability. The greatly increased cruise power requirement causes the ratio of installed thrust to vehicle weight to increase with design cruise speed, providing the capability of using a high rate of acceleration with corresponding improvements in block times.

Ride Quality

Ride quality refers to the comfort of the passengers in terms of absence of perceived accelerations. The accelerations arise from vibration induced by roughness of the track or guideway surface, sensed primarily as vertical, lateral, and roll motion; from track curvature, sensed as vertical and lateral sustained accelerations; from transient external loadings such as wind gusts; and from fore and aft acceleration due to accelerating and braking. Ride quality is affected by the track or guideway input to the moving vehicle and the response of the vehicle itself. Achieving good ride quality therefore involves a trade-off between suspension sophistication and/or refinement and the degree of smoothness built into and maintained in the track or guideway. The problem is complicated by the difficult quantification of the human comfort objective and its dependence on time of exposure, surroundings, noise, crowding, seating, and other extraneous factors.

The IPT concept requires a well maintained, high quality track structure and utilizes an advanced suspension system to produce improved vibration isolation under a variety of conditions, including reducing the net lateral acceleration felt by the passengers as the vehicle negotiates a horizontal curve. The price paid for this advancement may be increased suspension system complexity, possibly introducing new requirements for hydraulics system servicing into the train maintenance schedule.

The TLV concept introduces a more severe suspension problem because of the higher vehicle velocity. The vibratory acceleration response of a vehicle equipped with an active suspension system increases with speed as it travels over a typically imperfect surface. To maintain the same degree of vibration isolation with a passive system as speed increases, a softer suspension typified by a larger stroke capability (and larger relative vehicle/guideway motion) is required, aggravating the problem of controlling the vehicle under external and sustained loading. The non-contacting suspension, however, does reduce the high-frequency input from the guideway. The development of the suspension system is one of the most important goals of the current TLV research programs. Preliminary studies indicate that good ride quality can be achieved for typical guideway surfaces. The suspension system will have to be quite sophisticated, however, probably with active feedback control of the suspension elements. The details of the system will vary greatly, depending on the type of air cushion or magnet.

Ease of maintaining the guideway tolerances is expected to be one of the main attributes of the TLV systems. Reduced constant pressure and the exclusion of heavy freight traffic on the exclusive guideway will both tend to alleviate tolerance degradation.

System Capacity

The two factors which limit any system capacity over a particular link are the headway (time interval) at which trains can be run and the number of seats per train. For the IPT the operation and headway are based on conventional railroad control and signalling. The basic train separation is determined by block spacing. The ultimate capacity will depend on schedule interferences from freight and commuter service. The control requirement area is perhaps the most highly affected by existing facilities and increased demand for IPT service. Each application will have to be reviewed independently to determine the need for additional multiple tracks and/or passing sidings, revised signal systems, revised interlockings, improved communications facilities, and automatic speed enforcement equipment. At the present time, a service frequency of 8 to 15 trains per day in each direction is anticipated. At this service level freight and commuter interference problems would require a reasonable investment in additional facilities. With trains composed of ten 70-seat cars, the system would provide a one-way capacity of 5600 to 10,500 seats per day. Higher demands would require additional study to determine what increased capital investment for equipment would be necessary to allow increased service frequency. In any case, the system capacity would probably be limited by economic and scheduling factors instead of technical restrictions.

For TLV, the dedicated guideway and single speed service simplifies the train spacing problem. For the basic operation - dual one-way guideways - the headway is determined by the allowable spacing between trains based on either train stopping distance or terminal dwell time. With braking capacity to decelerate from 300 mph at an acceptable comfort limit, the stopping distance requires less than a two minute headway while the station dwell time (boarding time plus time for a train to clear the platform with adequate safety margin) would probably require more than two minutes. Minimum headways, of course, require a refined control philosophy backed up by a suitable command, control, and communication system for automatic train operation. Under these conditions a headway of 5 minutes presents no problems and a headway of 3 minutes appears feasible for the TLV system. The train length would be determined by either platform length (requiring satisfactory passenger movement designed into the terminal) or total power requirements of the train (i.e., power supplied through the wayside distribution system.) Present projections indicated that platform length should be limited to 1000 feet, allowing a maximum of 8 cars (800 passengers) for a TLV train. The power requirements of the high speed TLVs formed into trains put stringent demands on the wayside power distribution system. As indicated in the following section on power requirements, the predicted power level required for the TACV and repulsion MAGLEV are higher than for the attraction MAGLEV. Using the power requirement for an 8 car attraction MAGLEV train (approximately 25 MW) as an upper limit, the TACV trains would be limited to 5 cars. The resulting maximum system capacity using a 5-minute headway, in seats per day in one direction, would range from 84,000 for the TACV to 134,400 for the attraction MAGLEV, assuming 14 hours' operations per day.

Power Requirements and Energy Consumption

A prediction of the power required to operate HSGT systems is important for several reasons. The principal need is to determine and evaluate energy consumption as a direct operating cost. The installed power requirements also have a direct effect on the design of the vehicles (e.g., weight attributed to the power plant) and system (e.g., wayside power distribution system) and their operational characteristics. Additional factors directly related to power requirements are the quantity and type of air polluting emissions and the consumption of energy resources.

The parameters describing the power requirements and the energy consumption of HSGT alternatives and the estimated performance of each are presented in Table 3-1 and Figure 3-1. To place these data in context, guided ground modes [IPT, TLV (all three suspension types), Metroliner, Turbotrain] are given as well as the auto, a diesel bus, and a conventional medium range aircraft (DC-9-30) for reference.

All systems, except the aircraft, are compared on the basis of cruise power at a specified maximum continuous cruise speed. The DC-9-30 performance is estimated assuming a typical landing/takeoff (LTO) cycle, a total trip length of 300 miles, and a cruise altitude of 25,000 feet.

The specific energy values (10^3 BTU/seat mile) presented in Table 3-1 and Figure 3-1 refer to fuel consumption. The cruise power in the table is motive power, which is the power consumed in overcoming vehicle drag and providing the support and guidance functions. This motive power is divided by an overall efficiency (fuel energy rate-to-motive power) to obtain the specific fuel consumption.

The assumed efficiencies for the several modes are based on the engine and drive train efficiencies defined in the footnotes of Table 3-1. For the all-electric systems, an overall efficiency of 25% is based on the following:

Generating station efficiency	36%
Transmission line efficiency	90%
Distribution and collection efficiency	90%
On-board power conversion efficiency	85%
Overall efficiency	25%

The IPT system was assumed to be similar to the Turbotrain with respect to speed, weight, axle loading, and aerodynamic drag. IPT is presumed to have more efficient propulsion systems than the Turbotrain: regenerative gas turbines or diesel engines.

The difference between cruise power and aerodynamic drag power represents the power consumed by the support and guidance systems, which in the case of wheeled systems is made up of rolling friction and wheel bearing friction. For TLV systems, support and guidance power includes the cushion compressor power and associated momentum (or captation) drag power (to bring captured air up to vehicle speed) for air cushion systems, and magnetic drag power (to overcome eddy current losses in guideway) and magnetic operating power for the magnetic systems.

TABLE 3-1

GROUND TRANSPORTATION MODES
- Energy and Power Considerations -

MODE	NUMBER OF PASSENGERS	GROSS WEIGHT (LB)	CRUISE SPEED (MPH)	FRONTAL AREA[1] ($FT.^2$)	NUMBER OF VEHICLES	NUMBER OF AXLES	DRAG CO-EFFICIENT	CRUISE POWER (HP)	AERO DRAG POWER (HP)	EFFICIENCY (Fuel to Motive Pwr)	SPECIFIC ENERGY (10^3BTU)/ Seat-Mile)
Auto (U.S. compact)	4	3,000	60	20	1	2	.5	21	14	.17[6]	1.32
Bus	53	28,000	60	85	1	2	.46	174	112	.32[5]	.44
Metroliner	382	1,050,000	125	117	6	24	1.37	2960	2050	.25[2]	.63
NTL	987		130		12			11900	-	.25[2]	.95
Turbotrain	144	256,000	150	135	3	6	.38	1430	1140	.16[3]	1.05
	144	256,000	170	135	3	6	.38	2000	1645	.16	1.30
	326	440,000	125	135	7	10	.70	1600	1220	.16	.62
IPT	300	442,000	120	120	6	9	.62	1185	845	.28[4]	.30
	150	221,000	150	120	3	5	.38	1262	1020	.28	.51
	300	442,000	150	120	6	9	.62	2121	1645	.28	.43
	600	817,000	150	120	11	14	1.02	3560	2710	.28	.36
	900	1,190,000	150	120	16	19	1.42	5025	3800	.28	.34
	300	442,000	170	120	6	9	.62	2968	2390	.28	.53
	300	442,000	150	120	6	9	.62	2121	1645	.32[5]	.38
TLV:											
TACV	100	100,000	300	125	1	-	.22	7577	4900	.25[2]	2.56
	300	300,000	300	125	3	-	.40	16930	8900	.25	1.92
	600	600,000	300	125	6	-	.67	32910	16850	.25	1.75
	800	800,000	300	125	8	-	.85	40295	18900	.25	1.71
Repulsion MAGLEV	300	300,000	300	125	3	-	.40	15000	8900	.25	1.70
Attraction MAGLEV	300	300,000	300	125	3	-	.40	11730	8900	.25	1.33
DC-9-30[7] (for ref.)	115	98,000	565	-	-	-	-	-	-	-	2.55

[1]Basis for drag coefficient;

[2]All-electric propulsion;

[3]Aircraft gas turbine: Efficiency n = .18, Drive train efficiency n_{DT} = .87;

[4]Regenerative gas turbine: n = .32, n_{DT} = .87

[5]Diesel: n = .37, n_{DT} = .87;

[6]Otto cycle: n = .20, n_{DT} = .85;

[7]300 mile trip, including LTO cycle

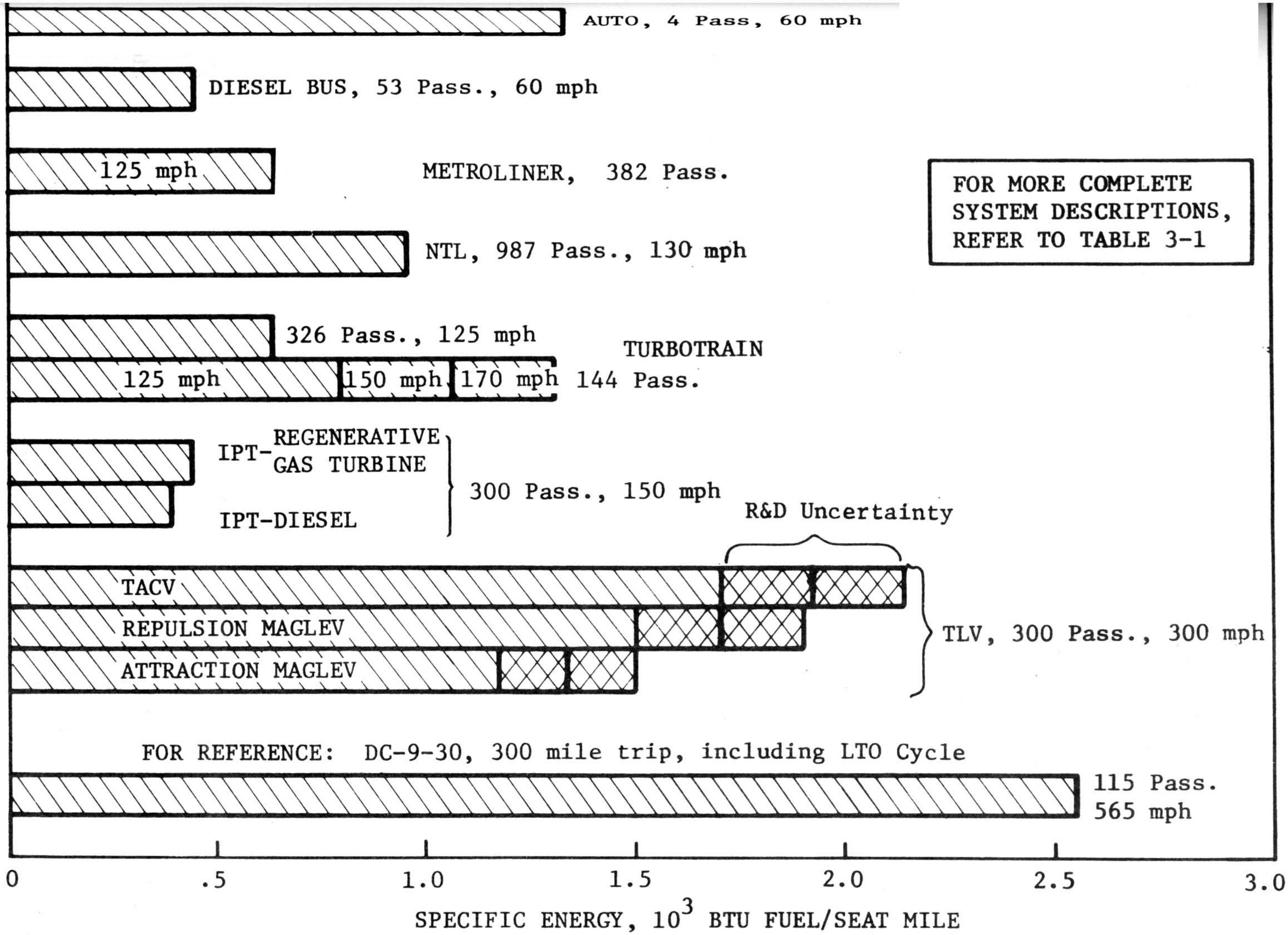

FIGURE 3-1
SPECIFIC ENERGY REQUIREMENTS FOR VARIOUS GROUND TRANSPORTATION MODES

(All systems, except DC-9-30 are compared on the basis of cruise power at specified maximum cruise speed)

The drag coefficients assumed for the rail and TLV systems are given in Table 3-2. The drag coefficients for the Metroliner and the Turbotrain were adjusted to match the following assumed power requirements:

- o Metroliner (6 car train): 5680 motive hp @ 160 mph; 7200 hp available.
- o Turbotrain (7 car, CNR system): 1600 motive hp @ 125 mph; 1600 hp available
- o Turbotrain (3 car, PCRR system): 2000 motive hp @ 170 mph; 2000 hp available.

The train resistance was determined using a standard formula[5] for the drag of railed vehicles.

For the Tracked Air Cushion Vehicle, air cushion compressor power (levitation and guidance) was taken to be 14.1 hp per 1000 lbs. of vehicle weight at 300 mph, a value based on a recent design study[6] of air cushion suspensions. This estimate assumes that guidance cushion

[5]Haase, R.H., and Holden, W.H.T., Performance of Land Transportation Vehicles, Report RM-3966-RC. The RAND Corp., Jan. 1964.

[6]Sussman, N.E., Air Cushion Designs for the Suspension Comparison Study, Report WP-9748, The MITRE Corp., 19 May 1972.

TABLE 3-2

DRAG COEFFICIENTS ASSUMED FOR POWER CALCULATIONS

Drag Coefficients

Mode	Lead Car (C_{DLC})	Following Cars (C_{DFC})	Base (C_{DB})
Metroliner	.39	.17	.13
Turbotrain	.10	.08	.12
IPT	.10	.08	.12
TLV	.10	.09	.12

Note: Total aerodynamic drag coefficient (C_D) for a train of N_C cars is given by:

$$C_D = C_{DLC} + (N_C - 1)\ C_{DFC} + C_{DB}$$

power is 62% of the levitation cushion power.[7] This compressor power estimate is reasonable, if somewhat optimistic, in light of the following quoted values for TACV systems:

System	Specific Compressor Power (hp/1000 lb.)	Speed	Refer to Footnote
Aerotrain 250-80	16	155 mph	8
Aerotrain 180-44	20	122 mph	8
Channel G'way system	20.5	250 mph	7
Channel G'way system	6.9	300 mph	9
TACRV	40	300 mph	10

Momentum drag power for the TACV is based on a cushion air flow requirement of 1.35 lb/sec per 1000 lbs. of vehicle weight for levitation alone,[6] with an additional 62% allowed for guidance requirements.

For the repulsion MAGLEV system, magnetic drag was estimated on the basis of a lift-to-drag ratio of 40, including drag associated with the guidance system.[11] Cryogenic power was assumed to be .33 hp/ 1000 lbs.

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[7] A Cost Comparison of Three Tracked Air Cushion Vehicle Configurations, Prepared for DOT, Tracked Hovercraft Limited, July 1970. Available from NTIS PB-197-501.

[8] The Evolution of Tracked Air Cushion Vehicles, Part One, Hovering Craft & Hydrofoil, Vol. 9, No. 11, August 1970.

[9] High-Speed Ground Transportation Systems Engineering Study, TRW Systems Group, op. cit.

[10] The Tracked Air Cushion Research Vehicle (TACRV) System Summary Report, Federal Railroad Administration, Office of Research, Development, and Demonstrations; May 1972, available from NTIS PB-211-216.

[11] Technical Feasibility of Magnetic Levitation as a Suspension System for High Speed Ground Vehicles, Prepared for U.S. DOT under Contract DOT-FR-10026, Ford Motor Co., February 1972, available from NTIS PB-210-50

For the attraction MAGLEV systems, magnetizing and control power were taken to be 1.3 hp/1000 lbs. and 0.1 hp/1000 lbs. respectively, for support and guidance. Magnetic drag was based on an overall lift-to-drag ratio of 100.[11]

Since the TLV systems are in the research and development stage, the power calculations are based on predictions which have a larger degree of uncertainty than numbers which rely on past experience. An estimate of this uncertainty, which amounts to approximately ± 12% of the nominal value for each TLV system, is indicated as a band of "R&D uncertainty" in Figure 3-1. It is calculated as the rms (root mean square) variation resulting from an assumed 15% uncertainty in aerodynamic drag and a 20% uncertainty in all other components of system motive power.

The effect of speed on the power consumption of the rail and TLV modes is given in Figures 3-2 and 3-3. For the TLV systems, the major components of consumed power are indicated. Note that for the rail systems, train size (number of passengers) is a variable.

The effect of train length on specific energy consumption is shown in Figure 3-4 for some of the systems (TLV and IPT). The benefit of train length comes entirely through reduction in aerodynamic drag per seat. The effect of train length is more pronounced for the attraction MAGLEV system because aerodynamic drag makes up such a large portion of the total power.

In summary, the electrical power, delivered to the vehicle through the power rail, required to supply two TLV systems (air cushion and attraction MAGLEV suspensions) for 400 and 800 passenger configurations is given below:

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[12] Ford Motor Co., op.cit.

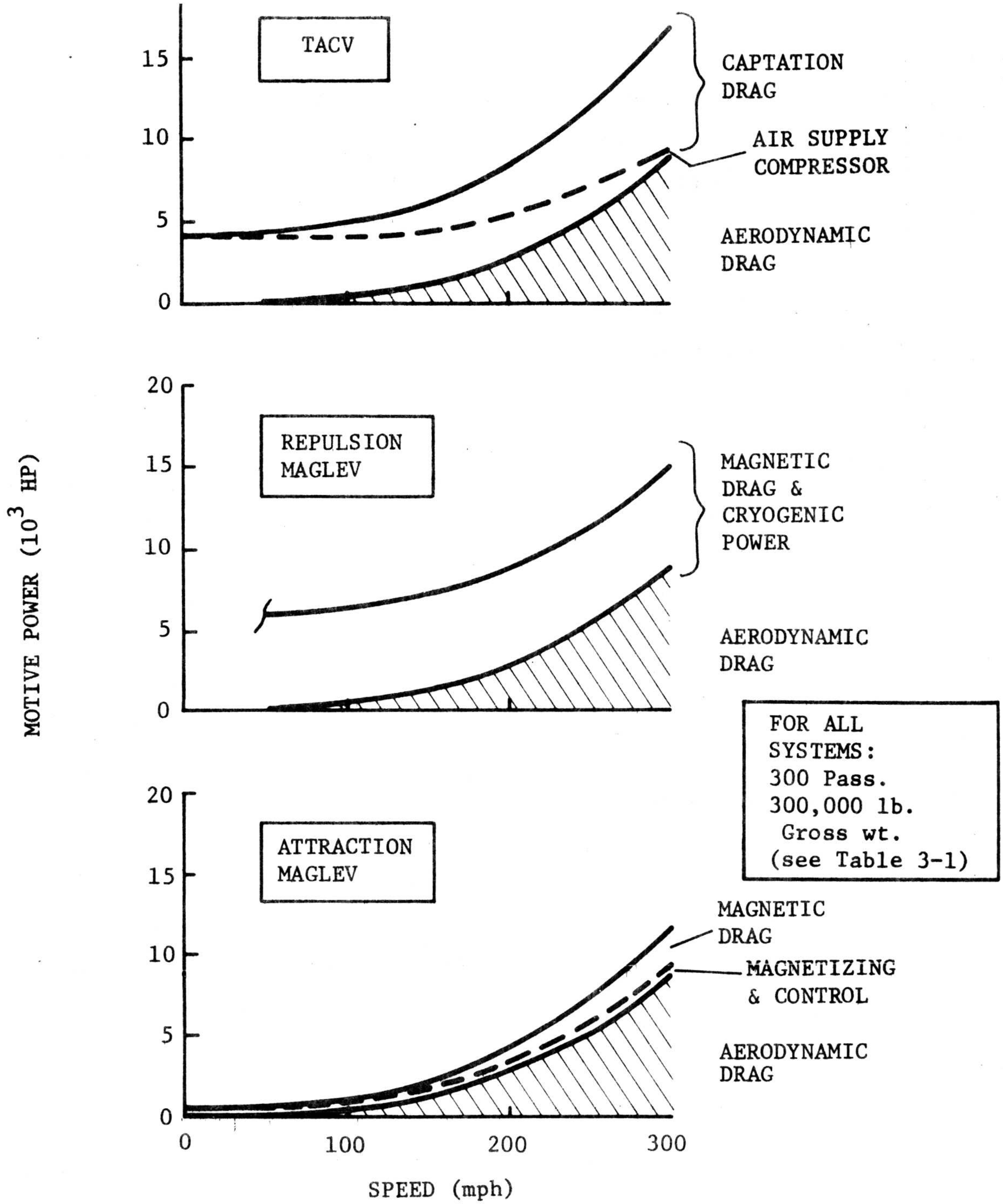

FIGURE 3-2
MOTIVE POWER REQUIREMENTS FOR TLV SYSTEMS

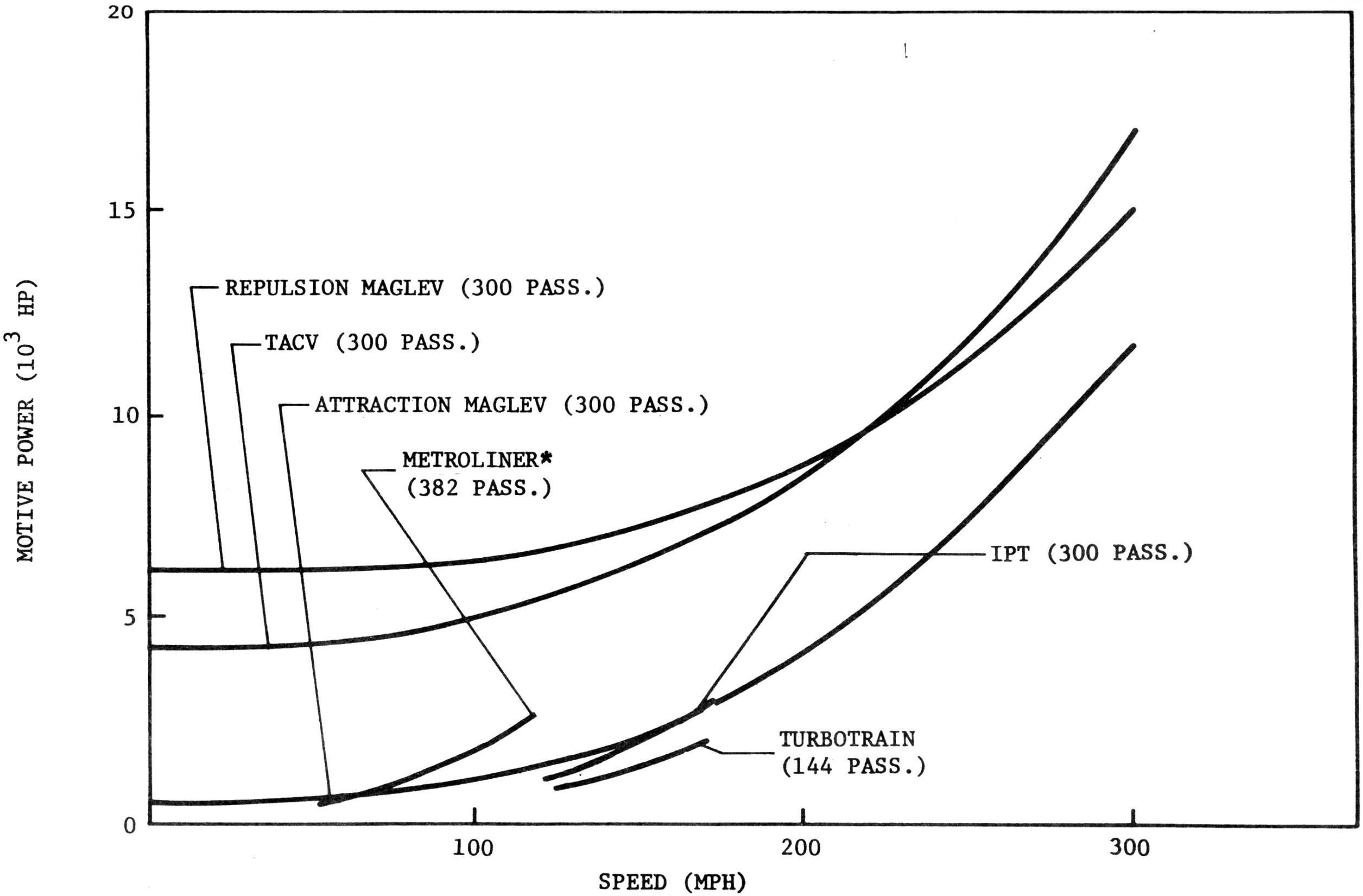

FIGURE 3-3
MOTIVE POWER REQUIREMENTS FOR VARIOUS HIGH SPEED GROUND TRANSPORTATION SYSTEMS

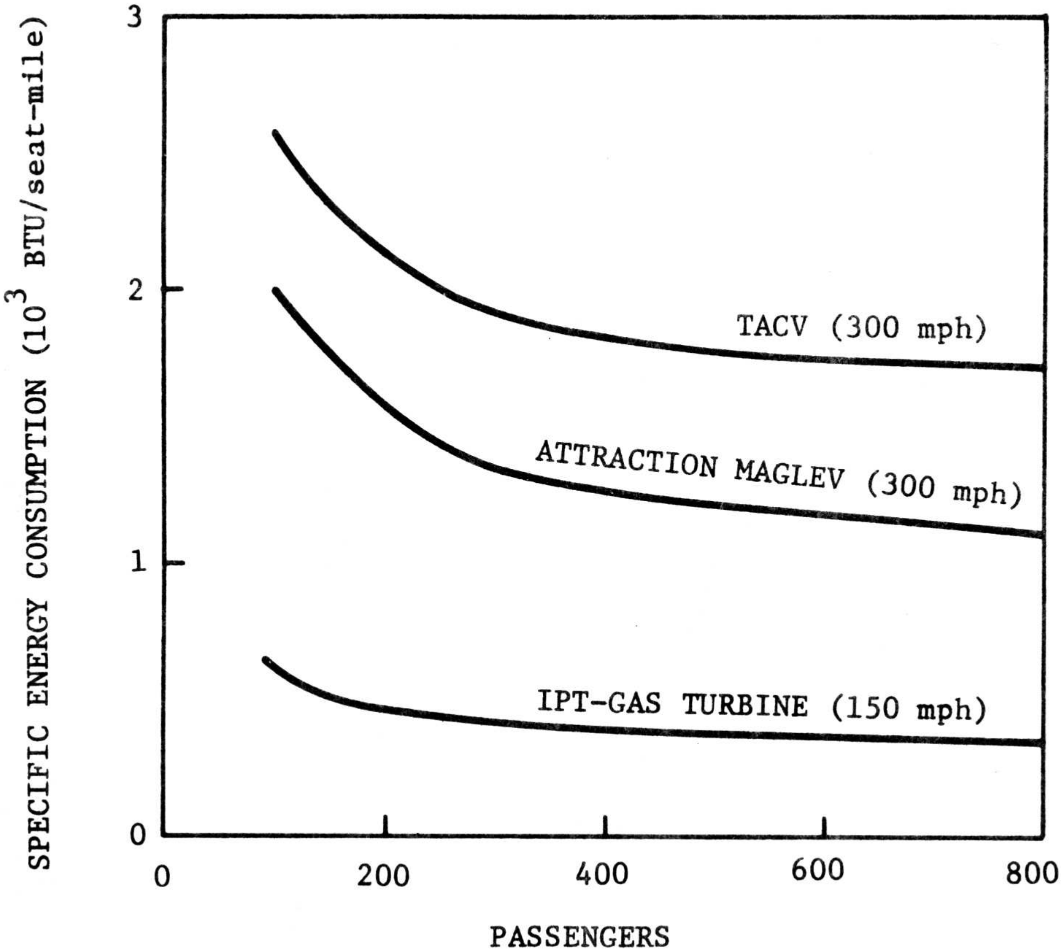

FIGURE 3-4
EFFECT OF TRAIN LENGTH ON SPECIFIC ENERGY CONSUMPTION
TLV AND IPT MODES

	Power at the Rails, 300 mph	
	400 Pass.	800 Pass.
TLV:TACV	19 Mw	35 Mw
TLV:Attraction MAGLEV	13 Mw	23 Mw

Noise

Noise from a HSGT system is an important factor in its implementation because of the impact it creates on the community environment. Excessive noise can cause a major deterioriation in the quality of life in the affected zone, limiting the uses of adjacent land, causing a reduction of property values and forcing owners to make investments in sound attenuating devices. In the extreme, noise could prohibit the implementation of a new system. The technical evaluation of noise is difficult, and the economic analysis is even more complex since it involves the trade-off between direct costs (noise research and noise abatement engineering) against indirect or external benefits in reduced environmental impact. Effects of noise from transportation systems have been analyzed in the previously mentioned NECTP[12] study. This section will present only estimates of HSGT noise sources and qualitative discussion of the potential impact on particular HSGT applications.

The physical properties of noise are well known, but the appropriate methodology for measuring subjective response of individuals and

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[13] Recommendations for NEC Transportation, op. cit.

communities to noise is still under debate. Physical measures of sound describe the sound pressure level measured in decibels (dB) and the frequency content of sound. The human ear is insensitive to very low and very high frequencies of sound. Various weightings of frequency spectra have, therefore, been used to reflect the noise perceived by the human ear. The "A" frequency weighting, producing a sound measurement in dB(A), is in common usage. A more recent and complex measure, developed to measure the annoyance from jet aircraft, is in the perceived noise level (PNL) measured in perceived noise decibels (PMdB). These measures of noise indicate subjective response to noise but do not indicate subjective judgment that noise is excessive. The community annoyance created by a new sound source, such as a HSGT system, will depend on the level, duration, and frequency of occurrence of the sound and also the existing background noise level. Ratings have been developed that attempt to consider the impact of some or all of these factors. Among these rating techniques are the Noise Exposure Forecast and the Noise Pollution Level.

Several measured values of transportation noise are compiled in Table 3-3, along with predictions for the new HSGT modes.

Transportation noise is definitely a problem. Noise abatement research and development programs, however, should give reasonable noise reduction rates. For example, the Quiet Engine Program technology for future generation aircraft engines is expected to produce a 20-25 dB noise abatement, with STOL and VTOL noise abatement technology achieving noise levels equivalent to CTOL aircraft. Similarly, a HSGT noise abatement research program, if successful, could yield the 15-20 dB noise abatement assumed in the TACV predictions. The 300 mph TACV, depending on the configuration, will produce noise levels comparable to a "noisy" truck or train. The 150 mph Urban TACV will be

TABLE 3-3 NOISE LEVELS FOR VARIOUS TRANSPORTATION MODES

	Mode	Speed (mph)	Noise Level @ 50 Ft. dB(A)	Noise Level @ 50 Ft. PNdB	Comments/References
HIGHWAY	Auto	60	70	84-88	Reference 2, 5
	Freeway Traffic	50-70	76	90	Reference 1
	Diesel Truck		90	101-104	Reference 1, 2, 3
RAIL	Freight	40		93-110	Reference 1, 2, 3
	Metroliner	107	92		Reference 4
	Turbotrain	97	89		Reference 4
	NTL (Japan)	124	87-92		Reference 7
TLV	UTACV	150	73		DOT Specification, Ref. 5
	Aerotrain	90	79-82		LIM vehicle (Ref. 6)
		150	97-99		Propellor vehicle (Ref. 6)
	TACV	300	83-98	96-111	Projected for 1985, Reference 1, 3
AIR	CTOL	Takeoff		120 (At 500 ft.)	Reference 2
	V/STOL	Takeoff		88-105 (At 500 ft.)	Reference 1, 3

References for Table 3-3:

1. Recommendations for Northeast Corridor Transportation, Vol. 2, September, 1971, NTIS PB-205-242.

2. High Speed Ground Transportation Systems Engineering Study, Tracked Air Cushion Vehicle Systems, TRW Systems Group, May, 1970, NTIS PB-145-030.

3. Rogstad, B., et al, Analysis of Major Short-Haul Transportation Problems, Report R-1586, PRC Systems Science Co., Nov., 1971.

4. E. Rickley, DOT/Transportation Systems Center, Cambridge, Mass., 16 October 1972 (from a TSC report on rail system noise, soon to be published).

5. Varney, F. M., Noise and Pollution Limits for 1972 Airport Access TACV, DOT/FRA/ORD&D, April, 1970.

6. Bender, E. K., et al, Analysis of Potential Noise Sources of Tracked Air Cushion Vehicles (TACV), Report DOT-TSC-194-1, Bold Beranek and Newman Inc., July, 1971.

7. Bray, D. E., Noise Factors in Future Fixed Guideway Transportation Systems, Conference on Accustics and Societal Problems, Arden House, June 18-21, 1972.

comparable to cars on a freeway. The MAGLEV system will be quieter than the TACV, but noise will still be generated by aerodynamic effects and power collectors, along with structure-borne noise from the guideway and power rails.

The HSGT systems are characterized by a different noise pattern than aircraft. They will produce a noise swath like a highway rather than a footprint in a particular area like aircraft operations at an airport. For IPT and TLV over existing rights-of-way, however, the community impact will be minimized because of the presence of existing noise sources.

Several noise abatement options exist in the design and implementation of an HSGT system. Policy oriented options include location of route, below-grade guideway, and speed reduction in built-up areas. Technology oriented options include vehicle design and sound barriers for the guideway.

Air Pollution

Emissions for the several modes have been estimated (on a $lb/10^3$ seat-mile basis), and the results are shown in Table 3-4 and Figure 3-5. The assumed emissions rates for the fossil-fueled propulsion systems are given below:

		Emissions ($lb/10^3$ hp hr)				
Engine	Mode	UHC	CO	NO_x	SO_2	PART.
Modified Spark Ignition-meeting 1975/76 Stnds.	Auto	2.6	21.4	2.5	--	--
Diesel[14]	Bus	1.8	10.5	17.5	1.3	0.6
	IPT	2.3	3.2	3.5	3.0	1.2
Regenerative gas turbine[15]	IPT	.7	2.5	2.2	--	--
Non-regenerative gas turbine[15]	Turbotrain	1.4	5.2	4.4	--	--

For the electrically powered systems, the assumed emissions levels are the following:

	Emissions ($lb/10^6$ BTU of fuel)		
Power Plant Configuration	NO_x	SO_2	PART.
A. Uncontrolled (1970) fossil-fueled stations with 1% S fuel	.75	1.3	.25
B. High-technology controls on fossil-fueled stations (available by 1990)	.35	.13	.02
C. 50% Nuclear (no emissions) and 50% configuration B	.18	.06	.01

For the DC-9 aircraft (used for reference only), the emissions are based on a typical Landing/Takeoff cycle, and on the following emission indices for cruise operation at 15,000 feet (consuming 5740 lbs. fuel/hr at 500 mph):

[14] Environmental Protection Agency, Air Programs Office, Compilation of Air Pollutant Emission Factors, revised edition, February 1972.

[15] Fraize, W. E. and Lay, R. K., A Survey of Propulsion Systems for Low-Emission Urban Vehicles, ASME Paper 70-Tran-49.

TABLE 3-4

GROUND TRANSPORTATION MODES EMISSIONS *

Mode	No. Pax	Cruise Speed (mph)	UHC	CO	NO_x	SO_2	Part.
			Emissions ($lb./10^3$ seat-mile)				
Auto[3]	4	60	.27	2.21	.26	–	–
Diesel Bus	53	60	.11	.67	1.12	.09	.04
Metroliner	382	125	–	–	(.47/.22/.11)[1]	(.82/.08/.04)	(.16/.01/.006)
	382	160	–	–	(.71/.33/.17)	(1.24/.12/.06)	(.24/.02/.01)
Turbotrain	326	125	.062	.23	.19	–	–
	144	170	.128	.47	.40	–	–
IPT (gas turbine)	300	150	.04	.13	.12	–	–
IPT (diesel)	300	150	.13	.18	.19	.16	.07
TLV							
Air Cushion	300	300	–	–	(1.44/.67/.35)	(2.50/.25/.12)	(.48/.038/.019)
Superconducting	300	300	–	–	(1.28/.60/.31)	(2.21/.22/.10)	(.42/.034/.017)
Ferromagnetic	300	300	–	–	(1.00/.47/.24)	(1.73/.17/.08)	(.33/.027/.013)
DC-9-30[2] (for reference)	115	565	.56	.73	.30	.13	.052

[1] A/B/C CORRESPONDS TO: A=Emissions from uncontrolled fossil-fueled generating stations, 1% S fuel, 50% coal, 50% oil

B=Emissions from highly controlled fossil-fueled generating stations, 1% S fuel, 50% coal, 50% oil

C=Emissions from 50% nuclear plants and 50% highly controlled plants

[2] 300 mile trip, including LTO cycle

[3] With 1975/1976 Emissions standards as set by the Amended Clean Air Act of 1970

*The question of relative toxicity of the various pollutants has not been addressed. This table and Figure 3-4 show only the quantities of pollutants to be expected.

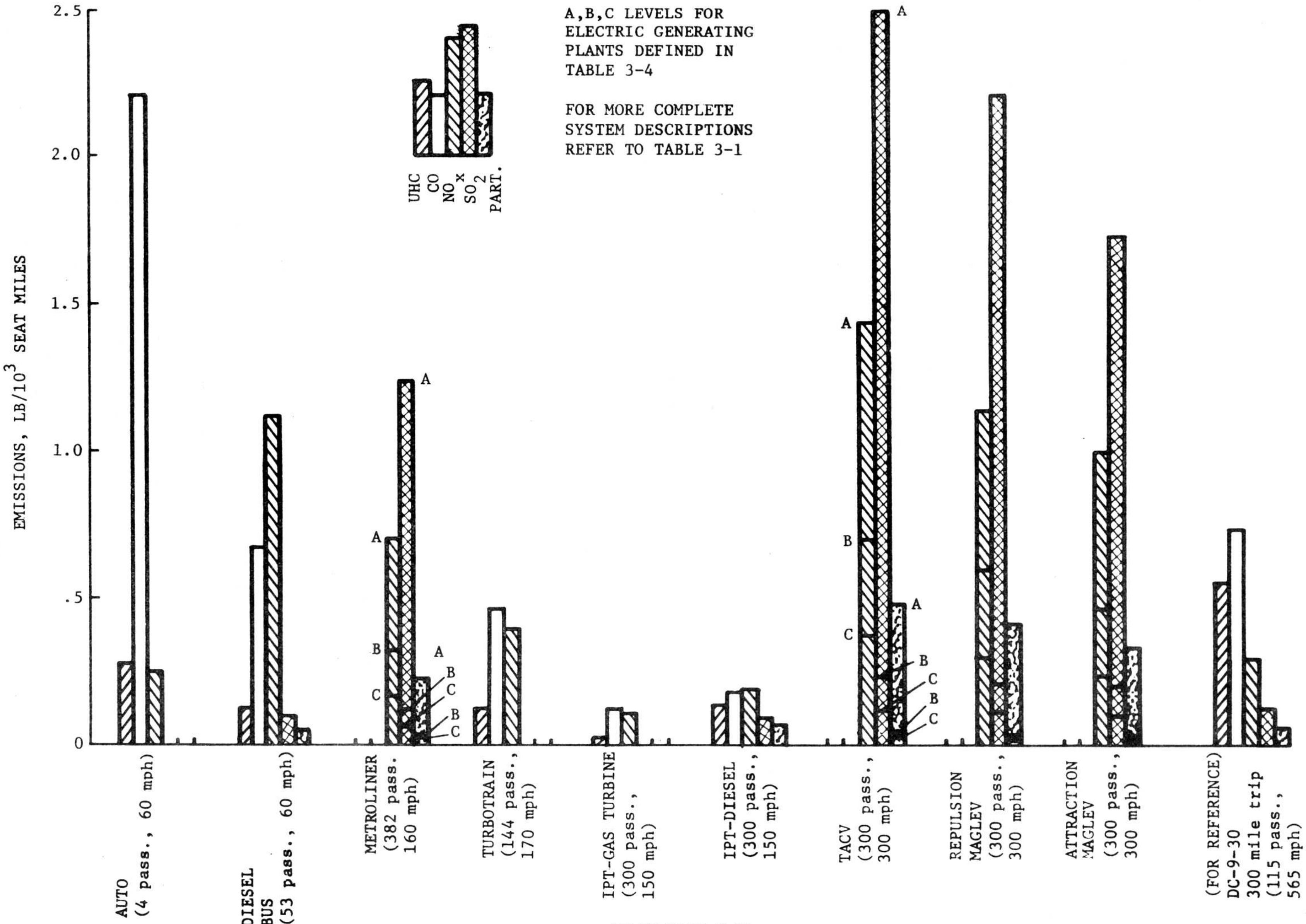

FIGURE 3-5
EMISSIONS FOR VARIOUS GROUND TRANSPORTATION MODES

Unburned Hydrocarbons (UHC)	:	4.0 lb/10^3 lb. fuel
Carbon Monoxide (CO)	:	5.0 "
Nitrogen Oxides (NO_x)	:	2.3 "
Sulpher Dioxide (SO_2)	:	1.0 "
Particulates (Part.)	:	.4 "

Figure 3-5 indicates a high price is paid, in terms of emissions, for electrified TLV used with existing electric generating station controls (level "A"). Even with high technology controls on fossil-fueled power stations, NO_x is still high compared to other modes except for the diesel-powered systems. Elimination of the NO_x problem must await the wide-spread use of nuclear power plants (1990 or beyond). None of the considered systems produce CO as profusely as the auto, although the diesel bus and the air modes make significant contributions. The IPT (gas turbine) is twice as clean as the Turbotrain because the assumed IPT regenerative gas turbine is more efficient and burns less fuel.

It should be understood that emissions for electrically powered systems occur at the central station, whereas the other systems generate emissions locally.

Safety

The passenger death rate for train travel is among the lowest for all transportation modes. With increased speed and increased traffic on existing trackage, effort will be required to maintain this safety level. One particular problem will be grade-crossing safety requiring automatic protection, including timing controls to provide for the variance between freight and passenger speeds, where grade separation is not economically feasible. In addition, the present problems of track and switch degradation with heavy freight service will continue to exist. Vandalism, foreign obstacles and people on the tracks may be alleviated by fencing. Signal system improvements may be necessary to handle the increased traffic.

Many of the foreseeable safety problems with a TLV system will be alleviated with the dedicated guideway. The excellent safety record of the Japanese NTL, (over 400,000,000 passengers without a fatality) operating on a dedicated right-of-way, illustrates that an isolated and protected system can overcome the potential hazards of increasing speeds. Foreign obstacles on the guideway could remain a problem for the TLV, depending on the vehicle/guideway configuration. Security isolation of the guideway (elevation, fencing) can be traded off against the development of an automatic foreign obstacle detection system.

TLV Suspension Systems

The TLV system includes two broad categories of non-contacting suspension systems. The Tracked Air Cushion Vehicle utilizes the flow of air from the cushion structure to maintain mechanical separation between the vehicle and its guideway. Air cushions are used to support the vehicle and also to maintain directional control by opposing reactions against guidance surfaces. The megnetically levitated vehicle employs magnetic field for support and guidance. Three such techniques have been demonstrated:

Repulsion Between Permanent Magnets

The recent development of rare-earth cobalt permanent magnets possessing good resistance to demagnetization gives new impetus to the old idea of using the repulsion between like poles to support and guide a vehicle. The advantages of permanent magnets for suspension are that there is no induced drag and no power is required for levitation. However, the system is unstable and supplementary guidance is essential. The cost of the guideway is probably the most overwhelming drawback.

Attraction Between Steel Rail and Servo-Controlled Electromagnet

Two German firms have already demonstrated the feasibility of this technique at speeds up to 100 mph. Two of the factors that might affect operation at high speed are the dependence of eddy current drag and repulsion on the conductivity and permeability of the steel rail. The alignment required of the guide rails for compatibility with the dynamic range of the servo, as well as for good ride quality, is also a critical factor.

Repulsion Between a Superconducting Magnet and Guideway Conductors

The greatest advantage of superconducting magnets in vehicle suspension is that they can stably levitate a vehicle moving over the track with a clearance of several inches. The conductors in the guideway may take the form of discrete or continuous sheets. Drag exists due to eddy currents induced in the sheet but the use of long coils and thick sheets results in acceptable lift to drag ratios. Significantly greater lift to drag ratios can be achieved by resorting to null-flux configurations at the expense of substantial guideway cost. The suspension is dynamically stable but virtually undamped so that active or passive damping must be supplied. The cryogenics aspect of superconducting coils is now considered to be well within the present state-of-the-art.

Suspension Comparison

At this time both the air cushion and MAGLEV concepts appear promising, with no one system having a clear-cut advantage. A comparison of the distinguishing characteristics of the air cushion, the superconducting repulsion MAGLEV, and the ferromagnetic attraction MAGLEV, which are the most promising of the TLV suspension systems, is presented in Table 3-5.

IPT Track Improvement Costs

One of the basic premises of the IPT concept is the reduction of investment in changes to route alignment (curve easements and bypasses) by improvements in train hardware design. Even so, substantial improvement of the track and signal systems of the present routes is required before IPT operation is feasible. Two basic types of improvements are necessary: track conditions must be improved to allow high-speed operation, and signal systems and grade crossing protection must be improved to permit safe operation at those speeds.

Much U.S. trackage is in far poorer condition than its British counterpart so that the British Rail claim of high speed on existing track for the advanced Passenger Train (APT) is not necessarily applicable in this country. As a result, the IPT must seek an optimal compromise between vehicle sophistication and track upgrading.

In general, track upgrading could involve four levels:

1. Repair of ties, ballast, hold-downs, etc. and general track work to obtain tolerances for high-speed.
2. Provision of multiple track and/or passing sidings for joint operation with freight traffic.
3. Substitution of new welded rail for bolted rail.

TABLE 3-5 CHARACTERISTICS OF TLV SUSPENSIONS

	Air Cushion	Repulsion MAGLEV	Attraction MAGLEV
Power	Relatively high compresser power and captation drag	Low magnet power. High eddy current drag	Low magnet power. Low eddy current drag.
Operating Clearance	1/10" to 3/4" (to keep power requirements reasonable)	Several inches	1/2" (lift magnet below rail)
Control of Levitation/Guidance Forces	Passive (active control considered)	Active (for damping	Active
Secondary Suspension (assuming normal track tolerances)	Required	None	Required
Guideway	Large surfaces required	Large surfaces with conducting sheets or coils required	Ferromagnetic rails required (may have to be laminated)
Contact Pressure	Lowest	Low	Highest
Status	Full size test vehicle operational (175 mph) France	Lab. experiments, small vehicle constructed	Full size test vehicle operational (100 mph) Germany
Noise sources (In suspension system)	Compressors, air cushions	None	None
Special On-board Equipment	Air Compressors	Cryogenic-cooled superconducting magnets. Low speed support system.	Sensors and controls for electromagnet

4. Changes in superelevation for high speed.

The first and second represent a minimum investment which must be made if high speed passenger trains are to be introduced at all. The third and fourth permit stepwise increases in average speed over a route as sections are improved. Obviously, those sections producing the best speed improvement at least cost would be upgraded first.

The cost predictions for upgrading a particular route and the average speed over that route will, of course, be highly dependent on existing site conditions. Parametric data relating speed improvement to track upgrading investment will show only general trends and not indicate the step increments of specific projects. Federal Railroad Administration estimates for upgrading facilities and track for particular routes considered in the cost/revenue studies of Chapter V are as follows:

Corridor	Average Speed	Cost of Upgrading/Route Mile
Chicago-Detroit	82	$202,000
Portland-Seattle	60	123,000
San Diego-Los Angeles	75	172,000

TLV Fixed Plant Cost Considerations

High speed ground transportation evaluations such as this study highlight the major role of investment costs in assessing the viability of a new Tracked Levitated Vehicle system. The fixed plant is the major cost item and therefore the factors which affect the magnitude and accuracy of this estimate must be understood. Control or reduction of the fixed plant investment requires effort in several areas because of the different nature of the elements which go to make up the total cost estimate. Three different areas - system-related costs, route-related costs, and access-related costs - will be discussed in relation to the fixed plant cost estimate of just over three billion dollars ($3 x 10^9) for the land, routeway and guideway construction, electrification, terminals, yards and shops in the NEC (Washington to Boston) TACV system discussed in Chapter V.

System-related costs

The items that can provide a basic fixed plant for a TLV system independent of site conditions are dominated by the guideway, electrification, and control and communications. They will be termed "System-related costs." For the NEC system, they contribute roughly 30% of the total fixed plant cost. The nature of the system-related costs is such that they are most highly dependent on the TLV research and development program and thus the range and accuracy of the estimates are dependent on R&D program success. Within the system-related cost group, the guideway is the most costly item, but holds the most promise for significant cost reduction. Most estimates of elevated guideway for an operational TACV range between $1 million and $3 million (1970 dollars) per double-track route mile. The estimates used for this study (1972 dollars) are $2.5 million per route mile for elevated guideway and $1.1 million per route mile for at-grade guideway. These projections are based on guideway design optimization techniques which reduce costs (e.g., through vehicle/guideway configuration tradeoffs and innovative construction procedures) but stay within state-of-the-art technology. A high priority guideway R&D program offers the potential for further reducing the projected cost.

Route-related costs

Land, roadbed earthwork, changes to existing facilities, such as utilities or roads, bridges, and rural tunnels are the dominant items affected by routing between access points. These elements, which are termed "route-related costs," contribute approximately one-half of the total fixed plant cost. All of the items are characterized by their sensitivity to route selection criteria such as speed limits, horizontal and vertical curvature tolerances, grade limits, tunnel sizes, wayside clearance limits, and vehicle loads.

Several system-related factors interact with route-related cost. To cite a few examples, the criteria for tunnel diameter are related to vehicle performance and have an impact on route-related costs. Well-distributed loads and stable dynamic qualities of the TACV can contribute to reduced bridge costs. Relaxation of horizontal and vertical curve and grade limit criteria, based on the vehicle capability, reduces the depths and length of embankments, in turn reducing earthwork and property acquisition costs. Furthermore, high speed vehicles promote unique routing options such as major excursions around highly congested regions.

The potential for reducing the route-related cost portion of the fixed plant investment lies in route-optimization investigations, with a tradeoff of reducing speed (with increased block travel time) for increased routing flexibility (with decreased cost). In any case, route selection criteria must be developed to be fully commensurate with vehicle performance capability.

Access-related costs

The few miles of TLV route adjacent to the system access points have a major impact on fixed plant costs. In the built-up areas, land acquisition and guideway construction costs are the highest. For example, in the NEC system the necessity for tunnels (which cost approximately 10 times as much per route mile as elevated guideway) is almost exclusively due to providing access to the city centers.

Similarly, underground terminals are more expensive. Consequently, approximately 20% of the total fixed plant cost is associated with the location of access points. Evaluation of this portion of the investment costs requires detailed investigations of alternate terminal locations allowing different methods of guideway construction. Suitable feeder systems might provide even greater flexibility of terminal location. The costs must be traded off against the portion of trip time associated with the access to the terminal since block travel time will be relatively invariant.

TLV Operations

The large investment costs for the new TLV systems require that a large patronage must be served to have a viable system. The capacity can be enlarged by two means -- by increasing the number of seats per train or by increasing the frequency of train operation. Either of these means provides attractive features but each approaches a technological limit. Increasing train size reduces the per passenger operating costs (due to power requirements, Figure 3-4, and crew cost) but approaches a limit in requiring unwieldy amounts of power per train to be supplied by the wayside power distribution system. Increasing train frequency makes the service more attractive to the traveler (reduced waiting time at the terminal) but approaches a limit set by train headway requirements.

The projected demand for the TLV in the NEC from Chapter V will be used as an example of what service characteristics are necessary. The 1985 projected service demand is 5.4×10^9 passenger miles per year for the Washington to Boston system. Applying an average 60% load factor over the route length of 444 miles and assuming service for 14 hours a day throughout the year, the system must provide an average of 2000 seats/hour throughout the day over the complete system.

If the peak-hour service were twice the average, i.e., 4,000 seats/hour, at peak periods the system would be operating at two-thirds the maximum capacity of a double guideway TACV installation.

The high service level indicates the TLV system should be implemented with full considerations of achieving a high capacity. The technical factors associated with high capacity are trains of vehicles, automatic command and control systems, and wayside distribution of high levels of power. The development of these features is the next logical step beyond the present tracked levitated research vehicles which are concentrating on basic principles such as suspension performance, LIM propulsion, and power collection. Looking ahead to providing growth capability, additional maximum system capacity can come from increased propulsion efficiency, allowing greater train lengths, and advanced control concepts, allowing smaller headways.

C. STATUS OF HSGT RESEARCH AND DEVELOPMENT

Previous sections have defined potential HSGT systems that could be implemented in the United States in terms of system characteristics and have discussed some technical factors involved in their development. As was pointed out, the technological performance and costs are estimates and projections based on our present data base. The basis for a decision concerning implementation of a new system becomes firmer only as advanced concepts are substantiated and refined through research and development programs.

Research, development, and testing of new transportation systems is progressing in North America, Japan, and Western Europe. Within the U. S. Department of Transportation, FRA/ORD&D is sponsoring programs for the purpose of exploring and evaluating the potential of new technology to furnish improved intercity passenger transportation. These programs are generally structured to proceed through studies, into hardware development, and then into demonstration projects if the hardware evaluation and cost/benefit comparison results are favorable. At each phase, decision points ensure that a program proceeds only as warranted.

This section will review these programs, both in the U. S. and abroad, to give an idea of the current status of HSGT development and the technical lead times involved in carrying these concepts to implementation status.

British APT

British Rail's Derby Research Center has completed the production of a prototype Advanced Passenger Train (APT). The designers claim that the train, with a new suspension system and lightweight construction, will be "the fastest, quietest, and smoothest riding in the world, and the first to be able to run at very high speed - up to 155 mph - on existing (British) rail routes with little or no alteration to track and signalling."[16] The principal features of the APT are:

- a wheel tread/rail relationship that provides truck stability up to at least 155 mph with little wheel maintenance;
- steering performance providing a 50% increase in speed without flange contact;
- provision to tilt the car body to reduce the sensation of lateral acceleration on curves; and
- lightweight construction to assist both braking and propulsion.

The project has been underway for several years, and the experimental APT-E has started tests. Following this, APT-P prototype train sets "should be carrying passengers by 1975."[17] Full production APTs could follow soon thereafter.

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[15] "Britain Sees Brisk Market for APT," Railway Age, Nov. 8, 1971, p. 30.

[16] Wickens, A.H., (Director of Laboratories, British Railway Board) "APT-E Takes to the Rails," Railway Gazette International, May 1972.

Canadian LRC

A Canadian consortium has demonstrated a prototype coach for a high-speed train - the LRC (Light, Rapid, Comfortable). The LRC's most significant engineering feature is its "powered banking" system, built into the car suspension. The trucks are basically of conventional design but have an additional bolster that can tilt the car body to compensate for up to 10 degrees of unbalanced superelevation. The coach is low, lightweight and has extensive soundproofing. The concept for a complete train could involve cars pulled by a single-unit 2900 HP diesel-electric locomotive or handled between a pair of such units operated in a push-pull mode. Such a train would operate up to 120 mph on existing track.

French TGV (Tres Grande Vitesse, or Very high speed)

An integral part of the plans of the French National Railroad, SNCF, to build new high-speed trunk lines is the development of lightweight trains that will run in regular service at speeds up to 300 km/hr (approximately 186 mph). The TGV 001 is an experimental gas turbine powered five-car set to develop and prove the technology for these trains. SNCF has become the acknowledged pioneer of gas turbine traction for high speed trains. In 1967, a two-car experimental unit reached 252 km/hr on trial. In 1970, four-car ETG sets went into public service at 160 km/hr and this year five-car RTG sets designed for 200 km/hr are due to enter service. The ETG and RTG are intended for secondary main lines; the TGV is directed toward the big intercity corridor market. Unlike the British APT, the TGV 001 does not feature a body-tilting mechanism and the running gear is conventional, the bogies being an improved version of those in use under modern SNCF stock. The reason for these differences is that the APT is designed to run on existing track while the TGV series is intended to run on new routes. After undergoing running trials at speeds up to 200 km/hr, the TGV001 testing was moved to SNCF's traditional racetrack between Bordeaux and Morcenx where speeds up to 300 km/hr have been reached.

U.S. Turbotrain

The Turbotrains, designed and built by the United Aircraft Corporation, have introduced new technology, such as turbine power, aerospace design practices, lightweight aluminum construction, and a pendulous suspension into a high speed passenger train concept.

The Department of Transportation has sponsored a demonstration of Turbotrain revenue passenger service on the Boston-New York route since April, 1969. The service generally has been limited to one round-trip daily. In addition to the Boston-New York demonstration, the Turbotrains have carried out extensive testing, made cross-country exhibition trips, and operated in special demonstrations. For the primary demonstration, DOT leased two Turbotrains from United Aircraft Corporation, who also provides maintenance and servicing of the trains. Penn Central operates the trains under contract to DOT.

The Turbotrain's lightweight welded aluminum bodies have an extremely low center of gravity and aerodynamic form. The pendulous suspension system provides support to a carbody at a point above the center of gravity. When the train passes through a curve at high speed, the passive suspension system operates to tilt the car body inward (beyond that caused by track superelevation) to reduce the sensation of lateral acceleration. Turbotrains can be operated through curves at speeds 30 percent higher than those of conventional trains.

Turbotrains are self-powered. The power plant consists of five ST-6B gas-turbines for propulsion plus one turbine for auxiliary power. The turbines are rated at 400 horse power each. During testing, prior to the demonstration, the Turbotrain easily reached its design speed of 160 mph. In one run on high-speed welded rail test track between New Brunswick and Trenton, New Jersey, it reached a speed of 170.8 mph. For the demonstration, however, the gearing was changed to provide a maximum speed of 125 mph.

U.S. IPT Development Program

FRA is investigating the feasibility of providing for improved high-speed rail passenger service in corridors throughout the United States through the Metroliner and Turbotrain demonstrations and the IPT Developmental Program. The steps to be followed in the IPT program are:

- o Define and quantify the technical requirements for satisfaction of the expected demand;
- o Determine what technology is available to satisfy these requirements;
- o Conduct research to fill any gaps in available knowledge;
- o Draft competitive procurement specifications for next generation equipment and draw up fixed plant improvement specifications for typical corridors.

The requirements for efficient fulfillment of IPT service can be broken down into several relatively independent elements - systems analysis, track, signal and control, suspension and overall configuration, propulsion, braking, body structure, furnishing and utilities, and fixed facilities. The available solutions in each area will be evaluated on their own merits and integrated into a final design, and therefore the IPT is not linked to a particular configuration.

Where solutions exist or are being developed by others, they need to be studied at least sufficiently to permit the definition of realistic and enforceable performance specifications and the knowledgeable evaluation of proposals for acceptability on the basis of probable success.

The IPT program is currently defining and evaluating the service requirements, examining the applicability of the following potential resources:

- o Past and current U.S. trains;
- o Ongoing DOT research, including Advanced Systems spinoff;
- o Overseas developments;
- o Analytical and/or modeling work specifically for IPT;
- o Testing specifically for IPT;
- o Prototype development for IPT; and
- o Supplier optimization via bid processing, incentives, etc.

Specific IPT projects are currently minimized due to limited funding. The present IPT program, including construction and demonstration of a prototype set prior to program commitment, may not provide service until 1977 or beyond. As an alternative, the full IPT prototype development can be contracted to the fleet supplier, with a possible procurement award point early in FY 74 and service in 1976.

French Aerotrain

The French Societe de l''Aerotrain began a vigorous program in 1965, with the start of construction of an experimental TACV system featuring an inverted "T" guideway and a propeller-driven vehicle utilizing low pressure plenum cushions. Testing of the vehicle followed in 1966. A more advanced jet-propelled vehicle was completed in 1968 and tested on the same experimental track. The program utilizing the experimental vehicles led to the construction of two commercial prototypes -- an 80-passenger intercity vehicle (designated 250-80), powered by a shrouded turboprop system and capable of 186 miles per hour, and a 40-passenger suburban vehicle (designated 180-44), powered by a linear induction motor and capable of 120 miles per hour. Testing of these two vehicles began shortly after their completion in late 1969. The Aerotrain 250-80 has demonstrated the feasibility of operation with air cushion support and guidance with speeds up to about 180 mph. This vehicle has accumulated a great deal of running experience, including a 2-1/2 month cycle of running for 5-1/2 hours (500 to 600 miles) per day.

The French government has decided to sponsor a commercial application of the Aerotrain. A 22 km route will link a new business center for Paris at La Defense, to a new town at Corgy-pontoise, northwest of Paris.

British THL

In England, in the early 1960's, Hovercraft Development Limited, a subsidiary of the National Research Development Corporation (NRDC), began studies of tracked air cushion vehicles. These studies indicated sufficient potential to spur the formation of a separate NRDC company, Tracked Hovercraft Ltd.,(THL), in 1967 to extend the scope of the TACV work through full-scale tests, development and demonstration. The company is now developing a facility for full-scale testing of a series of vehicles, as well as continuing a research program covering a range of new technologies for use in guided public transportation systems.

The THL Hovertrain test vehicle, which began operation in 1971, combines air cushion suspension, LIM propulsion and electric power collection. It is experimental in its function and has no provision for passenger carrying. All control is from the trackside. The Hovertrain uses peripheral curtain air cushions; secondary suspension is provided by means of a mechanical spring system working in conjunction with the air cushions. The guideway is of elevated box-beam construction. For the first phase of operation, two separate power supplies are provided on the track, one for the LIM and the other for the fan motors. The LIM produces sufficient thrust to enable the test vehicle to operate in the 150-200 mph speed range. Radio telemetry is used to convey data from on-board instrumentation to the track-side recording equipment that interprets and displays the information by means of suitable computers. The first phase of the guideway construction provides three miles of guideway and the program allows for the provision of a further five miles of guideway after initial testing. At present, one mile of track is in use and a speed of 100 mph has been reached.

U.S. TACV Research and Development

The U.S. TACV program is proceeding into the hardware development stage with the construction of a research vehicle (TACRV) and a prototype vehicle for urban applications (UTACV). The UTACV program, under Urban Mass Transit Administration sponsorship, is based largely on the French expertise. Design studies for 150 mph systems were carried out by Rohr Industries and by LTV Aerospace. Rohr is building a prototype vehicle that will be the first completely electrified passenger-carrying TACV. Full-scale research and development testing will include:

- Air cushion and air supply system performance;
- Advanced suspension systems design and its effect on improving ride comfort;

- o Vehicle aerodynamics;
- o Linear electric motor propulsion systems;
- o High-speed electric power collection from wayside power rails; and
- o Environmental acceptability.

The UTACV will explore these areas within the current 150 mph speed regime. The TACRV test program will extend the state-of-the-art up to 300 mph. Experimental data from the test program, correlated with theoretical predictions and analyses, will be used to develop designs for high-speed commercial systems.

Although the TACV represents a distinct class of vehicle, it is important to note that the data derived from the projects pertaining to suspensions and ride comfort, vehicle aerodynamics, linear motors, and wayside power collection will also be applicable to the design of other advanced high-speed ground transportation systems, particularly magnetic levitation.

The TACV effort in the United States began in 1965 with the Office of High Speed Ground Transportation (OHSGT) sponsoring a study of high-speed ground transportation at MIT. Since that time, highlights of the program have included a TACV system engineering study, by TRW Systems in 1967, which directed attention to tradeoffs arising in TACV systems design, followed by preliminary design studies of a TACRV capable of speeds up to 300 mph by General Electric Company, Grumman Aerospace Corporation, and Aeroglide Systems in 1968. Subsequent contracts were awarded to Grumman Aerospace for the engineering design of the TACRV in 1970 and construction in 1971, and to the Garrett Corporation for the design and fabrication of an electrical propulsion system (linear induction motor and its associated power conditioning equipment), a power collector, and power distribution system for the TACRV in 1971. A mile and a half of channel guideway is nearly complete, and the TACRV has begun low-speed testing.

To conduct tests of new transportation concepts, DOT is developing an integrated High-Speed Ground Test Center, including a high-speed guideway loop for the TACVs on a site near Pueblo, Colorado. The UTACV will begin operation in the middle of 1973. The time frame for possible implementation of a TACV system varies with the desired performance characteristics. The French experience indicates that a 150 mph system, utilizing individual vehicles, is currently feasible. To extend the technology base to 300 mph will require a minimum of two years' testing with the TACRV during which time the vehicle will be brought to its full research capability. Sufficient uncertainties exist such that a 300 mph prototype system cannot be initiated without TACRV test results.

Japanese MAGLEV Studies

In Japan, the Japanese National Railways (JNR) is directing research toward magnetically levitated trains which can convey passengers from Tokyo to Osaka in just over one hour. In one concept under consideration, long superconducting train coils are used in conjunction with shorter normal-conducting track coils. Propulsion is by means of a linear induction motor with the primary windings in the track. The active track circumvents the serious problem of high-speed wayside power pickup; however, the cost of miles of primary windings can only be justified where traffic density is high. Of several configurations under consideration by JNR, all seem to share the essential feature of a super-conducting train coil, aluminum loops in the guideway and some form of active guideway. In addition to the JNR Technical Institute, a large segment of Japanese industry is participating in magnetic levitation developments. Progress to date includes electromagnetic analyses of lift, drag and guidance forces due to various train-track coil configurations, measurements of the lift drag, a-c losses, and liquid helium consumption of small and full-scale superconducting magnetic cushions operating over rotating coil arrays, and sled tests over a 700-foot track of suspension and linear synchronous motor propulsion. A four-passenger magnetically levitated vehicle was demonstrated during the JNR centennial celebration in October 1972. This vehicle is propelled by a linear induction motor which has its powered winding in the guideway. Only an aluminum fin is required on board the vehicle for propulsion.

German Magnetic Test Vehicles

The German Ministry of Science is funding two magnetic test vehicle programs; one at Messerschmidt-Bolkow Blohm (MBB) and the other at Krauss-Maffei (K-M). The vehicles are presently operating on specially-constructed guideways near Munich. The attractive force between an on-board electromagnet and steel guide rails provides lift and guidance in both systems. A servo-control monitors the gap and adjusts the electromagnet current to overcome the inherent instability associated with the attractive force.

Because of the limitation of a 660-meter track, the original MBB vehicle can operate only up to 60 mph. To obtain data at higher speeds, MBB has built a rocket sled which reaches 120 mph on the same track. The K-M vehicle has reached 100 mph on a 1 km guideway. A 2-1/2 km guideway of lightweight design, plus an unmanned advanced test vehicle will be ready for rocket-propelled tests to 320 mph in early 1973. The German Ministry of Transport announced in October, 1971, its intention to construct a high-speed ground test track near Augsburg. Plans call for a 70 km loop designed to permit testing vehicles at speeds up to 350 mph.

Canadian MAGLEV Study

The Canadian Department of Transport has just initiated a study of superconductive systems for high-speed ground transportation. This activity will be conducted at the Institute for Guided Ground Transport at Queens University in Kingston, Ontario. The Canadian program will concentrate on superconducting magnet design, the cryogenics problems, and the development of a linear synchronous motor concept deriving thrust from switched powered coils in the guideway.

U.S. Magnetic Suspension Research and Development

FRA, early in 1971, awarded contracts to Ford Motor Company and Stanford Research Institute for analytical and experimental investigations of magnetic levitation. The objective of these studies is to determine whether magnetic fields can be used to support and guide passenger vehicles at speeds up to 500 mph.

In addition, ORD&D exchanges information with Canada, Japan, and Germany, each of which have government-supported programs in magnetic levitation. Cooperation has been gratifying as technical information has been freely and openly shared. Each country has performed system studies to compare various alternatives for providing 300 mph transportation.

The magnetic levitation efforts sponsored by the U.S. Department of Transportation have consisted of analyses and small scale experiments. Calculations have been made of lift, guidance and drag forces for rectangular coils moving over a "U" shaped aluminum guideway. Vehicle dynamic stability has been assessed. The effects of alternating magnetic fields and vibration have been measured on various superconducting coils. A 14 foot long vehicle supported by four superconducting magnets has been built and tested successfully at speeds up to 27 mph on a 500 foot track in Menlo Park, California. Valuable data on liquid helium consumption and stability of the magnets were obtained in these tests, in addition to dynamic performance.

The attractive maglev suspension is being evaluated via small scale tests. The parameters which limit the range of control for the servo-control system have been identified. Subsystem testing and research vehicles will be required for further evaluation and development of MAGLEV principles for HSGT. ORD&D is currently entering this phase and prototype designs cannot be expected for several years.

CHAPTER IV

IDENTIFICATION OF POTENTIAL MARKETS

Regions within the United States which constitute potential markets for Improved Passenger Trains (IPT) and Track Levitated Vehicles (TLV) are identified and described in this chapter. Based on the results of these analyses, potential markets for IPT and TLV are ranked in terms of their travel demand potential.

A. DIMENSIONS AND CHARACTERISTICS OF THE INTERCITY TRAVEL MARKET

Preliminary analyses conducted previously by Peat, Marwick, Mitchell & Co. indicate that in 1967 there were approximately 3.53 billion intercity person trips in the United States and that the number of trips will be nearly 3.5 times this size in 1995 (see Table 4-1).

Common Carrier Modal Usage

The number of passengers using the rail, air, and bus intercity modes in the United States in the year 1960 through 1968 is presented in Table 4-2. The total intercity common carrier market has grown over 17 percent during this eight-year period. The continuing decline in rail as well as the dramatic growth in air patronage is evident. Bus usage continued an erratic pattern of growth during the same period.

Composition of the 1967 Intercity Travel Market

Although there were about two common carrier trips per person in 1967, common carrier trips in total represented less than 13 percent of the intercity travel market (see Table 4-3). Results of the

TABLE 4-1

INTERCITY TRAVEL FORECASTS

Year	Number of Intercity Person Trips (Millions)	Magnitude Relative to 1967
1967	3,534	100%
1975	5,018	142
1980	6,361	180
1985	7,952	225
1990	9,895	280
1995	12,334	349

TABLE 4-2

HISTORICAL INTERCITY COMMON CARRIER RIDERSHIP
(MILLIONS OF PASSENGERS)

Year	Air*	Bus**	Rail**	Total
1960	52.4	187.7	122.7	362.8
1961	52.7	187.5	118.1	358.3
1962	56.0	186.1	117.2	359.3
1963	63.9	185.1	114.5	363.5
1964	73.0	185.8	114.8	373.6
1965	84.5	193.4	106.3	384.2
1966	97.7	203.2	105.3	406.2
1967	118.7	207.3	98.1	424.1
1968	134.5	199.0	92.6	426.1

* Domestic Scheduled Carriers
** Class 1 Carriers

TABLE 4-3

THE 1967 INTERCITY TRAVEL MARKET[1]

	Automobile	Bus	Train	Commercial Air	Other	Total
Total Person Trips (%)	86.1	2.6	1.4	8.0	1.9	100.0
Purpose of Trip (%)						
Business	12.8	10.0	15.1	51.3	29.4	16.2
Non-Business	87.2	90.0	84.9	48.7	70.6	83.8
Size of Party (%)						
One Person	19.8	62.4	46.1	65.9	46.9	25.5
More than One Person	80.2	37.6	53.9	35.0	53.1	74.5
Median Distance One-way straight line miles	100-199	100-199	200-499	500-999	200-499	100-199
Median Family Income Level (000's of dollars)	7.5-10.0	6.0-7.5	7.5-10.0	10.0-15.0	10.0-15.0	7.5-10.0

[1] 1967 Census of Transportation, Volume 1, National Travel Survey, Bureau of the Census, U.S. Department of Commerce, Washington, D.C., 1970.

National Travel Survey[2] suggest other preliminary conclusions regarding the problems as well as the potential of High-Speed Ground Transportation (HSGT). Over 80 percent of the intercity automobile trips involve a party size of more than one person, whereas multiple person party sizes occur in only 35 to 54 percent of the common carrier trips. Bus travelers have the lowest median family income level of users of the four main intercity modes -- reflecting the bus role as the lowest price common carrier.

Whereas over 50 percent of the air trips are for business purposes, only 10 to 15 percent of the trips by the other modes are business trips. The business traveler is generally considered more sensitive to travel time than to travel cost. Thus, if HSGT is to compete with commercial air and the automobile for the business travel market, it must offer a competitive door-to-door travel time. This suggests that the market potential for HSGT lies in the 75 to 400 mile distance range, and that it can compete most effectively in this range for those segments of the intercity market for which:

(1) travel cost is not a major issue (i.e., business travel); or

(2) HSGT is competitive on a true cost basis (i.e., the single-person travel party).

Composition of the Intercity Travel Market in the Northeast Corridor

An understanding of the variables influencing travelers' responses to and requirements for intercity transportation was developed

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[2] 1967 Census of Transportation, Volume 1, National Travel Survey, Bureau of the Census, U.S. Dept. of Commerce, Washington, D.C., 1970.

in a previous study of the intercity travel market in the Northeast Corridor[3] by identifying the most important groups of travelers, or submarkets. Ten submarkets, defined in terms of traveler and trip characteristics, were identified in this analysis. The modal choice behavior and relative size of each of these submarkets within each of the four markets considered in the analysis (Washington-Philadelphia, Washington-New York, New York-Boston, and Washington-Boston) are summarized in Tables 4-4 and 4-5, respectively.

It is evident from Table 4-4 that there are significant differences in the relative size of each submarket and that the submarket sizes are related to the intercity distances. Submarkets IX and X (non-business, two- and three-or-more person trips) constitute over 45 percent of the Washington-Philadelphia, Washington-New York, and New York-Boston markets but just over 33 percent of the Washington-Boston market. The automobile captures a dominant portion (over 70 percent) of the travel in these two submarkets for the first three cities and still claims a major share (over 50 percent) of the travel in these submarkets for the Washington-Boston market (see Table 4-5). Note that in general, diversion from the automobile to the air mode tends to increase as the size of the group decreases and as the intercity distance increases.

Rail captures a significant share of the demand for the two markets in which Metroliner service is offered -- Washington-Philadelphia and Washington-New York. In fact, it is interesting to note that rail and bus capture the largest portion of the trips in Submarket V (non-business, one person, medium income, CBD-CBD trips) in

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[3]Peat, Marwick, Mitchell & Co., "Analysis of the Intercity Travel Market in the Northeast Corridor," prepared for Strategic Planning Division, Department of Transportation, Washington, D.C., 1971.

TABLE 4-4

RELATIVE SIZE OF SUBMARKETS

Submarket		Market			
No.	Description	DC-PHL (136 miles)	DC-NY (225 miles)	NY-BOS (230 miles)	DC-BOS (455 miles)
	Business				
I)	One Person	17.4%	20.0%	18.6%	24.4%
II)	Two Persons	10.3	10.3	11.3	12.2
III)	Three or More Persons	7.1	6.7	6.2	6.0*
	Non-Business				
	One Person				
IV)	Low Income	4.1	3.8	3.8	4.5*
	Medium Income				
V)	CBD-CBD	1.4*	2.0	1.3*	
VI)	CBD-Suburbs	3.2	3.8	3.8	11.2*
VII)	Suburbs-Suburbs	3.2	3.2	2.5	
VIII)	High Income	2.4*	4.7	5.5	8.1*
IX)	Two Persons	20.9	20.3	22.8	18.0
X)	Three or More Persons	30.0	25.2	24.2	15.6
		100.0%	100.0%	100.0%	100.0%

*Cell size insufficient for shares to be statistically significant.

TABLE 4-5

MODE USAGE BY SUBMARKET AND MARKET

(THE FIRST MODE LISTED IN EACH CELL IS THE PRIMARY MODE. SIGNIFICANT SECONDARY MODES ARE LISTED WITHIN THE PARENTHESES.)

Submarket No.	Submarket Description	Market: DC-PHL (136 miles)	DC-NY (225 miles)	NY-BOS (230 miles)	DC-BOS (455 miles)
	Business				
I)	One Person	$\underline{C}$, (A,R)	$\underline{A}$, (C,R)	$\underline{\underline{A}}$, (C)	$\underline{\underline{A}}$
II)	Two Persons	$\underline{\underline{C}}$	C, (A,R)	C, (A)	$\underline{A}$
III)	Three or More Persons	$\underline{\underline{C}}$	$\underline{C}$, (A)	C, (A)	*$\underline{\underline{A}}$, (C)
	Non-Business				
	One Person				
IV)	Low Income	$\underline{C}$, (B,R)	$\underline{B}$, (C)	B, (C)	*$\underline{A}$, (B)
	Medium Income				
V)	CBD-CBD	*R, (B,C)	B, (R,A,C)	*B, (C,A)	*$\underline{\underline{A}}$ (V–VII)
VI)	CBD-Suburbs	$\underline{C}$, (R)	B, (C,A,R)	A, (B,C,R)	
VII)	Suburbs-Suburbs	$\underline{\underline{C}}$, (R)	$\underline{C}$, (B,A)	C, (A,B)	
VIII)	High Income	*C, (R,A)	$\underline{A}$, (R,C)	$\underline{A}$, (C)	*$\underline{\underline{A}}$
IX)	Two Persons	$\underline{\underline{C}}$	$\underline{\underline{C}}$, (B,A)	$\underline{\underline{C}}$, (A)	$\underline{C}$, (A)
X)	Three or More Persons	$\underline{\underline{C}}$	$\underline{\underline{C}}$	$\underline{\underline{C}}$	$\underline{C}$, (A)

Codes:

C - Automobile
B - Bus
A - Air
R - Rail

* - Cell size insufficient for shares to be statistically significant
_ (Underscore) - Major mode, 50 percent or more of submarket
= - Dominant mode, 70 percent or more of the submarket

these two markets, and that bus captures the largest share of the travel in Submarket IV (non-business, one person, low income trips) in the Washington-New York and New York-Boston markets.

B. PRELIMINARY STRUCTURING OF AN INTERCITY CORRIDOR NETWORK

In order to gauge the future market potential for IPT and TLV modes in the United States, a number of travel corridors that appear to have potential for successful opration of HSGT have been defined. Two criteria were considered necessary, but not sufficient, for a route between a given pair of cities to be included as a component of what is defined here as the national HSGT network. First, the terminal points for the route had to have a population of 500,000 or more according to the 1970 census. Second, the airline distance between the terminal cities had to be 400 miles or less, on the basis that the fastest HSGT (300 mph TLV) mode could have a travel time advantage with respect to air for distances up to 400 miles.

Potential routes which fulfilled these criteria were not necessarily incorporated into the national HSGT network. While all such routes were considered, some were not incorporated into the network because (1) insufficient intermediate markets (i.e., cities with 1970 populations in excess of 100,000) existed to supplement the patronage between the principal terminal cities and (2) a reasonable element of route continuity was not maintained. Thus, for example, the potential route between Louisville and St. Louis was not included in the hypothesized national network.

The preliminary national network for HSGT is presented in Figure 4-1. Routes were generally chosen to serve the populous intermediate points when optional routes were available. In some cases, other potentially important traffic generators, such as state capitals and resort areas, were also served. This network is reasonably comprehensive in both the East and Midwest. There are a total of nine east-west and eleven north-south routes and service is provided to over 95 percent of the cities with a population of 500,000 or more.

Service is also provided in the far west in the Seattle-Portland and California corridors. No HSGT service is provided in the Mountain states inasmuch as major population centers are too separated to fulfill the criteria specified above. The effect of establishing a specific population distribution policy and the results of a preliminary analysis of the market potential for HSGT service on the routes in the national network are discussed in the following sections.

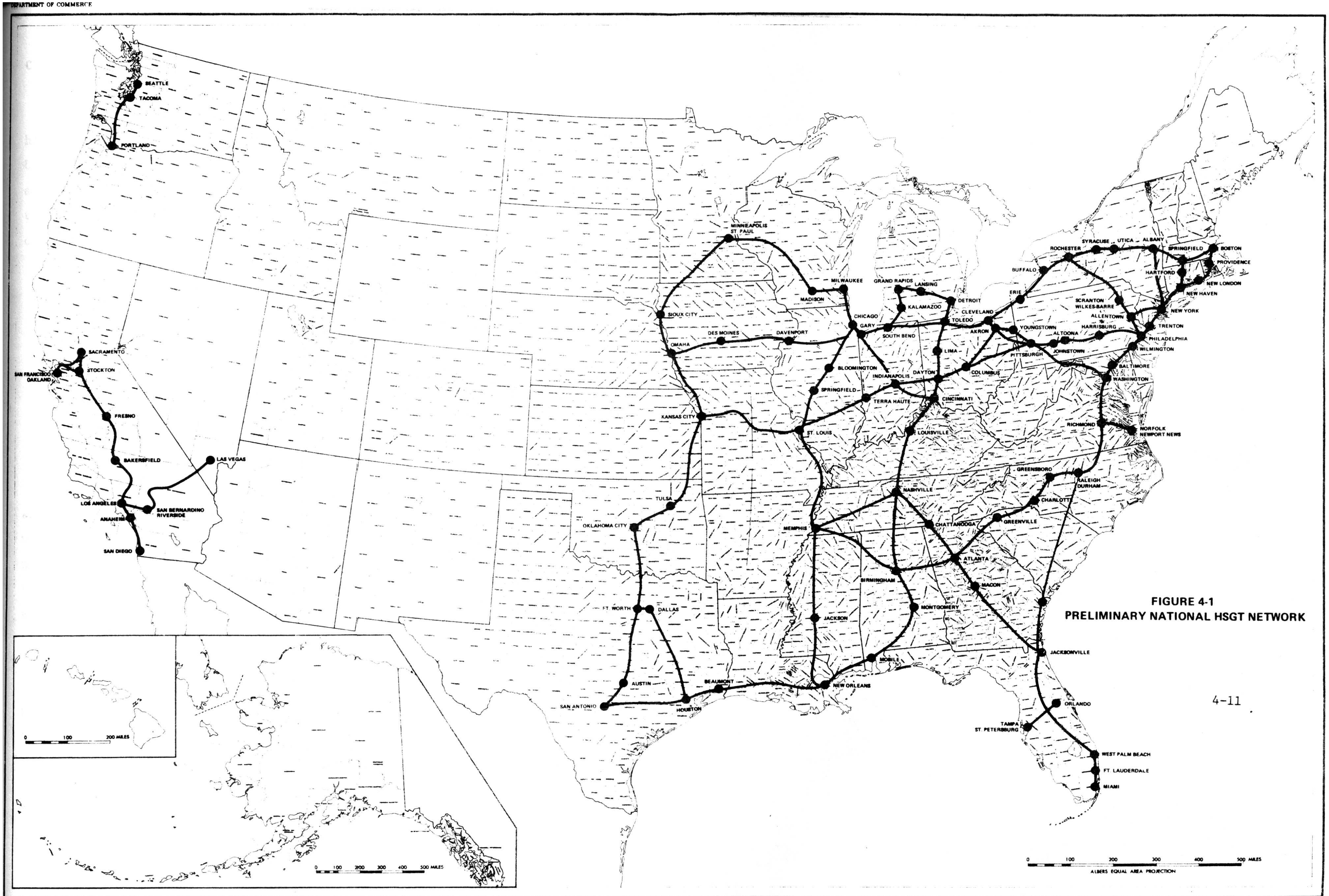

FIGURE 4-1
PRELIMINARY NATIONAL HSGT NETWORK

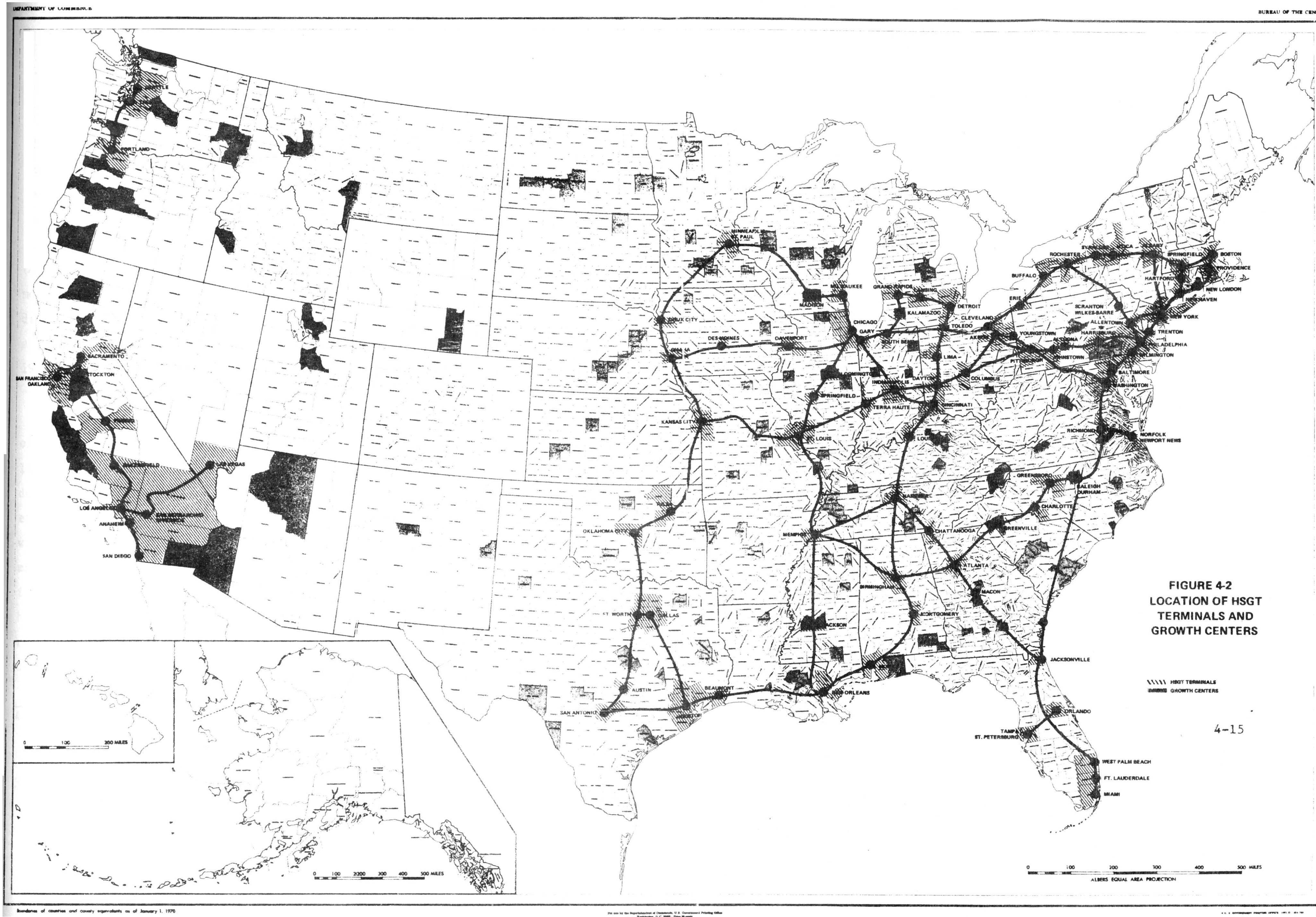

FIGURE 4-2
LOCATION OF HSGT TERMINALS AND GROWTH CENTERS

C. THE IMPACT OF A POPULATION DISTRIBUTION POLICY

The Commission on Population Growth and the American Future has developed a projection of the population distribution of the United States based on a policy of stimulating the development of a number of "growth centers". Growth centers were designated as those cities and metropolitan centers which met the following criteria:

- o the metropolitan area grew faster than the national rate of 13.3 percent during the past decade;
- o the area is more than 75 miles from an existing or projected metropolitan area of two million or more; and
- o the area's population did not exceed 350,000 in 1970.

The locations of the 121 growth centers identified using the above criteria and the locations of the potential HSGT terminals were examined to evaluate the impact of this population distribution policy upon the potential for HSGT (see Figure 4-2). Inspection of this figure indicates that very few of the 121 growth centers have also been designated as potential HSGT terminals or are along the right-of-way of a potential HSGT system.

To evaluate the impact of this population redistribution upon HSGT patronage, it was assumed that patronage would be proportional to population served. The overall effect of a growth center policy is that the population served by the potential HSGT system of Figure 4-1 would be reduced by about 6.5 percent in the year 2000, compared to what it would be in that year if the growth center policy were not followed. The effect would be smaller for prior years.

D. A PRELIMINARY MARKET POTENTIAL ANALYSIS

In order to characterize the market potential of the HSGT routes displayed in Figure 4-1, they have been evaluated on the basis of estimated passenger density, which is defined as the number of passenger miles per route mile per year. IPT and TLV travel demands were estimated from forecasted total demands using a version of the Cross Elasticity Modal Split Model[4] calibrated using data for the Northeast Corridor.[5] Total demands from actual surveys are not available for most of the markets of interest here. Demand estimates that were developed by PMM & Co. in 1970 for auto and air modes were used as a basis for developing total demand projections for 1975, 1985, and 1995.

It is acknowledged that absolute total demands over this network of links, and therefore absolute demands for HSGT systems over these links, are probably inaccurate. However, the methodology which produced them was consistent over the preliminary network, so these estimates can be used to rank links and corridors within the network with respect to the HSGT systems. In Chapter 5, more accurate estimates of demand were developed for a few corridors for which special information was obtained. The latter estimates provide a rough calibration ot the ranked corridors produced in the present chapter. The rankings themselves serve the purpose of identifying potential markets nationwide for HSGT systems.

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[4]McLynn, J. M., et al., "Analysis and Calibration of a Modal Allocation Model," prepared for National Bureau of Standards, U.S. Department of Commerce, Washington, D.C., 1967.

[5]"National Bureau of Standards Modeling for the NECTP," prepared for Office of High Speed Ground Transportation, U.S. Department of Transportation, Report No. NECTP-211, Washington, D.C., 1969.

The passenger density of each segment of the network was determined by summing the HSGT travel demand generated by each city pair requiring use of that link and then dividing by the link mileage. Link passenger densities were altered to the extent that HSGT travel could be diverted to and from other links, and to the extent that service is offered on connecting links. For example, New York to Rochester and Buffalo travel was routed via Albany, rather than Scranton (both routes are about equal in length via rail). Consequently, passenger densities for both routes would be altered if this traffic were re-routed. Similarly, the Buffalo-Rochester link traffic serves HSGT travelers to Erie and other cities farther west. When the Buffalo-New York corridor was defined, HSGT service was terminated at Buffalo, and the travel volume estimate for links east of Buffalo were appropriately reduced.

Selection of Test Systems

Five HSGT systems, defined by a test year, technology, and speed, were evaluated on the basis of potential for passenger density attracted. These systems are described in Table 4-6 below.

TABLE 4-6

TEST HSGT SYSTEMS

System No.	Year	Technology	Average* Speed
1	1975	IPT	80
2	1985	IPT	80
3	1985	TLV	300
4	1995	IPT	80

TABLE 4-6 (cont.)

TEST HSGT SYSTEMS

System No.	Year	Technology	Average* Speed
5	1995	TLV	300

*The speeds shown are average cruise speeds between stations. Extra time delays were added for intermediate stops to determine average corridor speeds for demand analyses. For the IPT demand analyses in Chapter 5, these time delays were omitted. See Appendix A.

Each system was tested using the preliminary 13,500 mile HSGT network presented in Figure 4-1. The air, auto and bus speeds and characteristics were not varied significantly between each test year. The only differences within each test year were the assumed technology and speed of the different HSGT systems. In addition, between test years, the total demand increased significantly (i.e., by 58 percent between 1975 and 1985, and by 55 percent between 1985 and 1995).

The characterization of market potential on the basis of passenger demand density is a multi-stage process in which the first stage concentrates on a comparison of the various HSGT systems over the preliminary network taken as a whole. It is not feasible to determine an optimum frequency and train length for each link of the network in the first stage comparison since such a solution requires the identification of the multi-link corridors over which trains might operate. Therefore, the first stage analysis assumes a constant HSGT frequency of 14 trains per day over the entire system.

In reality, the growth in demand can result in an increase in schedule frequency of common carrier modes - a factor which can enhance their attractiveness from a convenience standpoint. Therefore, the assumption of constant HSGT frequency can result in distortion of the demand estimate on links where demand is so light that 14 single car trains are not feasible or those with demand so heavy that more than 14 trains a day are desirable. However, most importantly, the ranking of links by demand is not distorted and such ranking is the desired product of the first stage analyses.

The second stage defines potential routes or corridors as combinations of links and then performs more detailed analyses of selected corridors in order to rank them relatively. The third stage consists of a cost-revenue analysis of the IPT and TLV over four selected corridors for which more accurate demand data is available. The results of the third stage are the subject of Chapter V. To provide a basis of comparison for the initial first stage ranking, all links were ranked with reference to an arbitrary fixed base demand level.

HSGT System Comparison

As part of the first stage analysis, Table 4-7 portrays the impact of performance characteristics of HSGT systems over the 13,500 mile HSGT network. The methodology involves a single base passenger density measure, which was taken to be two million passenger-miles per route-mile per year. The purpose is to show relative magnitudes of demand in several segments of the national network in order to identify and rank the various links with respect to market potential for HSGT; the <u>absolute</u> magnitudes of demand are probably not accurate and are therefore omitted. Then for each HSGT system the network mileage is sorted into four categories defined by mileage with passenger density greater than or equal to 100%, or between 67 and 100% 33 and 67% or 0 and 33% of base. Mileage and percent of total mileage falling into each category are shown in the four columns of Table 4-7 for each HSGT system.

Table 4-7 indicates that, on the basis of estimated passenger density, the IPT would grow from 2 percent of the network mileage in the highest category of passenger density in 1975, to 4 percent in 1985, and to 12 percent by 1995. A 300 mph TLV service would result in the highest level of passenger density on 20 and 46 percent of the potential network in 1985 and 1995 respectively. While these percentages are only approximate, they show some interesting trends.

The results indicate that the higher-speed systems can attract significantly more patronage than the IPT can in spite of a difference in fares ($3.00 + 8.5 cents per mile vs. $1.50 + 7.5 cents per mile respectively were used in developing these estimated passenger densities, see Appendix A).

Part of the greater success of the higher-speed systems is due to their capability to compete with the air mode for 200 to 400 mile city pair demands. An example of the greater advantage for TLV is given by the Los Angeles-San Francisco route (about 360 miles). The very high populations in both of these cities yield a high demand for this city pair, but there is very little patronage from cities in between. Thus, there is effectively no market potential estimated

TABLE 4-7

SUMMARY OF MARKET POTENTIAL ANALYSIS
(MILEAGE OF SYSTEM IN EACH DEMAND DENSITY CATEGORY)

				Mileage Distribution By Passenger Density Compared to Base Passenger Density**							
				≥ 100%		67-100%		33-67%		33% or Less	
System No.	Year	System	Average Speed*	Miles	%	Miles	%	Miles	%	Miles	%
1	1975	IPT	80	297	2	216	2	1195	9	11790	87
2	1985	IPT	80	513	4	906	7	1230	9	10449	80
3	1985	TLV	300	2703	20	3325	25	3760	28	3710	27
4	1995	IPT	80	1601	12	410	3	3491	26	7996	59
5	1995	TLV	300	6232	46	2694	20	3609	27	963	7

*See Appendix A for definition of average speeds as used in Chapter IV.

**Passenger density is defined as the number of passenger-miles per route-mile per year. In this table, the base for market potential was defined as 2 million passenger-miles per route-mile per year. % values are percent of total network mileage (13,500).

for an IPT even by 1995, whereas future demand estimates for the TLV will grow along with projected population growth for these two large cities.

Route Comparisons by HSGT Technology

The first stage analysis also includes the ranking of the five HSGT systems over the network on a link-by-link basis which is illustrated by the five Figures 4-3 through 4-7 respectively. The base passenger density used in each figure is noted thereon. For the IPT, the base was taken to be two million passenger-miles per route-mile per year, and for the TLV system it was taken to be four million passenger-miles per route-mile per year. As emphasized above regarding the base passenger density for IPT, the purpose here is to show relative magnitudes of demand in several segments of the national network in order to identify and rank the various links with respect to market potential for HSGT; the results are not intended to show accurate absolute magnitudes of demand. Comparisons between IPT and the TLV should take into account the fact that the base passenger density levels are not the same. The main purpose served by these maps is to categorize all network links for each of the HSGT technologies separately and to provide corridor comparisons for the two or three individual years that are indicated for each technology. Thus growth of passenger density over the network for the IPT system over the years 1975, 1985, and 1995 is depicted by Figures 4-3, 4-4, and 4-5. The TLV passenger density growth between 1985 and 1995 is depicted by Figures 4-6 and 4-7.

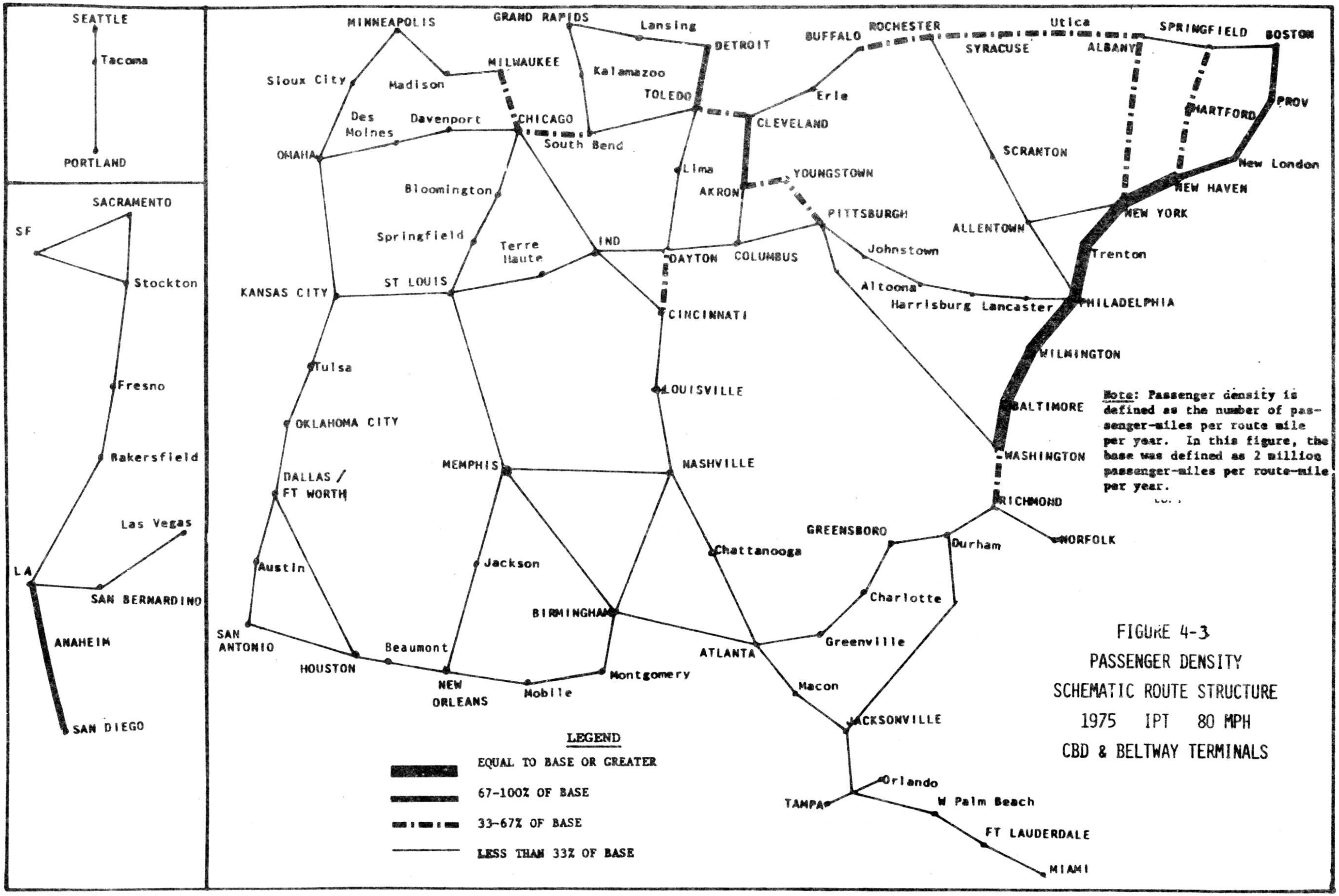


FIGURE 4-3
PASSENGER DENSITY
SCHEMATIC ROUTE STRUCTURE
1975 IPT 80 MPH
CBD & BELTWAY TERMINALS

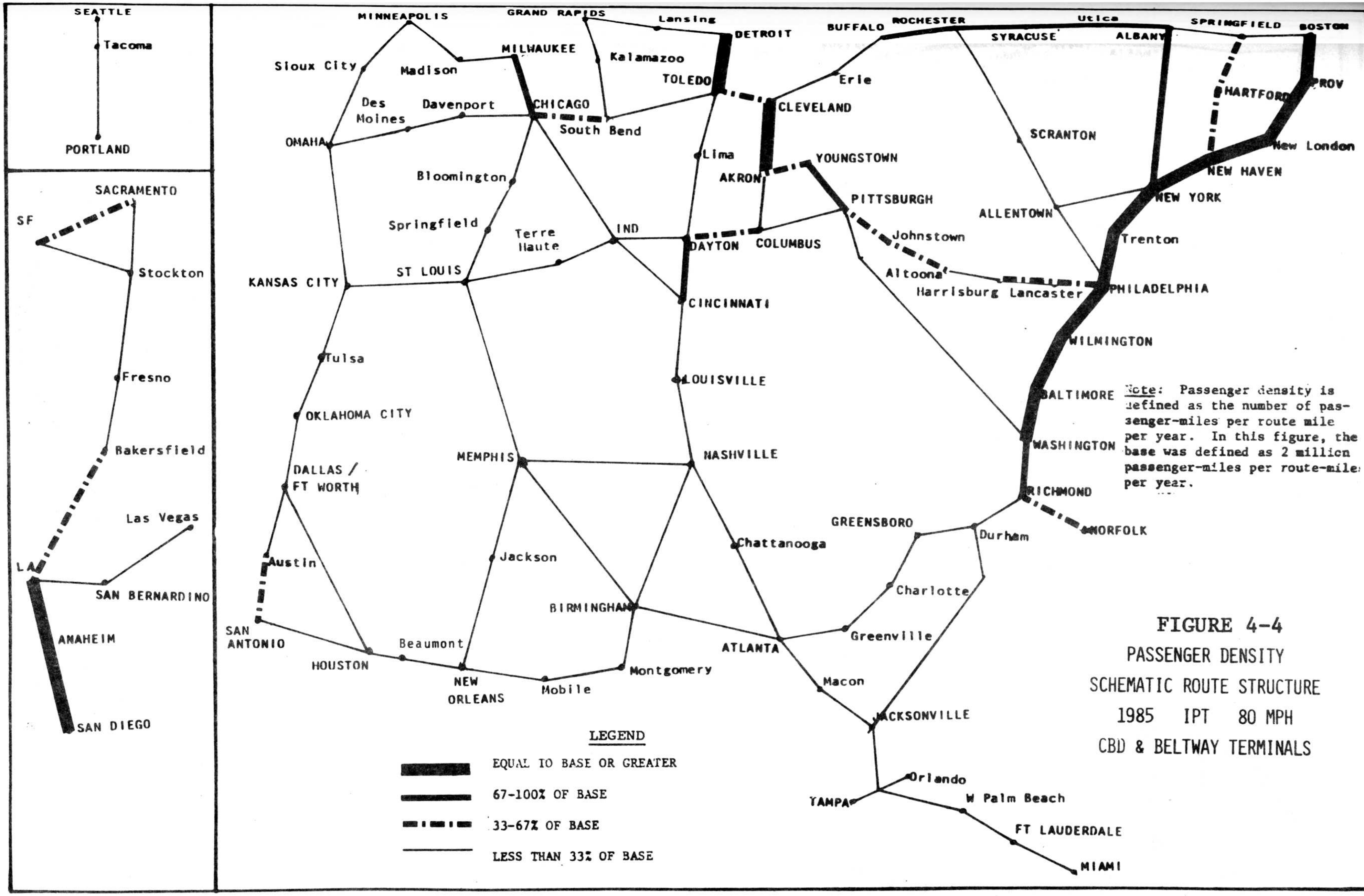
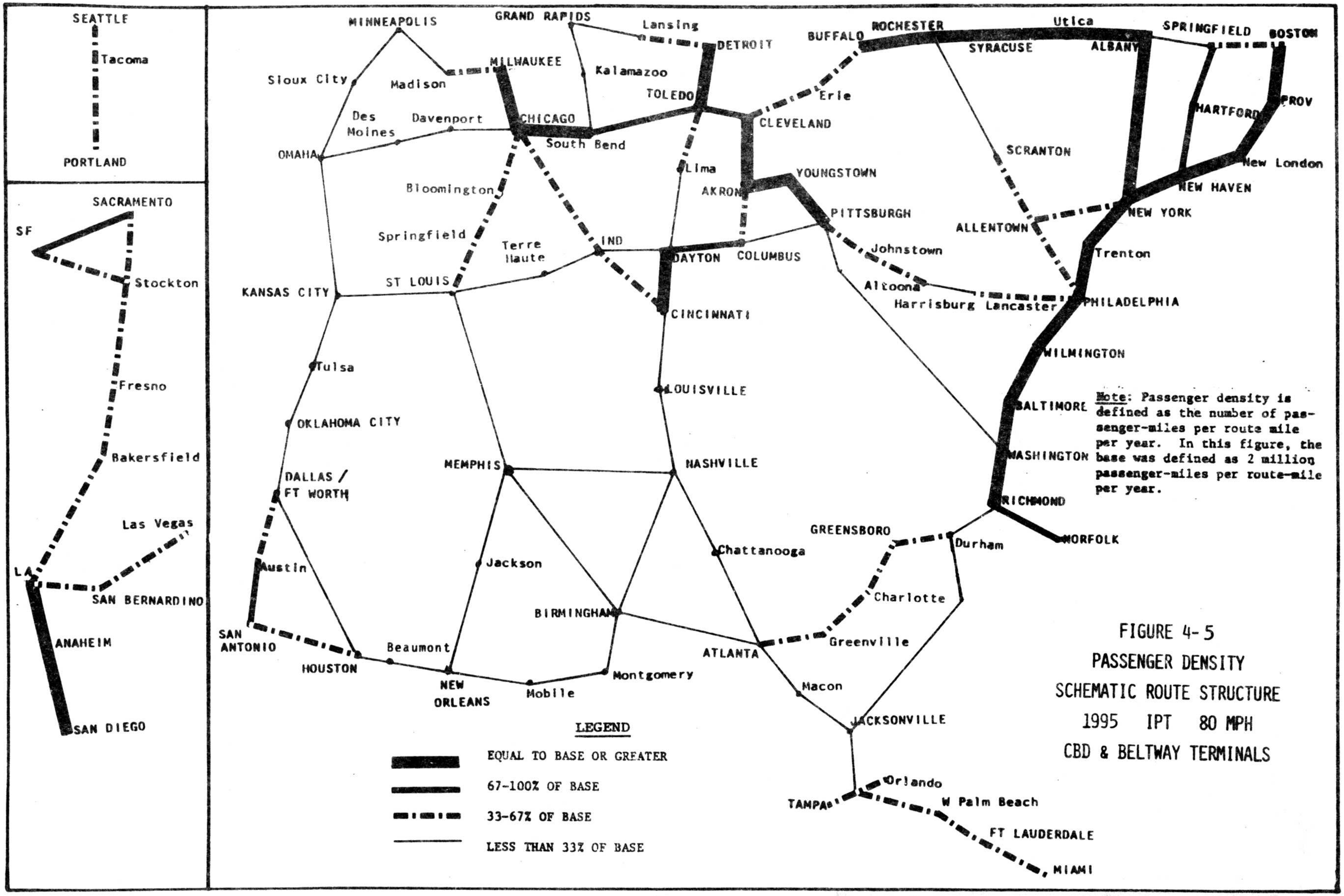
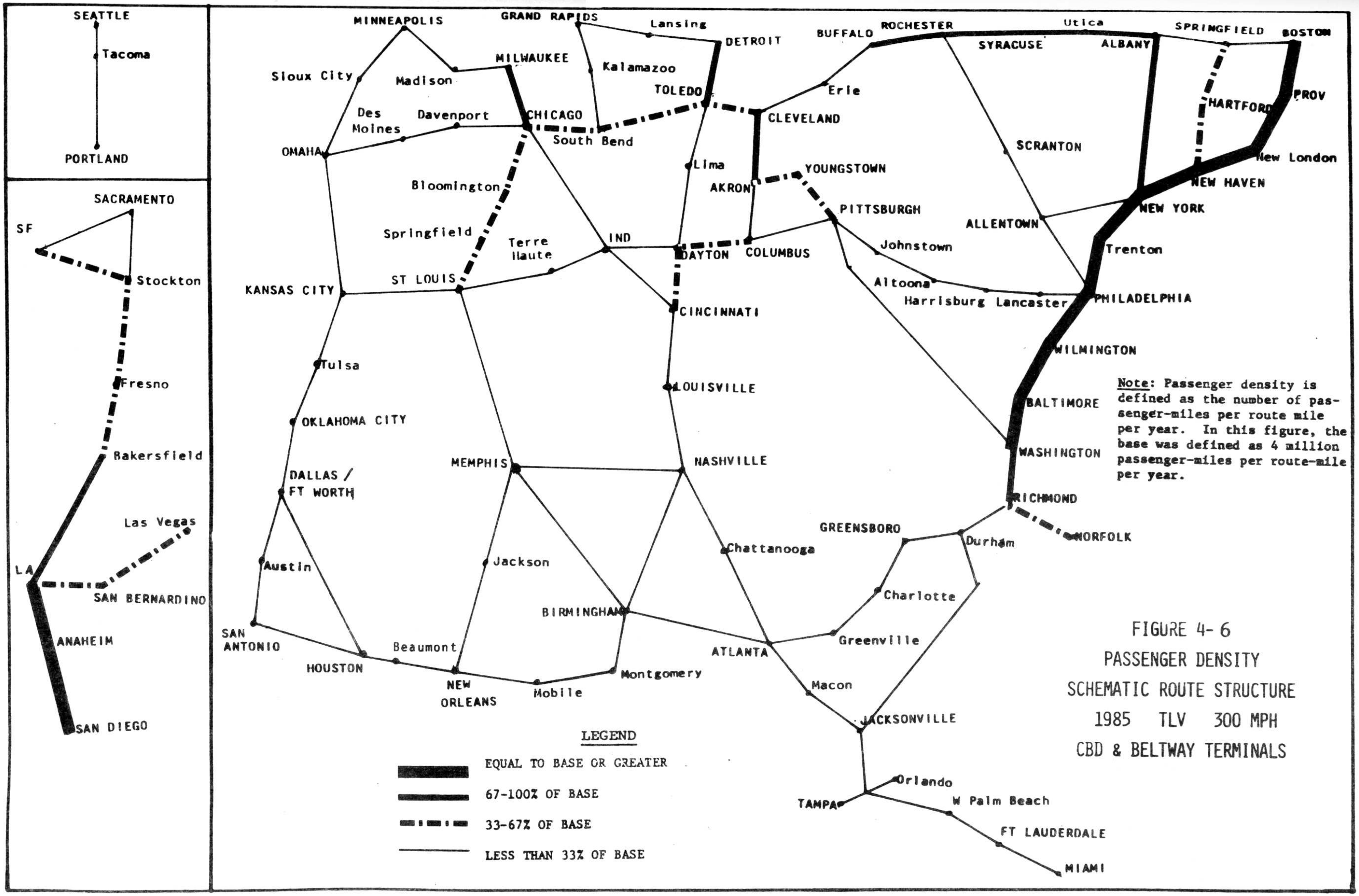


FIGURE 4-4
PASSENGER DENSITY
SCHEMATIC ROUTE STRUCTURE
1985 IPT 80 MPH
CBD & BELTWAY TERMINALS



Note: Passenger density is defined as the number of passenger-miles per route mile per year. In this figure, the base was defined as 2 million passenger-miles per route-mile per year.

FIGURE 4-5
PASSENGER DENSITY
SCHEMATIC ROUTE STRUCTURE
1995 IPT 80 MPH
CBD & BELTWAY TERMINALS



Note: Passenger density is defined as the number of passenger-miles per route mile per year. In this figure, the base was defined as 4 million passenger-miles per route-mile per year.

FIGURE 4- 6
PASSENGER DENSITY
SCHEMATIC ROUTE STRUCTURE
1985 TLV 300 MPH
CBD & BELTWAY TERMINALS

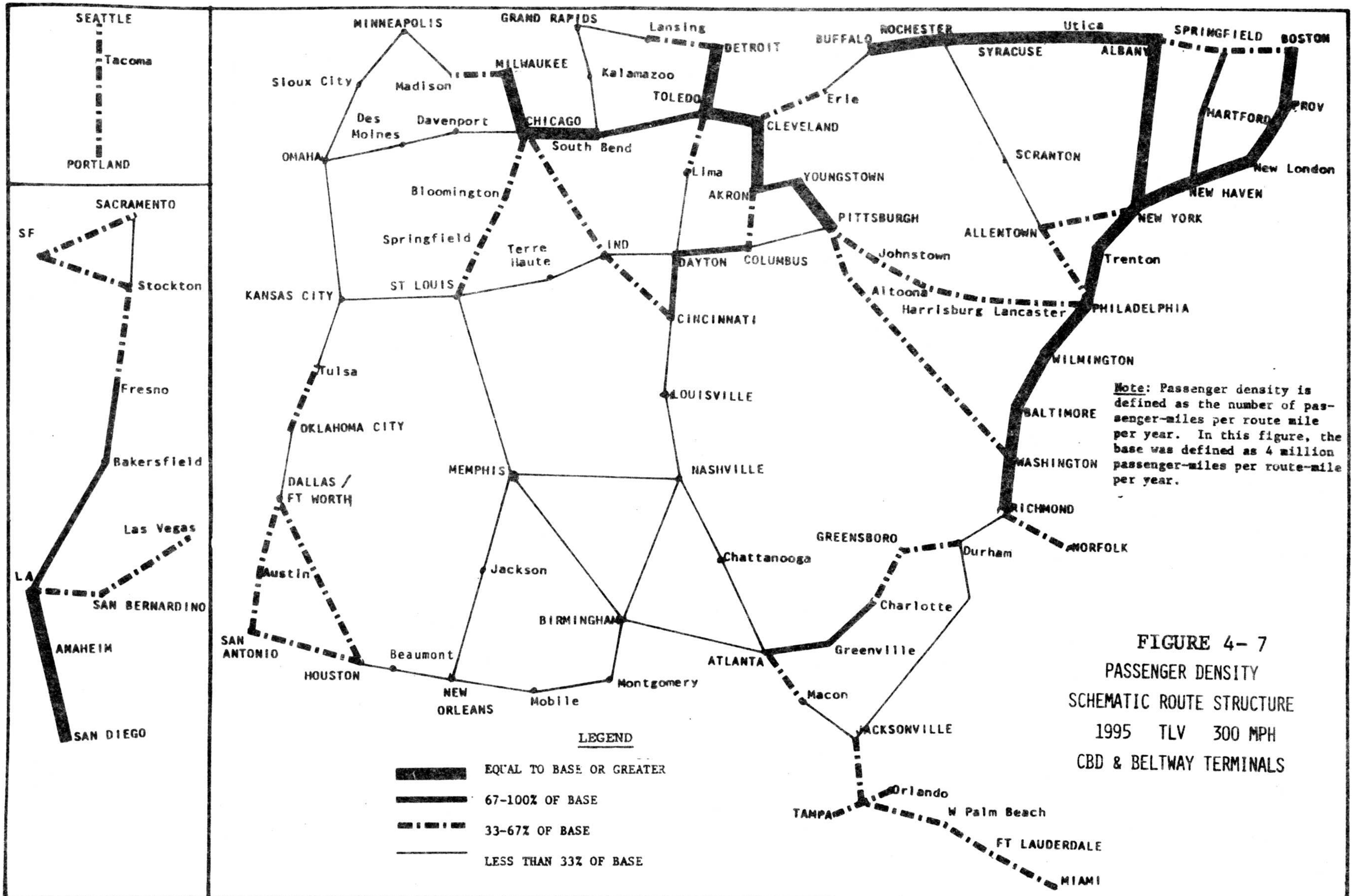


FIGURE 4- 7
PASSENGER DENSITY
SCHEMATIC ROUTE STRUCTURE
1995 TLV 300 MPH
CBD & BELTWAY TERMINALS

Definitions of HSGT Corridors

The second stage consists of developing corridors from the preliminary network. Table 4-8 lists corridors for each of the technologies separately and ranks them according to average passenger density. In the development of these corridors, generally, cities with a 1995 projected population of 500,000 or more were selected as terminal points for a corridor. In some cases, the HSGT corridor was then extended to a city with a forecast 1995 population of less than 500,000, if this extension appeared warranted by the estimated 1995 passenger density of the added links. The passenger density of all links of a potential corridor were averaged to develop that passenger density used in the corridor ranking.

A total of 17 corridors are listed for 80 mph IPT and 22 corridors for 300 mph TLV. Further, the definition of the IPT corridors has, in some cases, been extended for the TLV to incorporate more distant cities. For example, the IPT Chicago-Milwaukee corridor has been extended into the TLV Chicago-Milwaukee-Madison corridor. This illustrates the general capability of the higher-speed technology to improve its market more rapidly over its base year as population increases compared to the improvement of the slower technologies over their base years.

Neither the list of Table 4-8 nor the preceding maps should be interpreted as implying viability for any specific link or corridor. In fact, the lists are purposely made long enough so that the lowest corridors probably are not viable. The third stage of the potential market analysis, described in the next chapter, will cover the more detailed cost-revenue analyses of several selected corridors in the attempt to calibrate the lists. Corridors for the third stage include representatives from various levels of the list, not only the top "best bet" corridors.

TABLE 4-8

CORRIDOR RANKING
(FROM MARKET POTENTIAL ANALYSIS)

IPT SYSTEM (80 MPH)[1,2]

1. New York-Washington
2. New York-Boston
3. Los Angeles-San Diego
4. New York-Buffalo
5. Chicago-Milwaukee
6. Pittsburgh-Detroit
7. Washington-Norfolk/Newport News
8. Springfield/Hartford-New York
9. San Francisco-Sacramento
10. Chicago-Detroit/Cleveland
11. Los Angeles-Las Vegas
12. Cleveland-Cincinnati
13. Los Angeles-San Francisco
14. Pittsburgh-Philadelphia
15. Chicago-St. Louis
16. Tampa-Orlando
17. Seattle-Portland

TLV SYSTEM (300 MPH)[1,3]

1. New York-Washington
2. New York-Boston
3. New York-Buffalo
4. Los Angeles-San Diego
5. Chicago-Milwaukee-Madison
6. Pittsburgh-Detroit-Lansing
7. Chicago-Detroit/Cleveland
8. Washington-Norfolk/Newport News
9. Los Angeles-San Francisco
10. Springfield/Hartford-New York
11. Los Angeles-Las Vegas
12. Chicago-St. Louis
13. Cleveland-Cincinnati
14. San Francisco-Sacramento
15. Durham-Atlanta
16. Jacksonville-Miami
17. Philadelphia-Pittsburgh
18. Seattle-Portland
19. Dallas/Fort Worth-Houston-San Antonio ("Texas Triangle")
20. Chicago-Cincinnati
21. Washington-Pittsburgh
22. Boston-Albany

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(1) Market potential is measured by estimated passenger density.
(2) The base passenger density for IPT is defined as 2 million pass.-miles per route-mile per year.
(3) The base passenger density for TLV is defined as 4 million pass.-miles per route-mile per year.

CHAPTER V
COST-REVENUE ANALYSES

This chapter presents cost-revenue analyses of IPT and TLV in four selected corridors. The corridors are representative of the range in the rankings presented in the previous chapter. Two of the corridors are from the top of the ranking: the Northeast Corridor between Washington and Boston; and the California strip from San Diego to Los Angeles (for IPT) and northward to San Francisco and Sacramento (for TLV). The Chicago to Detroit corridor (via South Bend and Toledo) is believed to represent a medium density market (for IPT only) and the Portland-Seattle corridor (for IPT and TLV) exemplifies the lower range of the ranked corridors.

An examination of both HSGT systems is presented in terms of cost-revenue projections. The Net Present Value of each mode in these corridors is computed, for two different years of initial operation: 1975 and 1985 for IPT, and 1985 and 1995 for TLV.

The specific corridors and time periods analyzed are shown in the following tabulation:

Corridor	HSGT Mode	Initial Years of Operation
Northeast Corridor[1]	TLV	1985, 1995
California		
Los Angeles-San Diego	IPT	1975, 1985
Los Angeles-San Diego	TLV	1985, 1995
Sacramento-San Diego	TLV	1985, 1995
Chicago-Detroit	IPT	1975, 1985
Seattle-Portland	IPT	1975, 1985
	TLV	1985, 1995

The TLV[2] investment costs were based on average cost estimating relationships taken mostly from detailed cost analysis for the Northeast Corridor. These average relationships for the NEC were applied to the other corridors, in the absence of better data.

This chapter is subdivided into four sections. The first section presents demand and revenue projections for each corridor for the years being evaluated, and includes results of sensitivity analyses reflecting changes in demand for variation in: (1) average speeds (for IPT only); (2) fare structures (both IPT and TLV); (3) energy

[1]IPT in the Northeast Corridor was not examined, since analyses already have been performed of the IHSR-1 system in the DOT report, Recommendations for Northeast Corridor Transportation, September 1971, and in subsequent DOT documentation supporting proposed implementation of the Northeast Corridor rail recommendations. Any cost-revenue analysis of improved NEC rail service in this report would appear to be redundant.

[2]TLV cost estimates are provided only for the TACV system. Since magnetic levitation systems are in early R&D phases, MAGLEV systems definitions and costs are considered too preliminary at this time to be used for comparison purposes. The FRA has estimated, however, that MAGLEV system costs would be approximately of the same order as those for TACV.

crisis scenarios (both IPT and TLV); (4) modal constants used for IPT in the demand model; and (5) daily frequencies of service (TLV only).

Demand estimates used in this chapter have been developed using the data and methodology presented in Appendix A.

In the second section, estimated investment costs and first year operating costs are presented for the HSGT systems in the selected corridors. The third section indicates breakeven demand levels, given the expected cost estimates. The fourth section provides Net Present Value (NPV) computations for each corridor/system combination.

The IPT cost estimates presented in this chapter are largely those supplied by the Federal Rail Administration (FRA). Site-specific investment costs were estimated by FRA based on one level of service and performance of IPT. Similar site-specific cost estimates were not available for TLV other than for the Northeast Corridor (NEC costs are for primarily at-grade guideway, on largely new right-of-way). Site-specific cost and performance estimates were not available for TLV routes using primarily elevated guideway over existing rights-of-way.

A. DEMAND/REVENUE ANALYSES

This section presents the results of demand projections and revenue calculations for the IPT and TLV systems under various conditions.

The general approach to estimating rail demand in the selected corridors is similar to that of Chapter IV. Total travel demand is estimated, then apportioned among the competing modes according to their service characteristics. In the analysis of market potential presented in Chapter IV, total corridor demand estimates were based on incomplete data and thus only a preliminary ranking of corridors was considered justifiable. The lower confidence in these estimates is due to the absence of detailed nationwide historical demand data from which to make future projections.

For the cost-revenue analysis presented in this chapter, demand projections were based on recent survey data for the selected corridors (see Appendix A). The methodology presumes that total demand (sum of all modes) is insensitive to the type of service being offered by the individual modes, and also to the cost of fuel. Induced total demand attributable to the introduction of improved service and total demand suppressed due to higher fuel costs generally would tend to cancel each other, according to calculations made for this study.

The estimation technique for total demand was:

(1) obtain the most recent actual survey traffic volume data available;

(2) update to 1970 based on actual population and income growth;

(3) project population and income growth for each metropolitan area through 1995;

(4) estimate total demand between city pairs in 1975, 1985, and 1995 from the 1970 base, using growth rate of the two cities.

Table 5-1 presents the resulting total (all modes) transportation demand estimates for each corridor and year of interest.

The NEC forecasts were taken from the report Recommendations for Northeast Corridor Transportation, September 1971. Outside the NEC, the California corridor shows the highest growth rates, followed by Seattle-Portland, and finally Chicago-Detroit. Note that the San Diego-Los Angeles corridor accounts for over 50% of the total traffic in the San Diego-Sacramento corridor in 1985.

The procedure for estimating the HSGT share of the total demand (i.e., modal split) is described in Appendix A. In estimating the modal split, important parameters included are: door-to-door trip time, door-to-door cost, and frequency of service. Except for a few cases where very high demand made higher levels likely, the frequency of service was assumed to be 14 round trips per day.

Average speeds (including acceleration, deceleration, and station dwell) assumed for each of the IPT corridors were based on data supplied by FRA, and were as follows:

Corridor	Average Corridor Speed (mph)
Chicago-Detroit	82
Portland-Seattle	60
San Diego-Los Angeles	75

TABLE 5-1

TOTAL TRANSPORTATION DEMAND PROJECTIONS

(millions of annual passenger trips by all modes)

Corridor	Year			Percent Growth	
	1975	1985	1995	1975-1985	1985-1995
Chicago-Detroit	6.2	8.0	10.2	29%	27%
Portland-Seattle	3.1	4.4	5.8	42	32
San Diego-Los Angeles	33.7	49.7	68.0	47	37
San Diego-Sacramento	65.3	94.8	128.3	45	35
Washington-Boston[3]	203.0	300.0	444.0	48	48

For the TLV system operating on an all new guideway, it has been assumed that its cruise speed between stops is 300 mph. Allowances for acceleration and deceleration times were accounted for in station dwell times of six minutes.

The fare charged on an HSGT system is an important factor relative to demand and economic viability. Several fare equations were used in the various demand projections, as follows:

IPT	TLV
\$1.72 + \$.086/mile	\$3.44 + \$.097/mile
\$1.25 + \$.050/mile	\$2.51 + \$.057/mile
	\$1.25 + \$.050/mile

[3]Washington-Boston projections are taken from "Recommendations for Northeast Corridor Transportation," Volume 2, September 1972, page 5A-13. The demand projections for that study were developed by a methodology different from the one described above which was used for the other corridors of this study.

The high fares for both IPT and TLV systems are based on the fare structure used in the NECTP report.[4] The fares are similar, respectively, to that for Metroliner and to the national average for air. The lowest fare for IPT is used only in California corridor demand projections. This fare is used as a representative response to the very competitive Pacific Southwest Airlines service operating there.[5] The intermediate fare (i.e., $2.51 + .057/mile) and corresponding demands were used in the NPV analysis of TLV systems in California, because the lowest fare and corresponding demands would not provide revenue sufficient for system viability.

It is considered that problems in petroleum supply are highly likely within the next ten to twenty years. A severe petroleum shortage, with consequent price increases, could sharply increase the cost of transportation. HSGT demand projections were made under two energy scenarios: (1) fuel prices remain unchanged, in constant 1972 dollars; and (2) fuel prices increase by a factor of 3, also in constant dollors. Such price increases would make HSGT travel more attractive, relative to air and auto, since fuel is a smaller fraction of HSGT total cost as compared with that for the other modes.

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[4] Op. cit. The NEC fares were inflated from 1970 to 1972 dollars. For comparison purposes, Washington, D.C. to New York City IPT fare would be $20.65 versus the AMTRAK fare of $19 for METRO coach and $30.90 for METRO Club. The TLV fare would be $24.80 versus actual air fare of $26 ($34 first class).

[5] For comparison purposes, the IPT fare between San Diego and Los Angeles would be $7.60 versus air fare of $8. The intermediate and low TLV fares between Los Angeles and San Francisco would be $23 and $19.25 respectively versus the air fare of $16.50.

Sensitivity estimates were also obtained for IPT demand with respect to the rail modal coefficient,[6] a parameter used in estimating the modal split. The base case rail coefficient is the same as that for air. For comparison, demand sensitivity runs were made assuming a higher modal coefficient for IPT; i.e., that passengers perceived IPT as more attractive than in the base case. The higher modal coefficient was based on the rail coefficient used in Northeast Corridor Transportation Project model runs.

Service frequency, which was fixed at 14 trips each way per day for the base case, was allowed to increase as necessary to meet demand requirements in certain of the TLV runs. For IPT, a daily frequency of 14 round trips would be sufficient to satisfy estimated demand.

Only selected combinations of speed, fare, energy crisis, service frequency, and rail modal coefficient are presented in the following tables. The combinations were selected to show a range of demands and revenue useful in determining economic viability. Table 5-2 presents a summary of the demand projections for the parametric combinations selected for the IPT system. Results will be discussed for each corridor in turn.

[6] The modal coefficient is a demand model parameter which accounts for attractiveness (other than frequency, time and cost parameters) of one mode over another. If, for a particular O-D pair, the frequency, time, and cost of two modes are exactly the same, the mode with the greater modal coefficient value will generate more demand.

TABLE 5-2

IPT DEMAND/REVENUE PREDICTIONS

Corridor	Parameters: Speed	Parameters: Fare	Parameters: Rail Mode Exponent	Parameters: Fuel Cost Factor	Average Trip Length (mi.)	1975 Predictions: Passenger (Millions)	1975 Predictions: Passenger Miles (Millions)	1975 Predictions: Pax Mi. per Route Mile (Millions)	1975 Predictions: Revenue ($M)	1985 Predictions: Passengers (Millions)	1985 Predictions: Passenger Miles (Millions)	1985 Predictions: Pax Mi. per Route Mile (Millions)	1985 Predictions: Revenue ($M)
Chicago-Detroit (292 Route Miles)	82	A	.641	1.0	170	.298	50.8	.176	4.88	.395	67.1	.233	6.45
			1.0	1.0		.416	70.8	.245	6.80	.553	94.1	.327	9.05
			.641	3.0		.573	97.5	.338	9.38	.760	129.	.447	12.4
			1.0	3.0		.800	136.	.471	13.1	1.06	180.	.622	17.3
Portland-Seattle (186 Route Miles)	60	A	.641	1.0	186	.136	25.3	.136	2.41	.199	37.0	.199	3.52
			1.0	1.0		.192	35.7	.192	3.40	.280	52.0	.280	4.95
			.641	3.0		.265	49.3	.265	4.69	.386	72.0	.386	6.83
			1.0	3.0		.370	68.8	.370	6.55	.540	100.0	.540	9.57
San Diego-Los Angeles (127 Route Miles)	75	A	.641	1.0	127	1.18	150.	1.18	14.9	1.77	225.	1.77	22.4
			1.0	1.0		1.68	213.	1.68	22.2	2.51	320.	2.51	31.7
			.641	3.0		2.09	265.	2.09	26.4	3.15	400.	3.15	39.8
			1.0	3.0		2.97	378.	2.97	37.5	4.48	570.	4.48	56.7
		B	.641	1.0		1.88	239.	1.88	14.3	2.82	358.	2.82	21.5
			1.0	1.0		2.60	330.	2.60	19.8	3.88	493.	3.88	29.8
			.641	3.0		3.32	422.	3.32	25.3	4.99	633.	4.99	38.0
			1.0	3.0		4.73	600.	4.73	36.0	7.10	902.	7.10	54.0

Fares: A $1.72 + $.086 per mile
B $1.25 + $.050 per mile

NOTE: In all cases, daily service frequency = 14 round trips each way.

IPT: Chicago-Detroit

The total projected demand growth in this corridor for all modes is the lowest of the corridors examined in detail (29% from 1975 to 1985, or approximately a 2.6% compound annual growth rate). This results from the fact that the projected population growth rates are lowest for this corridor (see Section F, Appendix A).

In addition, it appears that the absolute size of observed demand (5.5 million passenger trips in 1970) is lower than might have been expected, given the size of Chicago and Detroit. This may perhaps be attributable to the large proportion of blue collar workers in the population of both cities, which would lead to a lower trip generation. Another possible reason may be the variety of intermediate cities (other than those along the corridor) which could attract a relatively large amount of the potential travel between the two cities. The above explanations are speculative and a more detailed investigation of the makeup of this corridors' population and travel habits would be necessary to obtain further insights.

By 1985, the most optimistic demand estimate for IPT is about .76 million trips per year (approximately 9.5% of the total market).[7] The Chicago-Detroit route includes stops at South Bend and Toledo, and these are reflected in the demand estimates cited above. The change in average trip length with the parametric variations reflects the relative contributions to the total demand of the shorter origin-destination pairs. Most noticeably, the situation with higher fuel costs shows a shift toward

[7] Market shares for automobile, air, and bus are shown in Table A-9 of Appendix A. (The market share for IPT shown in Table A-9 is slightly higher than that presented here because the site-specific speed of 82 mph, being lower than the 90 mph shown in Table A-9, caused the share to be smaller.)

more short distance trips, as rail replaces the auto for shorter trips. The high fuel cost condition (i.e., 200% increase) showed a 100% increase in passenger trips by rail.

IPT: Portland-Seattle

The demand growth rate for Portland-Seattle reflects the higher population growth rate expected for the Northwest region. The most optimistic estimate examined here shows a possible 8.8% of the market for rail.

Demand projections for Portland-Seattle are based on two zones, defined to include intermediate rail stops in Tacoma, Centralia, and Vancouver. These have relatively small populations. Available historical data were not sufficient to estimate demand other than between the two major zones. Hence, the average trip distance is shown as invariant for paramater changes. As with the Chicago-Detroit corridor the high fuel cost scenario produces almost a doubling of rail passenger trips.

IPT: Los Angeles-San Diego

The corridor currently has a high total demand and is expected to grow strongly with time. By 1985, even the least optimistic of the cases examined here yields estimated rail patronage in excess of 1.7 million, while the most optimistic case yields almost 5 million. The best modal split achieved is estimated to be about 10% of the total.

Some of the estimates were made using a fare which would be competitive with airline fare ($7.60 per one-way trip). Increasing the fare to equal that used for the rest of the country ($12.64, a 66% increase) decreased demand by about 37% but increased revenue by about 5%.[8] This is due to the relatively inelastic character of demand with respect to price, a property of the demand model for all the corridors examined in this study.

As with Portland-Seattle, the demand model operated on only two zones. The population/income sizes of these zones actually encompass planned rail stops at Anaheim and the northern suburbs of San Diego. Available historical data were not sufficient to estimate trips between Anaheim and downtown Los Angeles or combinations other than the two major zones. Thus, average trip length is indicated as invariant for all combinations of parameter values.

TLV: All Corridors

Tracked Levitated Vehicle demand was examined for initial operation in four corridors: Washington-Boston (Northeast Corridor), Portland-Seattle, San Diego-Sacramento and San Diego-Los Angeles. All estimates assumed a 300 mph cruise speed. The fare structure is higher for TLV than for IPT, consistent with the premium service offered by TLV.

Table 5-3 presents the demand and revenue estimates. The estimate for Washington-Boston is taken directly from the NECTP[9] while the others are based on the demand forecasting methodologies described in Appendix A. The estimate for Washington-Boston shows the highest demand. Demand for San Diego-Sacramento is only about one-half as large, while that for

[8] The relatively low air fares prevalent in California result from aggressive competition by Pacific Southwest Airlines (PSA). PSA is an intrastate carrier and thus its fares are not regulated by the CAB, as are those of interstate air carriers.

[9] Op. cit.

TABLE 5-[illegible]

TLV DEMAND/REVENUE PREDICTIONS

Corridor	Fare[1]	PARAMETERS: Fuel Cost Factor	PARAMETERS: Frequency (Rd. trips/ day, 1985)	PARAMETERS: Average Trip Length (mi.)	1985 PREDICTIONS: Passengers (millions)	1985 PREDICTIONS: Passenger Miles (millions)	1985 PREDICTIONS: Pax Mi. Per Route Mile (millions)	1985 PREDICTIONS: Revenue ($M)	1995 PREDICTIONS: Passengers (millions)	1995 PREDICTIONS: Passenger Miles (millions)	1995 PREDICTIONS: Pax Mi. Per Route Mile (millions)	1995 PREDICTIONS: Revenue ($M)
Washington-Boston[2] (444 route mi.)	A	1.0	46	135	40.	5400	12.2	660.	53.8	7270	16.4	890.
Portland-Seattle (166 route mi.)	A	3.0	14	166	1.48	246	1.48	29.0	1.96	327	1.96	38.4
San Diego-Los Angeles (114 route mi.)	A	1.0	27	114	4.45	508	4.45	64.6	6.22	710	6.22	90.4
		3.0	47		9.31	1060	9.31	136.	13.0	1480	13.0	189.
	B	1.0	27		6.45	731	6.45	93.8	9.00	1020	9.00	131.
		3.0	47		12.5	1420	12.5	182.	17.9	2040	17.9	260.
		3.0	14		6.96	791	6.96	101.	10.0	1140	10.0	145.
San Diego-Sacramento (638 route mi.)	A	1.0	23	180	11.0	1840	2.88	230.	15.2	2520	3.95	317.
		3.0	32		20.5	3690	5.78	428.	28.2	5090	7.98	590.
	B	1.0	23		15.6	2600	4.07	199.	21.5	3570	5.60	274.
		3.0	32		27.6	4960	7.79	352.	38.0	6830	10.7	485.
		3.0	14		18.0	3220	5.05	230.	25.0	4500	7.07	318.

Vehicle Speed = 300 mph

1. Fares: A $3.44 + $.097/mile
   B $2.51 + $.057/mile

2. Demand estimates for Washington-Boston are taken from NECTP Report and assume 3% compounded annual growth rate.

NOTE: Corridor lengths for TLV are defined to be less than those for IPT, reflecting the probable routing of new TLV guideways.

Portland-Seattle is expected to be less than four percent of that for Washington-Boston.

The San Diego-Los Angeles segment of the California corridor is also examined as a separate corridor because of the significantly higher demand density it exhibits. This city pair currently generates nearly half of the total demand in the California corridor, yet spans only about one quarter the route length. Since fixed investment costs increase nearly linearly with route length, the San Diego-Los Angeles corridor, as a distinct entity, promises to have a revenue/cost ratio markedly better than the San Diego-Sacramento corridor as a whole.

In terms of modal split, the TLV is estimated to capture the following percentages of total demand for the most economically optimistic case: Washington-Boston, 13%; Portland-Seattle, 34%; San Diego-Sacramento, 22%; and San Diego-Los Angeles, 19%.[10]

As for the IPT, the assumption of high fuel cost doubles estimated TLV demand in the California corridor.

Daily frequency of service was treated initially as being at a minimum level, fixed at 14 trips each way, independent of demand. Where applicable, service frequency was permitted to increase as needed to meet increases in demand for maximum train size.

[10] Market shares for each mode are shown in Table A-10 of Appendix A.

B. COST ANALYSIS

All costs used in the analyses are expressed in constant 1972 dollars. This section presents estimated investment costs, and operating costs for the first year of operation (i.e., 1975 for IPT and 1985 for TLV). The demand estimates used for cost analysis purposes in this section are based on the nominal case of: fuel cost factor of 1.0; site specific speeds for IPT; the higher fare cases discussed in the previous section; a daily service frequency of 14 round trips; and a modal coefficient value of 1.0.

The IPT and TLV routeway investment costs are based on estimates supplied by the Federal Railroad Administration. IPT routeway improvements include such items as track upgrading, fencing of selected parts of the right-of-way, road crossing protection, and improvements to the signalling and communication systems. Costs are also included for terminal improvements. The resulting cost estimates for the IPT systems are given in Table 5-4.

TABLE 5-4

IPT INVESTMENT COST
(millions of 1972 dollars)

	Chicago Detroit	San Diego Los Angeles	Portland Seattle
Total Costs of Improvements[1]	59	22	23
Vehicles[2]	(7)	7	(5)
TOTAL	66	29	28

[1] FRA estimated additional funds required for the IPT development, test, and demonstration program total $24 million.

[2] Vehicle cost, including 20% spares, to the nearest million for first year operation based on the larger of fleet to serve demand or ( ) fleet to supply minimum frequency of 14 per day. Unit cost is taken on $560,000 per car.

Vehicle investment costs are a function of fleet size which may be determined by either (1) the number of vehicles needed to serve the estimated first year demand or (2) the number of vehicles needed to make up trains to provide a minimum schedule of 14 round trips a day on hourly departures. In either case, turnaround time was taken as one hour. For San Diego-Los Angeles, the schedule requirement was only 8 vehicles so the 12 vehicles needed to serve demand were controlling: for Chicago-Detroit and Portland-Seattle, the minimum schedule requirement of 12 and 10 cars respectively were controlling.[11] In computing breakeven and net present value, a continuous equation using only fleet size for demand was used; this results in an underestimate of total system costs by less than 2% in the worst case, and no error for cases in which service is above minimal level. The investment costs for an IPT vehicle are estimated by the FRA to be about $8,000 per seat, or $560,000 per vehicle for the 70-seat capacity assumed in this study.[12]

Investment costs for the TLV system are based on (1) new guideway cost data developed for this study, and (2) cost estimating relationships for TACV contained in the RMC report developed for this study,[13] and on an earlier 1969 NECTP report.[14] The cost estimating parameters are summarized in Table 5-5.

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[11] Vehicle requirements include a vehicle float factor of 20 percent, based on an FRA estimate that present rail practice is to maintain a float of 20% extra vehicles over those in service.

[12] This cost estimate assumes a purchase of at least 200 vehicles, as would be likely if an IPT system were implemented in several corridors. Purchased in small numbers, vehicles are estimated by FRA to cost about $12,000 per seat.

[13] RMC Incorporated, Final Report UR-189, June 9, 1972, "Unit Cost Estimates for Improved Passenger Train and Track Levitated Vehicle Systems."

[14] NECTP Interim Report, April 1970, "Cost Analysis for NECTP, Volume I," NECTP-222, prepared by RMC, Inc., December 1969, NTIS PB-190-942.

TABLE 5-5

TLV INVESTMENT COST ESTIMATING RELATIONSHIPS

Element	Unit Costs (millions of 1972 dollars)	Notes
Storage and Service Yards	11/Facility	Based on NEC estimate
Major Overhaul Shop	2/Facility	Based on NEC estimate
Terminals		
Suburban	9/Facility	Based on NEC estimates
Downtown	13/Facility	
Underground	31/Facility	
Electrification	.576/Route-Mile	Includes substation costs
Control and Communications	.180/Route-Mile	No foreign obstacle detection; similar to "automatic train operation" costs based on New Tokaido Line & BART
Land - Urban, California	1.3/Route-Mile	
elsewhere	2.75/Route-Mile	Based on NEC estimates
Rural, California	.08/Route-Mile	
elsewhere	.16/Route-Mile	Based on NEC estimates
Route Preparation (at grade g'way)	1.36/Route-Mile	Average NEC estimate
Major Bridges	18.6/Bridge-Mile	Based on NEC estimates
Tunnels	29.8/Tunnel-Mile	Based on NEC estimates
Guideway - At Grade	1.10/Route-Mile	MITRE Corp. estimates for "U"-shaped guideway
Elevated	2.5/Route-Mile	
Vehicles	1.56/Vehicle	Average based on fleet size of 100

The total system investment costs for TLV systems in the three corridors are presented in Table 5-6. Research and Development costs are not included because there is no fair basis for allocating this cost to the different corridors until it is determined how many corridors might support a TLV system.

In arriving at the TLV system costs, the following assumptions were made:

1. Four storage and service shops were assumed for the NEC and San Diego-Sacramento corridors. Two such facilities were assumed for the shorter corridors. Each corridor has one major overhaul facility.

2. For terminal construction, only "high density" cost values are used so as to plan for demand growth. In the NEC, Baltimore, Philadelphia, and New York City are all assumed to have underground terminals. The following cities are all assumed to have urban (above ground) terminals: Washington, D.C., Wilmington, Trenton, Meadows, New Haven, Providence, Boston, Portland, Seattle, San Diego, Los Angeles, Oakland, and Sacramento. All others are assumed to have suburban-type terminals.

3. For the base case in the California and Portland-Seattle corridors, the guideway mix is assumed to be the same as that for the NEC, i.e., 1% bridges, 4% tunnels, 16% elevated, and 79% at grade. This results in a cost of approximately $4 million per

TABLE 5-6

TLV INVESTMENT COSTS

(millions of 1972 dollars)

Element	Corridor: Boston-Washington	Portland-Seattle	San Diego-Los Angeles	San Diego-Sacramento
Yards & Shops	46	24	24	46
Terminals	211	53	44	97
Electrification	256	96	65	367
Control & Communication	80	30	21	115
Route Preparation & Guideway Construction[1]	1854	664	457 (370)	2559 (2080)
Land	557	62	57	210
Subtotal	3004	929	668 (581)	3394 (2915)
Vehicles[2]	211	(8)	15	42
TOTAL	3215	937	683 (596)	3436 (2957)

[1] The lower values, in parenthesis, are in accordance with lower cost estimates established by the RAND Corporation in an unpublished study for the Department of Transportation, Office of Assistant Secretary for Research and Technology. The lower Route Preparation and Guideway Construction costs reflect the RAND assumptions of (1) no tunnels; and (2) approximately 50% of total mileage elevated, and 50% at grade.

[2] Vehicle requirements for initial year of operation; those for Portland-Seattle are based on a minimal level of service; otherwise, based on demand. The demand estimates used for NEC and the Portland-Seattle corridor are based on a fare of $3.44 + .097/mile and for the California corridor a fare of $2.51 + .057/mile. Investment cost for TACV vehicles is estimated as $1.56 M per vehicle.

route-mile for construction and route preparation. A RAND[15] study has indicated a somewhat different mix in California, consisting of no tunnels, and the percent at grade and elevated guideway split evenly. No indication of bridge construction was given in the RAND report, so the NEC estimate of 1% is used here. This latter mix results in costs of approximately $3.2 million per route-mile for guideway construction and route preparation. These lower figures are shown in parentheses in Table 5-6. In the absence of a detailed site-specific analysis of the California and Portland-Seattle corridors, the NEC percentage mix appears the most reasonable to use.

4. Land costs for TLV in the NEC are estimated to be $557 million[16] in 1972 dollars. In the Portland-Seattle corridor, land costs are estimated based on the RMC cost estimating relationships (see Table 5-5), and the assumption that the 16% elevated portion of the track is to be built entirely on urban land. For the California corridors, land cost estimates are based on the RAND study,[17] which indicates a cost of $114 million for the total San Diego-Sacramento corridor. This is prorated on a mileage basis to estimate

[15] "Impacts of Alternative Intercity Short-Haul Transportation Systems on the California Corridor," The RAND Corporation, RN-7616-DOT, unpublished draft, September 1971.

[16] NECTP Interim Report, NECTP-222, December 1969 indicates land costs of $464 M in 1970 dollars.

[17] Op. cit.

the cost for the San Diego-Los Angeles corridor. However, the TLV route selected for the San Diego Sacramento corridor in this study is 12% longer than the route assumed by RAND (638 mi. vs 568 mi.) and thus the land cost estimate is increased accordingly. Average land costs per route mile are estimated to be lower in California than in the NEC, consistent with the lower average density of population.

5. Based on the NECTP estimate[18] of TACV demand and vehicle requirements, it was determined that each annual passenger trip requires a vehicle investment of approximately $5.30.[19]

6. The minimum level of service, the same as that assumed for the IPT systems, is set at fourteen round trips per day, with a one-hour turn-around time. These service assumptions result in minimum vehicle requirements (including 20% spares) of 5, 5, and 12 units, respectively, for the San Diego-Los Angeles, Portland-Seattle, and San Diego-Sacramento corridors. Demands projected for the NEC and for San Diego-Los Angeles warrant greater-than-minimum service, and thus larger-than-minimum fleet sizes. Breakeven costs and net present values are computed without taking minimum fleet size requirements into account, which results in underestimates of total system cost of less than 1%, in the worst case.

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[18] "Recommendations for Northeast Corridor Transportation," DOT, September, 1971.

[19] The NECTP Study assumed only an 8% float factor; the figure of $5.30 represents an adjustment of the NECTP figure to reflect a 20% spare vehicle allowance and a different unit vehicle cost.

Operating Costs

The relationships and data used in this study to estimate operating costs are those developed by RMC,[20] and shown in Table 5-7. Although these are the best estimates available at the present time, they should be reconsidered as better information becomes available. Costs were developed on these bases for each corridor and system, and include fixed annual costs for terminals and routeway, and variable costs related to passenger-miles.

Terminal operating costs are based on the NECTP Interim Report[21] estimates of peak passengers per hour (PPH) and operation and maintenance costs, at the various NEC terminals. Averages were obtained for large (i.e., urban) terminals and small (i.e., suburban terminals for systems HSRA[22] and TACV. The HSRA averages were reduced to approximate the OPT system. The resulting estimates are:

	IPT		TLV	
	Urban	Suburban	Urban	Suburban
Peak Passengers/Hour	700	350	1300	500
Annual Terminal Operations and Maintenance Per Facility (10^3)	$450	$190	$750	$250

Annual costs for route-way-related maintenance (guideway, power, and control) are approximately $13,400 per route-mile for the IPT and $34,000 per route-mile for the LTV. Passenger dependent variable

[20] Op. cit., pp. 80 and 130.

[21] "HSGT Mode Service Analysis in the Northeast Corridor," NECTP-214, TRW Systems Group, December 1969.

[22] "HSRA" is the designation given to a higher speed rail system than IPT, with substantially upgraded NEC right-of-way, terminals, and other fixed facilities.

TABLE 5-7

ESTIMATING RELATIONSHIPS FOR ANNUAL OPERATING COST

ITEM	UNITS	IPT	TLV (TACV)
°Power	\$/Car Mile \$/Train Mile	- .50	.179 -
°Crew	\$/Train Mile	1.84	.20
°Vehicle Maintenance[1]	\$/Car Mile	.382	.764
°Guideway Maintenance	$\$10^3$/Route Mile	7.40	10.0
°Power Maintenance[1]	$\$10^3$/Route Mile		19.5
°Control Maintenance[1]	$\$10^3$/Route Mile	5.988	7.24
°Indirect Operating Costs Mile[3]	\$/Passenger	.023	.015
°Terminal Operations & Maintenance[2]			
Urban	$\$10^3$/Facility/yr.	100 + .5 * (PPH)	100 + .5 * (PPH)
Suburban	$\$10^3$/Facility/yr.	50 + .4 * (PPH)	50 + .4 * (PPH)

[1]Vehicle, Power, and Control Maintenance Costs include 66 percent burden.

[2]Fixed Operating Cost plus Variable Cost Per Peak Hour Passenger (PPH) Demand.

[3]Indirect operating costs are those incurred in providing services; they are not directly related to vehicle operation. Some of the costs for passenger serviceson board accrue on an hourly basis (e.g., cabin attendants); therefore, the "per mile" costs would be less for higher speed service.

costs include components attributable to power requirements, crew compensation, vehicle maintenance, and indirect operating costs. Cost estimates are summarized in Table 5-7, and again as part of Table 5-8.

Turbine fuel for the IPT is estimated to cost $.50 per train mile, based on a fully allocated cost study of conventional rail passenger service conducted by Peat, Marwick, Mitchell & Company. Results of this study were updated to reflect 1972 prices.

TLV power costs are based on the assumption that electrical power can be purchased at high voltage primary substations, then distributed to substations along the route, at an average net cost of $.011 per kwh. The estimated cost of power for TLV would then be $.179 per vehicle mile, of which 35% would be attributable under peak load to the air cushion levitation system.

Crew costs for IPT are estimated from a 1970 sample of wages for Turbotrain crews, inflated for subsequent increases. Costs are estimated as $1.84 per train mile.

For TLV, crew costs are estimated to be $.20 per train mile based on previous NEC estimates, and projected to 1972 prices. It is assumed that new work agreements can be negotiated so that TLV would operate with a one-man crew.

Guideway maintenance costs for IPT are based on data obtained by Louis T. Klauder and Associates.[23] After certain adjustments, a

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[23] Louis T. Klauder and Associates, Report of the Pennsylvania Railroad Company's Maintenance of Way Expenses New York to Washington, D.C. 1956 to 1965, Incl., prepared for DOT (1969).

TABLE 5-8

SYSTEM COSTS

(1972 dollars)

Corridor	Total Investment (millions)		Annualized Investment Cost (millions)		Annual Operating Costs			
					Fixed (millions)	Variable, per		
						car mi.	train mi.	passenger mi.
IPT	Fixed	Vehicles[1]	Fixed	Vehicles[1]				
Chicago Detroit	$59	$6.55	$6.5	$.89	$5.5	$0.38	$2.34	$0.023
Portland Seattle	23	6.55	2.6	.89	3.9	.38	2.34	.023
San Diego Los Angeles	22	6.55	2.4	.89	3.0	.38	2.34	.023
TLV								
Washington Boston	$3004	$5.30	$442	$.72	18.0	$0.94	$0.20	$0.015
Portland Seattle	929	5.30	138	.72	7.8	.94	.20	.015
San Diego Los Angeles	668	5.30	99	.72	5.9	.94	.20	.015
San Diego Sacramento	3394	5.30	504	.72	25.9	.94	.20	.015

[1]Per million annual passenger trips.

basic annual maintenance cost of $3,934 per track mile was derived, assuming an annual traffic density of 6 million gross tons (MGT). Further corrections were then made to adjust for anticipated traffic density, average block speed, and the fact that the guideway would be shared with commuter and freight traffic. For the case of two tracks along the route, the resulting annual cost is expressible as 1900 $(MGT)^{0.585}$, in 1972 dollars. Taking 50 tons to be a representative weight for one vehicle, typical passenger demand forecasts for the San Diego-Los Angeles corridor, given 70-seat vehicles operating at 60% load factor, lead via the above formula to annual costs of $2100 per route mile.

A similar calculation was made for TLV, drawing upon analogous data for conventional track, and assuming the guideway to be used solely by the TLV system. The resulting cost is given by the expression $3400 + 2880\ (MGT)^{0.585}$, in 1972 dollars. The constant is included to allow for maintenance of drainage, erosion control, etc. Nominal traffic leads to an annual cost estimate of $10,000 per route mile.

Vehicle maintenance costs for IPT are estimated based on Penn Central's experience with Silverliners, transit equipment data, and projections of Metroliner costs. The estimates have been adjusted to allow for the increased speed and power of IPT vehicles, as well as maintenance economy resulting from careful development and prototype testing. The resulting IPT estimate is $.23 per car mile, not including burden.

The corresponding estimate for TLV is $.46 per car mile, based on previous studies.

Past railroad experience indicates that the cost of maintaining all route electrification and guideway communication and control equipment is approximately 2% of the initial investment. The resulting estimates for both IPT and TLV are included in Table 5-7.

A burden has been added to all of the foregoing vehicle, power, and control maintenance costs to allow for overhead and general expenses identified with the maintenance of equipment and property. An average burden rate equal to 66% of direct maintenance costs was assumed, based on conventional railroad maintenance practices and airline maintenance data.

Indirect operating costs are those incurred in providing services, but not directly related to vehicle operation. Since some indirect cost items tend to be accrued on an hourly basis (e.g., on board attendants), railroad data based on the slower trains currently in existence would lead to over-estimates on a per-passenger-mile basis. Also, because of the effect of costs accruing on an hourly basis, the higher speed TLV would incur lower indirect operating costs per passenger mile than would the IPT. The use of rail data would lead to yet further overestimates, as a result of the 20% average load factor which has characterized conventional rail service, in contrast to the 60% load factor assumed for IPT and TLV. Instead, the indirect operating costs for IPT and TLV were estimated on the basis of airline cost experience, adjusted to exclude items related solely to aircraft operations, and to eliminate costs included elsewhere in the analysis. Costs were developed on the assumption of an intermediate level of service, more complete than existing railroad service but not on a par with that currently provided by major airlines. The resulting cost estimates are \$.023 per passenger mile for OPT and \$.015 for TLV.

Cost estimates, as summarized in Table 5-8, include components which depend upon the numbers of car miles and train miles required annually by passenger demand. In using these estimates, it is assumed that the system operates at an average load factor of 60%, with service frequency adjusted as necessary to maintain this load factor, except that service is not permitted to fall below the average daily level of 14 round trips considered to be the minimum required for widespread passenger acceptance of the system. It is further assumed that train lengths average 7 cars for IPT and 4 cars for TLV.[24]

The passenger-mile cost estimates used for analysis may possibly lead to underestimates of cost for corridors in which service is constrained by the minimum service level requirement since this would result in average load factors less than the assumed 60%.

Total annual operating costs are augmented by an annualized equivalent for capital investments. These are based on a 10% annual rate, applied to all investments over their economic lifetimes (infinite for land, 25 years for fixed facilities, 14 years for vehicles). These cost-equivalents are summarized as part of Table 5-8.

[24] The IPT train length is constrained by platform length. TLV train length is limited by power requirements (see Chapter III).

C. BREAKEVEN ANALYSIS

An initial test of the possible economic viability of a new system is to identify the patronage required to break even; that is, to estimate the patronage, at an assumed fare structure, so that revenues cover annual costs. Breakeven patronage can then be compared against estimated modal patronage in future situations. Comparison with forecast total demand in the corridor provides an indicator of potential viability. Table 5-9 summarizes the results of the analysis.

Another measure of potential economic viability is the fare or equivalently, the system cost per passenger mile required to break even, given any particular patronage estimate. The feasibility of this fare can then be determined by comparing it with those of competitive modes.

Figures 5-1 and 5-2 relate breakeven fare (in cents per mile per passenger) to patronage (in total annual passenger miles) for the IPT and TLV systems, respectively. Table 5-10 summarizes breakeven fares for the IPT and TLV systems, given typical patronage estimates for the corridors studied. The mathematics of the analysis is presented in Appendix B.

The dominant qualitative feature revealed by the analysis is the high degree of sensitivity of breakeven patronage to average fare per passenger mile. For example, Table 5-9 indicates that a fare decrease, for IPT in the San Diego-Los Angeles corridor, from 9.95 to 6.00 cents per passenger mile (40% decrease) results in an increase in patronage required to cover costs from .77 to 2.8 million passengers (260% increase). This strong sensitivity is explained by reference to Figure 5-1.

TABLE 5-9

BREAKEVEN PATRONAGE

SYSTEM/CORRIDOR	AVERAGE TRIP DISTANCE (miles)	FARE STRUCTURE	AVERAGE FARE (cents/pass.mi)	EXPECTED 1985 PATRONAGE (mill.pass)	BREAKEVEN Annual Pass. (millions)	PATRONAGE as % total demand all modes in 1985
IPT						
Chicago-Detroit	170	B	9.60	.76	1.3	16
Portland-Seattle	186	B	9.52	.39	.66	15
San Diego-Los Angeles	127	B	9.95	3.2	.77	1.6
San Diego-Los Angeles	127	C	6.00	5.0	2.8	5.6
TLV						
Washington-Boston	135	A	12.25	40	35	
Portland-Seattle	166	A	11.77	1.5	9.6	210
San Diego-Los Angeles	114	A	12.71	9.3	9.4 (8.2)*	19 (16)
San Diego-Los Angeles	114	B	10.11	12.5	13 (11)	26 (22)
San Diego-Sacramento	180	A	11.61	20.5	33 (28)	34 (29)
San Diego-Sacramento	180	B	9.56	27.6	42 (37)	43 (38)

Fare Structure: A $3.44 + $.097/mile
B $1.72 + $.086/mile
C $1.25 + $.050/mile

*Breakeven Patronage in ( ) is for lower TLV investment based on RAND study.

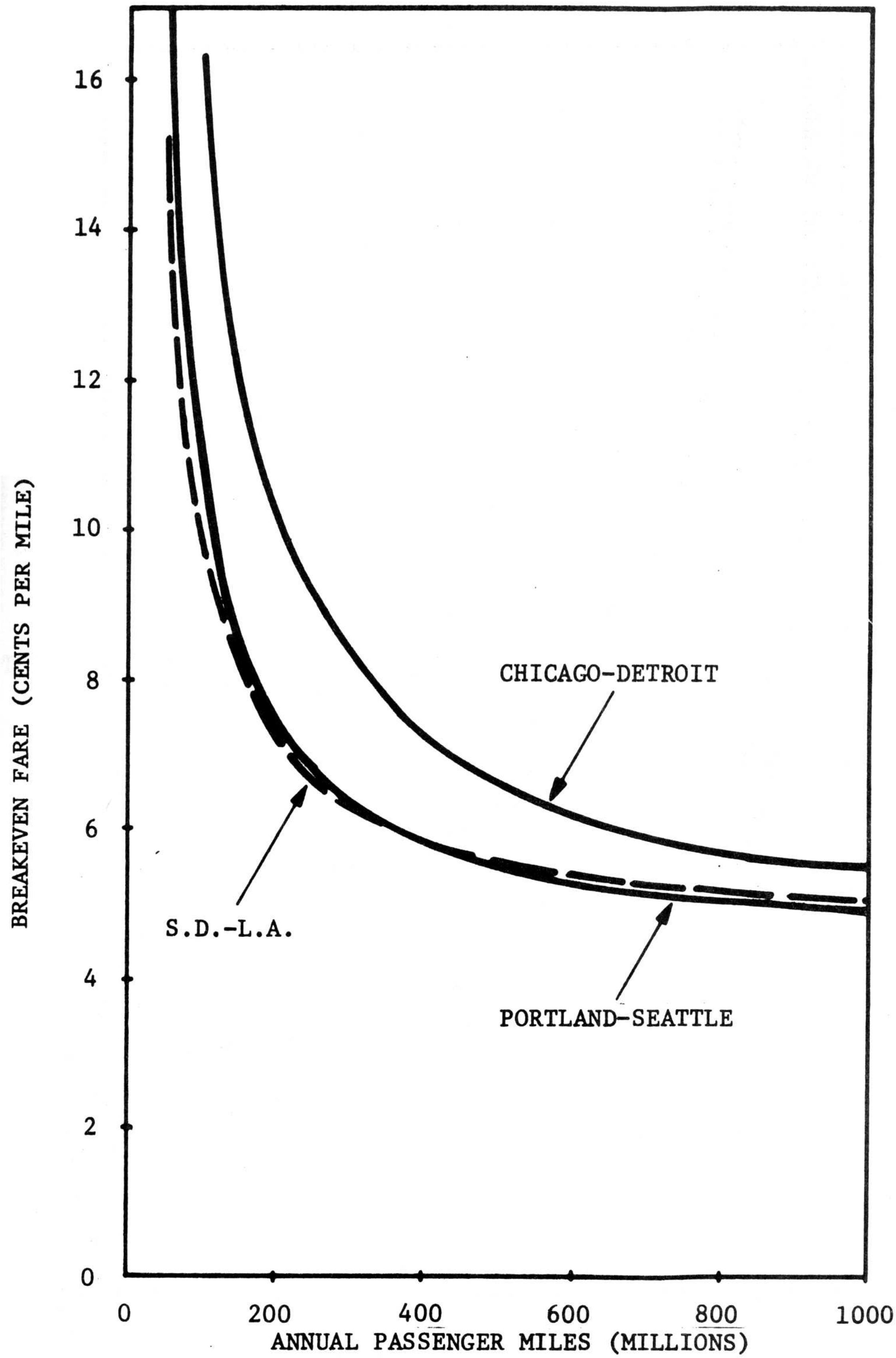

FIGURE 5-1. IPT BREAKEVEN FARE (1972 DOLLARS)

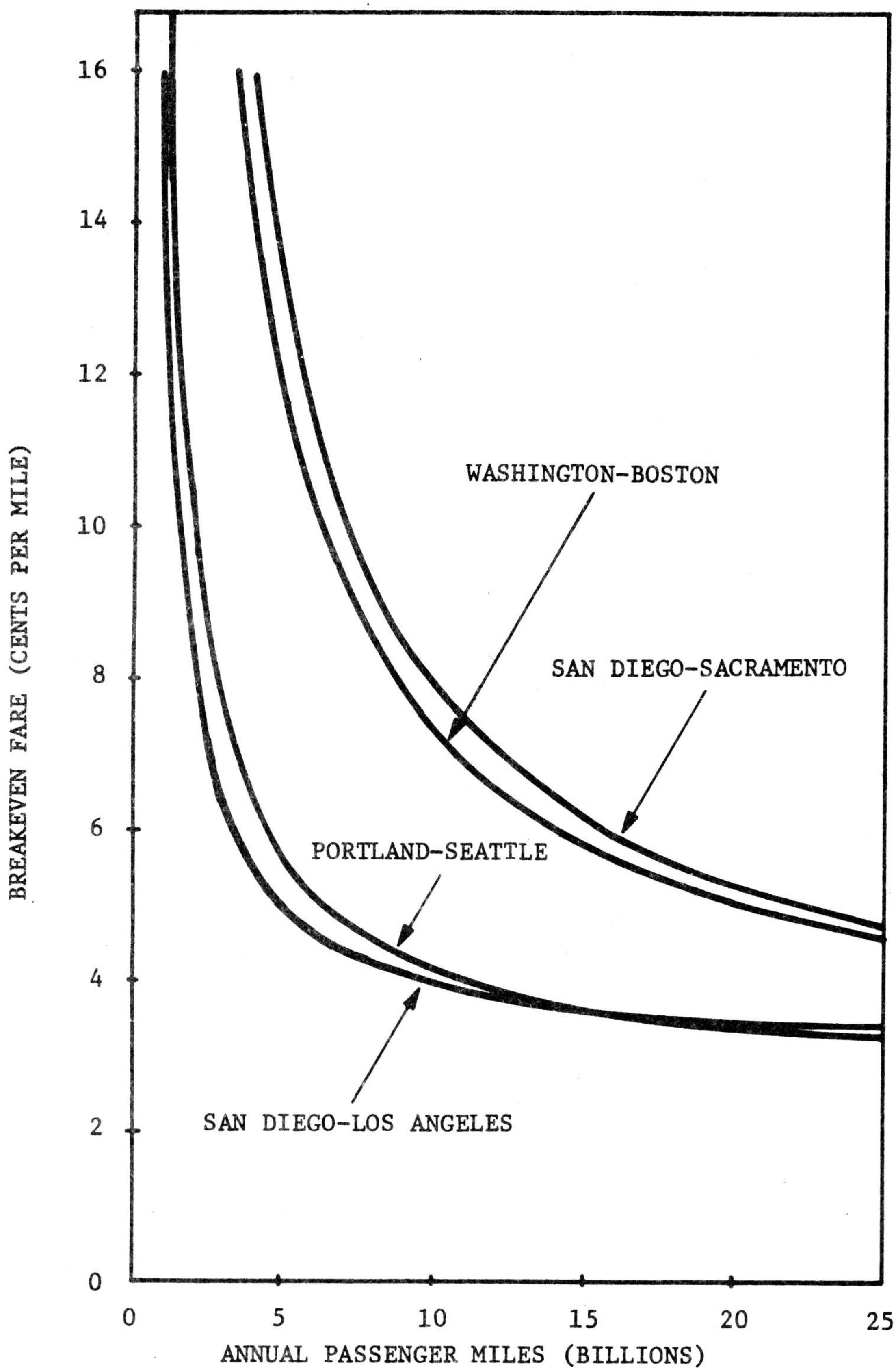

FIGURE 5-2. TLV (TACV) BREAKEVEN FARE (1972 DOLLARS)

TABLE 5-10

BREAKEVEN FARES

SYSTEM/CORRIDOR	TYPICAL ESTIMATED 1985 PATRONAGE (million pass. miles)	FARE TO GENERATE TYPICAL 1985 PATRONAGE (¢/mile)	FARE TO BREAKEVEN (¢/mile)
IPT			
Chicago-Detroit	129	9.60	13.52
Portland-Seattle	72	9.52	13.20
San Diego-Los Angeles	400	9.95	5.84
TLV			
Washington-Boston	5400	12.25	11.26
Portland-Seattle	246	11.77	61.60
San Diego-Los Angeles	1060	12.71	12.77
San Diego-Sacramento	3690	11.61	17.03

The ordinate (breakeven fare) can be interpreted as the cost per passenger mile, and is comprised of two components, one for variable operating cost, the other for fixed investment cost. This latter decreases when patronage is large, since the fixed cost is then allocated among more passenger miles. Figure 5-1 illustrates that effect. For large patronage, the breakeven fare tends toward a constant value, just sufficient to recover the variable operating cost. It can be seen from the figure that a given percentage decrease in fare will always give rise to a more than proportionally large percentage increase in breakeven patronage.

As an example of the above, one can derive the components of cost per passenger mile from data given in Table 5-8 for the San Diego-Los Angeles IPT system. Annualized fixed investment cost (2.4 million) added to annual fixed operating cost ($3.0 million) gives $5.4 million dollars which, in order to break even, must be recovered from however many passenger miles of service are provided. The annualized vehicle investment cost is about 0.70 cents per passenger mile ($0.89 per passenger trip divided by 127 miles average trip length). The variable operating costs add to about 3.76 cents per passenger mile (38 cents per car mile divided by 42 passengers, plus $2.34 per train mile divided by 420 passengers--10 car trains, 60% load factor--plus 2.3 cents per passenger mile). One can consider the 4.46 cents per passenger mile (variable operating cost plus vehicle investment) as the average marginal cost per passenger mile, and only the difference between the fare and 4.46 cents per mile is available to pay the fixed costs of $5.4 million. Thus, from a fare of 9.95 cents per passenger mile, 5.49 cents is available for fixed costs, and 98 million passenger miles (0.77 million passengers traveling an average of 127 miles per trip) would be required to cover the fixed costs. From a fare of 6.00 cents per passenger mile, only 1.54 cents would be available for fixed costs, and 351 million passenger miles (2.8 million passengers) would be required to break even.

Tables 5-9 and 5-10 indicate that an IPT appears promising for the San Diego-Los Angeles corridor, and unpromising for Chicago-Detroit and Portland-Seattle. TLV systems for Washington-Boston and San Diego-Los Angeles also appear promising, while Portland-Seattle does not. For the latter, the patronage to break even is more than twice that anticipated for all modes. The TLV system for San Diego-Sacramento, from Tables 5-9 and 5-10, appears not to be economically viable.

D. NET PRESENT VALUE ANALYSIS

Net Present Value (NPV) is a more complete measure of economic viability than either the breakeven demand or the net profit (or loss) for any particular year of system operation. A system operating at a loss in its first year may have a positive NPV as computed over its total life. Therefore, an NPV analysis was performed on all system/corridors, under the following assumptions:

- Demand, and thus revenue and variable operating costs and vehicle investments, will increase at rates shown in Table 5-1.
- All capital investments (other than vehicle replacements) for the IPT will be made during the one year prior to the start of operation.[25]
- Capital investments for the TLV system (other than vehicle replacements) will be made annually in amounts equal to one-seventh of the total required, beginning seven years before the start of operation.
- Land has an infinite economic life.
- Vehicles have an economic life of 14 years.
- All other capital investments have an economic life of 25 years.
- The systems have no salvage value at the end of their lives.
- The discount rate is 10 percent (6% was used in some of the sensitivity runs).

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[25] A one-year period for capital investments was assumed for purposes of the NPV analysis. In actual practice, the time required for improvements and construction may be two years (or even longer) and the capital investments would be made over a corresponding period.

NPV calculations are shown in two ways: (1) discounted to 1975 regardless of year of starting service and (2) discounted to year of start of operation.

The net present value was estimated for each corridor and system under situations selected with the aid of the previous breakeven analysis. The object was to determine a range of conditions for possible viability: i.e., conditions for zero NPV or positive NPV. Tables 5-11 and 5-12 summarize the results. The tables include a larger number of cases for the California corridors than elsewhere, so as to permit the inclusion of more than one fare structure, in view of the anticipated fare competition in California from PSA. Tables 5-11 and 5-12 also express the computed NPV's as percentages (possibly negative) of discounted base investment. This measure, a discounted percentage-return-on-investment, is useful for comparing systems with differing initial costs, or systems (possibly similar) which differ as to their initial year of operation (and thus whose costs are discounted by different amounts).

Also, it permits an immediate calculation of the amount of subsidy required by a system in cases where the measure is negative. If NPV divided by discounted base investment is minus one (-1.0), then all operating costs are recovered, and the required subsidy is 100% of the initial investment. If the measure is -0.35, then the subsidy required would, for example, be 35% of the initial investment.

The mathematics of the NPV analysis is presented in Appendix B.

IPT NPV Results

As shown in Table 5-11, an IPT system operating in the San Diego-Los Angeles corridor would yield a positive NPV under many circumstances.

TABLE 5-11

IPT NET PRESENT VALUES

Corridor	PARAMETERS: Speed (mph)	Fare	Rail Mode Constant	Fuel Cost Factor	Discount Rate (%)	Base Investment ($M), Discounted to 1975 if system starts in 1975	1985	NPV($M), discounted to start of operation, if system starts in 1975	1985	NPV($M), discounted to 1975, if system starts in 1975	1985	(NPV, discounted to 1975) ÷ (Base Investment, discounted to 75), (%), if system starts in 1975	1985
Chicago-Detroit	82	A	.641	1.0	10.	59.	22.7	-78.2	-68.2	-78.2	-26.3	-132.	-116.
			1.0	1.0	10.	59.	22.7	-65.9	-51.7	-65.9	-20.0	-112.	- 88.
			.641	3.0	10.	59.	22.7	-49.8	-30.5	-49.8	-11.8	- 84.	- 52.
			1.0	3.0	10.	59.	22.7	-26.4	0.4	-26.4	0.1	- 45.	0.
			1.0	3.0	6.	59.	32.9	- 4.9	35.5	- 4.9	19.8	- 8.	60.
Portland-Seattle	60	A	.641	1.0	10.	23.	8.87	-41.8	-34.1	-41.8	-13.1	-182.	-148.
			1.0	1.0	10.	23.	8.87	-35.0	-24.3	-35.0	- 9.4	-152.	-106.
			.641	3.0	10.	23.	8.87	-26.1	-11.4	-26.1	- 4.4	-114.	- 50.
			1.0	3.0	10.	23.	8.87	-13.3	7.5	-13.3	2.9	- 58.	32.
			1.0	3.0	6.	23.	12.8	- 3.7	28.0	- 3.7	15.7	- 16.	122.
San Diego-Los Angeles	75	A	.641	1.0	10.	22.	8.48	55.5	108.	55.5	41.6	252.	490.
			1.0	1.0	10.	22.	8.48	99.3	173.	99.3	66.6	452.	785.
			.641	3.0	10.	22.	8.48	137.	232.	137.	89.3	623.	1050.
			1.0	3.0	10.	22.	8.48	216.	350.	216.	135.	981.	1590.
		B	.641	1.0	10.	22.	8.48	- 2.9	20.2	- 2.9	7.8	-13.	92.
			1.0	1.0	10.	22.	8.48	14.5	45.8	14.5	17.7	66.	208.
			.641	3.0	10.	22.	8.48	32.7	73.9	32.7	28.5	148.	336.
			1.0	3.0	10.	22.	8.48	67.3	126.	67.3	48.5	306.	571.

Fares: A $1.72 + $.086/mile
B $1.25 + $.050/mile

NOTE: NPV's are based on assumptions of:
(1) Daily service frequency of 14 trips each way.
(2) No induced total demand resulting from introduction of IPT.
(3) No suppression of total demand resulting from higher fuel prices.
Study calculations show that the latter two effects tend to cancel each other out.

TABLE 5-12

TLV NET PRESENT VALUES

Corridor	Fare	PARAMETERS: Fuel Cost Factor	PARAMETERS: Frequency (Rd. Trips/ day, 1985)	Discount Rate (%)	Base Investment($M) Discounted to 1975 if system starts in: 1985	1995	RAND mix 1985	RAND mix 1995	NPV($M)discounted to start of system operation, if system starts in: 1985	1995	RAND mix 1985	RAND mix 1995	NPV($M)discounted to 1975 if system starts in: 1985	1995	RAND mix 1985	RAND mix 1995	(NPV,discounted to 1975) ÷ (Base Investment, discounted to 1975), (%), if system starts in: 1985	1995	RAND mix 1985	RAND mix 1995
Washington-Boston	A	1.0	46	10.	1550	598			1160	3000			446	446			29	75		
	A[1]	1.0	46	10.	1550	598			-165	1240			- 64	185			- 4	31		
	A[1]	1.0	46	6.	1940	1080			2330	4440			1300	1380			67	128		
Portland-Seattle	A	3.0	14	10.	483	186			-1090	-1020			- 422	-152			-87	-81		
		3.0	14	6.	614	343			- 857	- 746			- 478	-233			-78	-68		
San Diego-Los Angeles	A	1.0	27	10.	347	134	302	116	- 412	- 197	- 294	- 79	- 159	- 29	-113	- 12	-46	-22	-38	-10
		3.0	47	10.	347	134	302	116	178	627	296	744	69	93	114	111	20	70	38	95
		1.0	27	6.	440	246	382	213	- 44	282	61	387	- 24	88	34	121	- 6	36	9	57
	B	1.0	27	10.	347	134	302	116	- 592	- 449	-474	-331	- 228	- 67	-183	- 49	-66	-50	-61	-42
		3.0	47	10.	347	134	302	116	- 236	74	-118	192	- 91	11	- 46	28	-26	8	-15	24
		1.0	27	6.	440	246	382	213	- 306	- 86	-202	18	- 171	- 27	-113	6	-39	-11	-30	3
		3.0	14	10.	347	134	302	116	- 553	- 378	-435	-260	- 213	- 56	-168	- 39	-61	-42	-56	-33
San Diego-Sacramento	A	1.0	23	10.	1770	681	1520	584	-2930	-2210	-2280	-1560	-1130	-328	-879	-232	-64	-48	-58	-40
		1.0	23	6.	2240	1250	1920	1080	-1510	- 429	- 939	145	- 845	-134	-524	45	-38	-11	-27	4
		3.0	32	10.	1770	681	1520	584	-1310	4	- 663	653	- 506	1	-256	97	-29	0	-17	17
		3.0	32	6.	2240	1250	1920	1080	913	2890	1490	3460	510	901	831	1080	23	72	43	100
	B	3.0	32	10.	1770	681	1520	584	-2740	-1950	-2090	-1300	-1060	-290	-805	-194	-60	-43	-53	-33
		3.0	32	6.	2240	1250	1920	1080	-1190	6	- 612	580	- 663	2	-342	181	-30	0	-18	17
		1.0	23	6.	2240	1250	1920	1080	-2560	-1880	-1990	-1310	-1430	-587	-1110	-408	-64	-47	-58	-38
		3.0	14	10.	1770	681	1520	584	-3450	-2920	-2800	-2270	-1330	-434	-1080	-337	-75	-64	-71	-58

1. This case assumes a demand of 30M passenger trips in 1985, as compared with 40M for the first case.

Fares: A $3.44 + $.097/mile
B $2.51 + $.057/mile

NOTE: NPV's are based on assumptions of:
(1) No induced total demand resulting from introduction of TLV.
(2) No suppression of total demand resulting from higher fuel prices.
Study calculations show that these two effects tend to cancel each other out.

Typical values of discounted return on investment show the system to be attractive as an investment in the San Diego-Los Angeles corridor.

In the Chicago-Detroit and Portland-Seattle corridors, an IPT system would in most circumstances yield negative NPVs. Under certain conditions (e.g., no fuel shortage, and system starting operation in 1975), these negative NPVs would have magnitude greater than that of the discounted initial investment. This means that, in this analysis, revenue was insufficient to cover operation and maintenance costs over at least the early portions of system life.

These results notwithstanding, prospects for an IPT in the Chicago-Detroit and Seattle-Portland corridors may not be entirely bleak. According to Table 5-11, IPT systems in these corridors beginning operation in 1985 would have zero or positive NPV under conditions of high fare, favorable public attitude, and high fuel cost.

TLV

A TLV system between Washington and Boston, beginning operation in either 1985 or 1995, has a strongly positive NPV, given a projected demand of 40 million annual passengers in 1985.

In the Portland-Seattle corridor, a TLV system yields a negative NPV under even the most extreme circumstances. This is consistent with the breakeven analysis of the previous section, which showed that a TLV demand was required for breakeven equal to more than twice that expected for all modes for Portland-Seattle.

The California corridor appears to offer future potential markets for TLV. California is comprised of dense population centers undergoing rapid, channelized development. NPV estimates for a TLV system in both the entire California corridor and the San Diego-Los Angeles subcorridor are included in Table 5-12.

For the San Diego-Los Angeles subcorridor, Table 5-12 indicates a positive NPV for operation starting in 1985, in the event of a fuel shortage. If a fuel shortage does not occur, positive NPV's operations starting in 1995 would require a low (6%) discount rate.

For the entire California corridor, a system beginning operation in 1995 yields a positive NPV at 10% discount rate, assuming high fare levels and a fuel shortage.

TLV, because of its speed, could compete with short haul air service. The effect of this competition will depend on the way in which the attractiveness of the two modes varies with service frequency, and on the service policies which evolve. For example, airline service could develop in the form of very frequent service by medium size aircraft from a few major airports, less frequent service by large aircraft from a few airports or dispersed service by smaller aircraft on moderate frequency schedules among many airports. Similarly, TLV service could develop either in the form of moderate frequency schedules using variable train size to alter capacity, or variable frequency schedules using a moderate train size. For analysis, a standard scenario was assumed, in which both air and TLV frequency would grow with demand. To test for sensitivity, a second scenario was assumed in which air frequency would grow with demand, but TLV frequency would be limited to 14 round trips per day, or, roughly, one departure per hour.

Table 5-12 shows the results of NPV analysis of both scenarios and illustrates the strong influence on modal split of the convenience provided by an adequate service frequency. The variable frequency cases correspond to one departure every 15 or 20 minutes, yet this is sufficient to alter a non-viable or marginally viable system (at one departure per hour) into one which can be expected to operate at a substantial profit.

Net present values were calculated for the TLV system in the California corridor using discount rates of ten percent, as prescribed by OMB, and six percent as a sensitivity test. The results show that a system operating between San Diego and Sacramento, and starting operation in either 1985 or 1995, could operate at a profit, given high fare and high fuel cost, if a discount rate of 6% were applicable. Profitable operation is also indicated at a 6% discount rate for a system starting in 1995, under conditions of low fare and high fuel costs. Because of the very large cost involved in TLV right-of-way and guideway in California, both a detailed on-site study and reliable unit cost-performance data are essential before implementation decisions are reached.

Additional Considerations

The NPV estimates have been made on the basis of demands derived explicitly for two assumptions regarding the potential shortage of petroleum, as reflected in increases in petroleum prices. The "base" assumption, more conservative though not necessarily more likely, is that the relative price of petroleum will not change. The alternative assumption, indicative of a petroleum shortage, is that prices will increase to 300% of their non-shortage values. In effect, this might be termed a "manageable" level of shortage, under which the normal supply-demand relationship could still apply. Note, however, that the shift away from the higher fuel-consuming auto is moderate even at triple the fuel cost. Thus, if fuel were in truly critical supply, price would be likely to continue to escalate. Analysis of such severe crisis conditions is complicated by two factors: (1) the total demand would be likely to decrease from the projected levels if the price of travel were to rise too far; and (2) some form of external government action in the form of fuel rationing or travel restrictions would be likely to take the place of the supply-demand marketplace relationships.

CHAPTER VI

INSTITUTIONAL FACTORS

Evaluation of new transportation systems necessarily deals with their effects at some point in the future. The cost analyses of the previous chapter consider the investments needed in the future to implement the physical plant and the costs of its operation at some time still further in the future. We cannot, however, in the total evaluation neglect those legacies from the past which, while not necessarily physical, are just as real as rivers to be bridged or tunnels to be dug. From the standpoint of difficulty in solution, problems with union work rules, ICC regulations or public image may constitute just as much a barrier to the HSGT system as a river and may be considerably more difficult to reduce to a monetary cost estimate.

For discussion purposes, we use the term "institutional" to refer to those factors which arise out of long usage, custom, past legislation, etc., which have become accepted today and might continue into the future. To be institutionalized, a factor need not be explicit as in a union contract or a regulatory statute; public attitudes or "folk lore" may be just as firmly entrenched. The point is that such factors do exist and can act as a constraint to any form of change.

As it is used in this chapter, a "constraint" is any factor which acts as an impediment to the implementation of a transportation system. There is no value judgment implied concerning whether constraints are "good" or "evil", valid or invalid. The general public's misconception about a system may be a constraint to its implementation; so is their reluctance to commit additional land to transportation systems. Misconceptions may be changed by information, but land use desires may be firmly rooted in value systems and life styles.

Constraints are not exclusively factors to be altered, ignored or subverted nor are they solely factors that are unalterable; they are, in fact, of both types. The political process ultimately decides which are which. Planners and policy makers are faced with the task of estimating what form the constraints of the future will take, how they will be affected by the political process, and what the combined effect will be for transportation systems.

This chapter is concerned with a discussion of the major societal and financial factors which are felt to be most critical to the success or failure of HSGT systems. Also to be included in the final version of the report is an important operational consideration -- the potential interference between high-speed IPT service and slow speed freight and commuter traffic. The specific factors being considered are listed below in their order of presentation.

A. Public Attitudes
B. Land Use and Availability for Right-of-Way
C. Financial Considerations
D. Management Structure
E. Labor Relations

A. PUBLIC ATTITUDES

The ultimate decision regarding which alternative HSGT systems will come to fruition will depend partially upon the attitude of the general public. An individual's opinion will be based on two major sets of factors: (1) those influencing his choice of high-speed ground transportation as a direct consumer of transportation services; and (2) those non-user factors which determine the desirability of HSGT relative to other transportation alternatives and to the total allocation of resources.

While the issue of modal choice is frequently thought of in terms of travel time, fare and convenience, other factors will influence the consumer's decision. These factors include the heavy dependence of today's traveling public on the automobile (87 percent of all intercity travel in 1970) and on aviation (9 percent of all intercity travel in 1970).[1] The notion that the automobile is a symbol of the American way of life should not be dismissed lightly. The privacy, personal image, flexibility, and perceived low costs are all factors which contribute to the large comparative advantage of the automobile. For aviation, the combination of speed, fare, and the airlines' image of trying to pamper the passenger has resulted in the rapid growth of aviation's share of the common carrier transportation market. If the intercity HSGT systems are to achieve widespread consumer acceptance, they must succeed in providing very desirable types and levels of service.

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[1] Transportation Association of America, Transportation Facts and Trends, April 1971.

A problem which must be overcome if widespread acceptance of any HSGT system is to occur is the existing image of passenger train travel now embedded in the minds of the public. Only a few of the older travelers remember the "crack" trains. More recent experience with poor scheduling and reliability, lack of amenities, uncleanliness, and poor terminal facilities has developed a bias which may be difficult to overcome. AMTRAK is making a conscious effort to improve the image of passenger rail service and there is evidence that it's trains, particularly the Metroliner and Turbotrain, are making progress in this direction.

The fact that AMTRAK is operating at a continuing loss may have an additional impact on the public image of passenger rail transportation. On the one hand, AMTRAK deficits may tend to confirm the impression of passenger rail travel as a "loser" and discourage potential travelers from selecting the mode. As a related effect, the public's reservations against supporting more expensive HSGT systems would probably become stronger on the assumption that these systems would result in greater deficits requiring increased subsidies through tax dollars. On the other hand, the potential for erasing or significantly reducing the overall deficit in passenger train operation offers a counter incentive to the public to support improved HSGT. Widespread backing on this basis would of course require public credence that IPT or TLV can replace losing operations with those that pay their way.

The degree to which the public will approve of HSGT systems is, and will continue to be, closely identified with public opinion on environmental and resource issues. At the present time there is growing public awareness of "the energy crisis" and high public awareness of the environmental consequences of transportation, particularly of aviation and the automobile. Successful planning for and publicizing of the development of HSGT systems must deal with these concerns in a highly visible and positive manner. Public support for any HSGT system will be related to the degree to which the systems overcome the environmental and resource constraints relative to existing competitive modes. For TLV systems, or any system needing major public investment, a true and urgent need must be demonstrated (e.g., a critical reduction in air pollution or in congestion) before acceptability can be expected.

Concern for open-space preservation, natural beauty and other aesthetic considerations are also significant aspects of the general public's acceptance of new transportation systems. As in the case of new highways, community residents can reasonably be expected to protest about HSGT structures on new rights-of-way which could sever a community, disrupt established land patterns and mar the natural beauty of an area. IPT's use of existing rail rights-of-way, with minimal land required for curve straightening, should prove acceptable in this regard. To the extent that TLV cannot use existing rights-of-way and requires new land, opposition to TLV deployment can be expected on grounds of alternative land uses, open space preservation, and aesthetic considerations.

While the problem of land acquisition is virtually non-existent for IPT, the location of existing rail rights-of-way through the center of many small towns could create problems. High-speed trains running at grade level through these communities might create active opposition by residents. Some incidents which could elicit adverse community action might be avoided by early work with the communities to keep them informed of proposed plans and developments. Perhaps even more important will be the pre-recognition of community hazards to avoid accidents which could evoke strong public opposition.

The general public as taxpayers is also concerned with any new system which requires a large amount of Federal funding through the R&D, implementation and quite probably the operational phases. Support for heavily subsidized systems, which are objectionable to many taxpayers despite possible long term benefits, will be difficult to obtain, since the expressed needs of the public usually translate into immediate requirements for quick and seemingly simple solutions.

Taxpayers individually are not concerned about "transportation systems", but about the particular segment of the system which impacts them: traffic jams which slow their commute to work; the lack of mass transit which hinders them from holding jobs far from home; accidents which injur their kin and raise insurance costs; highways, airports, etc., which destroy property values; and exhausts which foul their air. Aware though they may be that these irritations are systemic, they demand immediate relief rather than programs with system payoffs years later.

Public acceptance then is a potential problem for both IPT and TLV systems if heavy funding is required from the Federal government and if these systems do not show a clear possibility of payback. To the extent that private funds, Federally guaranteed loans or other payback concepts could be arranged, acceptance of either system would tend to improve. For funding of these new systems to gain political acceptability, they must either give the hope of competing economically with alternative modes or at least not require unduly heavy new subsidies.

In summary, the public's attitude toward new HSGT systems will be influenced by some factors under the control of DOT such as:

- o The success of R&D in overcoming environmental and resource (primarily land and energy) constraints;

- o The success in publicizing the relative significance and worth of HSGT in alleviating future environmental and/or resource crises;

- o The avoidance of any early incidents which might spark public disapproval;

and by other factors beyond the control of DOT such as:

- o The degree to which an energy crisis develops that severely restricts the use of petroleum;

- o The degree to which air congestion and highway congestion grow and contribute to delays and inconvenience for air and auto travelers;

- o The degree of success of the AMTRAK experiment over the next few years;

- o The willingness of possible investors to participate in financing of new HSGT systems.

B. LAND USE AND AVAILABILITY

Perhaps the most significant and pervasive institutional factor which requires consideration is the issue of land. It becomes the most significant issue when viewed from the perspective of availability of land for HSGT systems requiring new rights-of-way. At the same time, the effects which HSGT system implementation could have on current and future land use patterns also affect the social and political acceptability of the systems. To deal adequately with land as a factor in HSGT implementation, both of these aspects require detailed examination.

The taking of land for public transportation facilitites has met with increased resistance by the public at large. There is reason to believe that land use in the future is likely to be the most serious institutional obstacle to the development of new transportation systems. Community opposition to airport expansion and new airport site selections have become commonplace news. Highway and freeway projects have been stopped by concerned citizen groups not only in urban areas but in sparsely populated areas as well.

Land in relation to a HSGT transportation system involves two principal uses: terminal facilities for servicing traffic entering or departing the system and right-of-way for transport between terminals. Rights-of-way can be placed in two general categories; joint-use and exclusive-use right-of-way. The first type is characteristic of IPT service operating on existing rail along with freight and conventional commuter trains. Exclusive-use routes are typified by TLV where no other mode shares the facility.

In evaluating alternative HSGT systems, it is necessary to determine the number of acres required to implement the service as well as the value of the property taken. Land for new or expanded systems usually is not taken from a featureless plain. Considerations of topography, current land use, climate, and many other factors must be linked to a specific geographical region to draw more than the following general conclusions concerning the relative importance of land requirements in new transport technologies.

To be economically viable, higher cost TLV systems require more passengers than IPT. Consequently, the market (city pairs) for TLV systems must be situated in areas of high population density where land is most difficult to acquire and where there is increasing competition for alternative uses of this valuable resource. At the same time, however, it is a virtual certainty that railroad rights-of-way exist in these markets and that compatible land use patterns have already been established along their rights-of-way and around the terminal areas. New service over existing tracks may be limited in speed and hence performance but can operate over land already committed to rail operations and hence should not encounter any significant community resistance in terms of land-taking. Varying resistance to the straightening of existing rights-of-way for IPT can be expected depending on the degree of straightening, while construction of a new fixed guideway for TLV would generate the strongest community opposition due to its large land impact.

C. FINANCIAL CONSIDERATIONS

General

The present financial condition of the nation's railroads makes it imperative that any planning for new rail systems include detailed emphasis of financial considerations. Six of the nation's 69 Class I railroads -- the major companies that account for 99% of rail traffic -- already are bankrupt. The Interstate Commerce Commission has listed more than ten others as "marginal", meaning that they could go bankrupt in the near future. Railroad industry net income in 1971 totaled $355 million, or 2.7% of revenues -- and much of that came from non-railroad operations. This situation highlights the problems of financing system operation versus the issue of financing capital outlays related to system development and implementation. In some cases, the costs of maintaining existing rights-of-way, including the payment of property taxes, has drained revenues needed for improvements. Financial mechanisms proposed for HSGT systems must therefore adequately address these and other issues if any proposed HSGT implementation is to be successful.

There are two fundamental issues: (1) the relative degree of involvement by the government and the private sector in financing a HSGT system, and (2) the extent to which the system would be expected to pay its own way. Clearly the involvement of private capital will be determined by expectations of potential profitability which is a function of total dollar costs, the time frame of cost and revenue streams, as well as the degree of risk and uncertainty associated with system development and operation. Under present conditions, the financial position of the railroad industry makes it appear unlikely that any new rail system could ever be developed without substantial federal support. Since rail passenger service has been pointed out by the industry as a major contributor to the poor financial performance of the railroad industry, private investors may be somewhat reluctant to re-enter a market which has been unprofitable for so many years. On the other hand, several recent developments seem to justify the expectation of private support. The auto-train linking Florida with the Northeast represents a successful rail venture backed by private capital. Penn Central's investment in the Metroliner is another example of private capital made available for improved rail service. If the recent financial performance of the Metroliner can be maintained and broadened, the bias of private investors against financing passenger rail service may be considerably reduced.

Funding the capital outlays for new guideway construction (TLV) or improvement to existing ROW's (IPT), land purchases, and other infrastructure development will all require sizeable financial resources, and assistance probably must come primarily from the Federal government, if implementation is to be accomplished. With regard to operations, partial subsidization could be required for all HSGT systems initially.

Methods of Financing

What are the mechanisms which could be used for procuring the necessary financing in the public and the private sectors?

A possible means of assuring adequate Federal funding would be through a trust fund arrangement to encourage the funding of alternative modes of transportation to take into account local as well as national considerations. "Single-mode trust funds are inflexible and prevent sensitive use of budgeting to achieve changing objectives. . . . There are valid questions to be raised relative to taxing a given mode to support development of another, but it is more demonstrably true today that inflexible re-investment of tax revenues from a highly viable mode to support further development of that mode tends to lead to imbalances in total transportation development."[2]

It is noteworthy that such an approach has been proposed in Congress and endorsed by Secretary Volpe. In testimony before a Senate subcommittee on September 7, 1972, the Secretary stated that amendments to the proposed Federal-Aid Highway Act of 1972 "should provide that funds authorized for the Federal-Aid urban system be available for the acquisition and construction of rail transit facilities and equipment, as well as the highway projects. . ."[3] Earlier in 1972 the Secretary, with Presidential approval, had "recommended to the Congress that the Highway Trust Fund become the sole source of Federal financing for both highway and mass transit programs."[4]

There are other forms of government assistance not involving large transfers of funds, but which serve to increase the availability of private funds for projects requiring large capital outlays. The Federal government, for example, could provide loan guarantees to help finance both implementation and operation and thereby facilitate investment by the private sector in HSGT systems. Private investors

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[2] Some Impacts of Civil Aviation and Implications for R&D Policy, prepared by the Program of Policy Studies in Science and Technology of the George Washington University for the joint DOT/NASA Civil Aviation R&D Policy Study, September, 1971.

[3] Department of Transportation News Release, Office of the Secretary, September 7, 1972, DOT-79-72.

[4] Ibid.

react similarly if tax provisions and/or depreciation rules favorable to HSGT systems were enacted.

There are useful precedents and elements in the AMTRAK concept. The government could share the expenses with the private sector and leave the operation of the system to a quasi-public management structure.

The Federal government could finance directly or provide loan guarantees[5] to finance R&D, the right-of-way and its improvements, and allow the private sector to invest in the operation and maintenance of the HSGT. Private investors may be attracted, particularly if the Federal capital investment indebtedness is forgiven unless and until the HSGT operation achieves a reasonable profit. Once the predetermined profit level is surpassed, payback to the Federal government of its investment would begin under a formula that ensures continued reasonable profit levels. Such a financing concept is analogous to that used by a number of European governments in supporting their aerospace industries in competition with the U.S. aerospace industry. For example, the French and German governments have committed $433 million to the development of the A-300 B airbus and have pledged to guarantee another $820 million to $870 million in bank loans to finance initial production. The break-even point for the aircraft is 250 units to recover the development cost. At 360 aircraft, the French and German governments start receiving repayments of their subsidies.[6] As another example, of $175 million committed to date for the development of the short-haul jet transport VFW-614,

[5] In this connection, it may be noted that the proposed Surface Transportation Act provides for loan guarantees to the railroads.

[6] Analysis of U.S. Leadership Position in World Civil Aviation, by PRC Systems Science Company and SYSTAN, Inc., for National Aeronautics and Space Administration, NASA Report Number 114, 449, April 1972.

most has been in the form of subsidies and credit guarantees by the German and British governments. First deliveries are expected in 1973-74; the break-even point is estimated by the company at 175 aircraft and repayment to the governments begins in 1980.[7]

In addition to issues of financial structure, there are also questions of alternative feasible means of providing specific financial incentives once the basic structure has been agreed upon. Debt issues could be tax-exempt, taxable, or taxable but qualifying for interest rate subsidies to be provided by the U.S. Treasury. This latter device allows for a reduction in the cost of raising the required capital but would not necessarily impose a net drain on the U.S. Treasury since taxes levied by the Treasury on interest income from taxable bonds could generally equal the subsidy paid by the Treasury to the borrower of these long-term funds. Many economists believe that taxable debt with interest rate subsidies is an efficient and equitable means of providing Federal financial support to borrowers. There is also some interest by the U.S. Treasury in this approach, at least as a possible alternative to tax exempt bonds or loan guarantees.

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[7] Ibid.

D. MANAGEMENT STRUCTURE

The question of management structure is closely tied to the financial considerations discussed above. From those discussions, it is clear that there will be substantial Federal involvement of some form at least for the initial funding. The Federal involvement may take any of the forms noted in the previous sections. Given this fact, there is a question both of how to manage capital improvements, and how to operate and maintain the systems. Two separate management structures may well be required for these two facets.

An organization for making HSGT capital improvements would be expected to lease existing roadbed from railroads or acquire new right-of-way, raise funds for improvements and perhaps vehicles through one or more of a number of financing concepts discussed previously, contract for construction and maintenance of the right-of-way improvements, and establish and collect user charges related to right-of-way improvements.

Organizational alternatives for managing these improvements include AMTRAK and a national passenger track improvement corporation.

Organizational alternatives for operating the system can span the range from private involvement to a fully nationalized system. Separation of implementation and operations makes it easier for the private sector to participate in the financing and management of the operating system if there is evidence of profitability.

One of the problems in effectively organizing and managing HSGT implementation is that of dealing with a high degree of fragmentation of responsibility. In the Northeast Corridor, ten states plus the District of Columbia and well over a dozen major regional agencies have responsibility and authority for transportation planning and investment. In addition, hundreds of local government agencies are involved. Even if the Northeast Corridor situation is more complicated than that of other regions, it would appear that the task of designing and establishing an effective management structure is a formidable one.

However, there is no evidence that any of the considerations discussed in this section would constitute an insurmountable barrier to implementing either of the HSGT alternative systems.

E. LABOR RELATIONS

The introduction of new transportation systems such as TLV and the attempts to improve existing systems, such as IPT, are likely to pose a number of labor problems with regard to crew composition, work rules, wages, and union jurisdiction over segments of the work force. In recent years, innovation and changes in these areas have been exceedingly difficult for the railroad industry but some improvement in this situation is observable at present.

Whether, in fact, labor would put major institutional roadblocks in the way of fixed guideway systems is doubtful. It is more likely that labor demands would pose a problem in the actual operation of fixed-guideway systems rather than in the implementation of systems.

For HSGT, the labor question can be examined from the perspective of management structure (i.e., private railroad company, AMTRAK, or a fully nationalized rail industry) or from the perspective of degree of system innovation (IPT or TLV).

As discussed in the preceding section, an organization with at least as much government involvement as AMTRAK is the most likely structure to manage HSGT systems. To the unions, however, AMTRAK appears essentially as just another railroad company. Current rail labor relations should be expected to continue since existing rail unions will most likely claim jurisdiction over HSGT operations. This is particularly true of the IPT system, with its use of existing roadbeds, present technology and a strong identification with current rail operations. The TLV systems imply a major advance in technology and less identification with current rail operations, but it is an open question whether this fact would provide a basis for establishing new rules with labor unions and redefining craft jurisdictions.

A new organizational structure or the introduction of a new system sometimes offers an opportunity to reach a new understanding with labor in labor-management relations directed at increasing job opportunities through expanding the market (in this case, lowering the costs by means of more efficient operations so as to create a greater demand for HSGT).

A policy promoting increased labor-management cooperation is likely to be especially important in any corridor(s) where competition with other transportation modes is especially keen and the balance between cost and revenue is delicate, in that union demands could become a decisive factor in the success of HSGT operations.

CHAPTER VII

CONTINGENCIES

This chapter discusses energy shortage and air congestion - the two developing U.S. problem areas which are of considerable relevance to any evaluation of the IPT and TLV systems as high-speed ground transportation alternatives.

A. ENERGY SHORTAGE

This section is devoted to a review of the current and future energy situations confronting the U.S., and to the formulation of energy forecasts for three time periods:

- Short term - now to late '70's
- Mid term - late '70's to mid '80's
- Long term - mid '80's to 2000

Three forecasts are presented for each time period. A "most probable" forecast is emphasized, while "most pessimistic" and "most optimistic" variations are given as extremes.

The impact of impending energy problems on modal patterns of transportation in general, and the relevance of these situations to evaluation of the IPT and TLV systems in particular, are analyzed.

For the sake of clarity, the material in this section is presented according to the following outline:

- Summary of Energy Trends
- Impact on Modal Patterns of Transportation

- Relevance of Energy Trends to IPT and TLV Applicability
- Detailed Analysis of Energy Trends

Summary of Energy Trends

The significant features of the most probable U.S. energy trends for the next 20- to 30- years can be summarized by time frame:

In the short term (now to late '70's):

- Shortage in U.S. refinery capacity, causing refined petroleum product prices to rise rapidly, perhaps as much as 50% over the next 3 years.
- Electric power shortages, aggravated by nuclear power plant delays.
- Growing dependence on foreign fuel sources (especially petroleum), but without significant crude oil cost increases.

In the mid term (late '70's to mid-'80's):

- Gradual introduction of synthetic petroleum and gas.
- Gradual relief of both the refinery and electric power shortages, with electric power supply just catching up with rising demand by the end of the period.
- Substantial rise in petroleum prices, now more dependent on crude costs than on refining costs, with crude costs reaching 2 or 3 times current levels by 1985.

In the long term (mid-'80's to 2000):

- Availability of abundant electric power, with fast breeder reactors predominating among the capacity additions; thermonuclear fusion plants may reach the demonstration stage.

- Significant use (10-20% of all fossil fuels) of "synthetic" fossil fuels (e.g., gas and oil from coal, oil from shale) especially in pipeline gas and as transportation fuel for fleet systems. Cost will be comparable to natural petroleum products during this period.
- Introduction of a hydrogen economy in selected urban areas toward the end of the period.

In essence, the short term represents an energy crisis period; the mid-term will be the transitional period leading to the long term stable energy situation based on abundant, clean electric power which may be stored, transported, and used in mobile systems and in stationary total energy systems in the form of hydrogen.

In the most pessimistic case, the energy crisis might continue into the mid- and long terms with electric power remaining scarce and synthetic fuel processes failing or turning out to be environmentally unacceptable; hence, there would be no hydrogen economy, and the liquid fossil fuel shortage may become acute because of inadequate refinery capacity and/or curtailment in delivery of foreign crude. Fuel may become rationed, and gasoline costs would exceed $1.00 per gallon within the short term.

In the most optimistic case, the short-term energy crisis might be eased with rapid increases in refinery capacity. Commercially successful development of synthetic fuel processes would stabilize petroleum costs through the mid-term at roughly twice the current level. Nuclear-based electric power would become abundant and low cost by the end of the mid-term, and the introduction of the hydrogen economy would be realized.

Impact on Modal Patterns of Transportation

To illustrate the impact of energy trends on U.S. transportation, the effect of the most probable forecast in the short and long terms will be considered (the mid-term period will merely see a transition between the short and long term transportation situations).

As part of the reaction to increasing cost and scarcity of petroleum, the interaction between buyers and sellers of transportation services might very well develop as described below:[1]

- Through the 70's (the short term), petroleum products cost will increase, perhaps substantially, while electric generating capacity remains in tight supply. The owner of the private automobile, already under pressure from the cost of anti-pollution and safety devices and their attendant lower gas mileage, would face, in addition, a fuel price rise. Since fuel is a major perceived cost item in automobile operation, particularly for longer, intercity trips, some auto intercity demand would tend to shift to less expensive modes.

  - bus and rail, for which fuel is a smaller part of the total price would become comparatively more attractive in a period of rising auto operating costs, although some increase in common carrier fares might be expected. For passenger trains, fuel cost increases might initially be offset by higher efficiencies in new engines and lighter rail cars of an improved passenger train. Busses might be developed in larger sizes to offset rising fuel and labor costs and to provide capacity for increased demand.

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[1]The OEP study of "The Potential for Energy Conservation" (Footnote 8) suggests that substantially the actions described here, e.g., "a shift of intercity freight from trucks to rail, intercity passengers from air to rail and bus, and urban passengers from automobiles to motorized mass transit," are among the most significant energy conservation measures that might be considered for adoption as policy.

- oo air travel, in which fuel makes up about 10 percent of the present ticket price, would experience a moderate fare rise, probably not sufficient to discourage the demand for time-important trips. The stronger impact would fall on fares for long-haul air trips for which no adequate substitute mode exists. Thus, the overall impact on air demand would be small.

- oo medium- and long-haul freight might tend to shift from truck to rail since fuel costs make up a higher fraction of trucking prices than of rail freight costs. However, labor costs make up such a large portion of truck costs that small changes in labor rates over the time period might overshadow fuel cost changes.

- oo the automobile industry would tend toward production of smaller, less powerful cars to offset both fuel costs and pollution regulations. The net effect would be a car less attractive for long distance travel, resulting in a further shift away from auto for intercity trips. In addition, the efficiency of urban use of fossil-fueled autos might be greatly improved through incentives for such energy-saving concepts as car pools, staggered work schedules to minimize traffic delays, and improved automotive propulsion systems that operate more efficiently at low speeds typical of urban driving. If urban air quality regulations are strong, short range battery powered electric cars might be introduced, perhaps for rental fleets in urban areas.

- o In the late 80's and the 90's (long term), petroleum (natural and synthetic) will be available, but expensive (3 or more times current cost). At the same time, the successful development of breeder or, possibly, fusion reactors for power generation might overcome the shortage of electric power and make that form of energy relatively plentiful.

- oo because of high fuel costs, private auto travel on intercity trips would be greatly reduced, except possibly for family outing and vacation trips in heavily loaded cars. Major shifts would occur to those modes which were not as fuel limited. Urban auto travel would be largely by electric car, primarily because of petroleum costs, not energy savings, since electric cars and mechanically powered cars have comparable overall efficiencies. The strong desire for the personal mobility provided by the auto will provide sufficient market pressure to ensure the adequate supply of automotive fuel but at the high cost levels forecast.

oo rail on high density lines would move strongly to electrification for both freight and passengers, since the presence of a cheap power source might offset the cost of electrification. The large potential increases in rail demand for both passenger and, to a lesser degree, freight could over-reach the capacity of many of the present lines.

oo bus and truck might be judged essential for connectivity along routes not covered by rail. Units would tend to be larger and engines smaller, leading to lower over-the-road speed.

oo car-on-train and truck-on-train could assume a larger importance in long distance travel.

oo dual mode intercity highways using high-speed pallets for the urban electric cars could be introduced.

oo aircraft, because of their high fuel consumption, would encounter special difficulty in a time of high fuel costs. The larger aircraft associated with long-haul might be adaptable to some form of nuclear power plant or might be able to use other fuel sources. Air travel prices would rise, because of higher fuel costs, and demand would fall below present projections; but little modal shift from long-haul air could be expected.

oo short-haul air, using smaller aircraft, might not be able to switch from petroleum fuels and might be forced to raise fares along with petroleum prices. Air trips tend to be those considered important by the travelers, however, and the trips would probably still be made whether or not an adequate substitute mode were available.

oo in the event of direct fuel rationing, private auto and short-haul air would be most likely to be affected since both are high consumers of fuel and adequate alternate modes would exist for many city pairs.

oo TLV as a high-speed, electrified ground mode would be the logical alternative to short-haul air. At 300 miles per hour, TLV could be competitive to air over-all trip time out to a distance of 300 or more miles. The saturation of many rail lines from the influx of auto diverted passengers and truck-diverted freight would necessitate new right-of-way and guideway construction in any case. If new guideway were constructed, a logical step would be to make it for very high-speed TLV and expect it to carry both the long distance rail passengers and the air-diverted traffic. The rail might then concentrate on lower speed local traffic more compatible with the freight traffic speeds.

Relevance of Energy Trends to IPT and TLV Applicability

Finally, it is appropriate to consider how IPT and TLV systems can be substituted for less energy-efficient modes (e.g., auto and air) in future U.S. energy shortage situations.

For the most probable energy trends, IPT offers the following:

- o More efficient use of the increasingly tighter supply of petroleum than is possible with the intercity automobile.

- A capability to use the lower grade refinery products which might not suffer as much from a refinery capacity shortage as would gasoline.

- A system which, because of its on-board power supply, offers more routing flexibility and independence from presently overloaded electrical power grids.

- Provision for subsequent operation on hydrogen fuel or synthetic petroleum, whenever either becomes readily available.

Within a 10- to 15-year time frame, for the most probable energy trends, TLV offers a technological alternative to short-haul air systems; TLV uses less energy per seat-mile than does short-haul air, and, by virtue of operation on electric power (which by the end of the mid-term, is no longer in short supply) is adaptable to any basic heat or energy source.

For the most pessimistic energy trends, IPT would become vitally important for short-haul intercity trips in the short and mid-terms as demand for automotive fuel is not met and the electric power shortage prevents use of electrified systems (including autos) in urban areas. IPT might be given priority on petroleum use, and would thereby be in a position to pick up much of the short-haul air market. On the other hand, TLV would appear to have very little application in the most pessimistic situation because of TLV's relatively high energy consumption and because of the electric power shortage.

For the most optimistic energy trends, the pace of introduction for both IPT and TLV could be greatly slowed and would involve the following:

- IPT might be introduced in the short and mid-terms to:
  - gradually upgrade corridor systems for short-haul trips.
  - accommodate increased demand for rail service which could result from the likely doubling of automotive fuel costs.
  - avoid new highway land acquisitions.
- IPT might not find sufficient market to expand in the mid- to long time frame if automotive travel again becomes low cost (perhaps through the use of hydrogen or synthetic petroleum as abundant fuels, and the development of more efficient automotive systems).
- In the long term in the Northeast Corridor there would be a market great enough to support a TLV system, but elsewhere in the country its prospects would be much less promising.

In summary, IPT systems appear to fulfill vital transportation needs for all energy scenarios considered, with IPT's role growing more critical as the energy picture darkens. On the other hand, TLV systems seem to offer the greatest benefit as an alternative to short-haul air travel in a situation in which electrical energy is plentiful and petroleum is in short supply.

Detailed Analysis of Energy Trends

The following discussion of the energy supply-demand situation is based on what appears to be the best data immediately available. Any comprehensive survey of all recent studies of the energy problem is clearly beyond the scope of the present study. Nevertheless, there can be little doubt that problems in the supply of energy, particularly petroleum-based and electric, will occur at some point within the next few decades.

A brief general look at the overall energy resources picture is a helpful introduction to the development of near-, mid-, and long-term forecasts of energy trends. As an example of recent studies indicating the growing pressure on our finite traditional energy sources, M. K. Hubbert[2] summarizes the world energy situation to be as follows:

- The largest sources of stored energy, other than nuclear, are the fossil fuels.

- Of the initial total mineable world reserves of coal and lignite, about 1.8 percent have been consumed; the coal production peak will probably occur around the year 2150, with 90 percent of the world's coal consumed by 2300.

- Of the initial total world reserves of producible crude oil, 13.6 percent have already been consumed; the crude oil production peak will probably occur around the year 2000, with 90 percent of the world's crude depleted by 2032.

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[2]Hubbert, M. K., "Energy Resources for Power Production," Paper 1AEA-SM-14611, Proceedings of the Symposium on Environmental Aspects of Nuclear Power Stations, International Energy Agency, Vienna, 1971.

- Within the U.S.A., approximately 55 percent of the total producible crude oil and natural gas liquids have been consumed; the U.S. production peak occurred around 1970; the point of 90 percent depletion will be reached around the year 2000.

- Thirty-six percent of the initial total reserves of U.S. natural gas have been consumed; the U.S. production peak will probably occur in 1977.

- Of the energy sources likely to be commercially available within the next decade, only nuclear energy, using breeder reactors, promises to be adequate for the world's requirements for several centuries or more beyond the point of fossil fuel depletion. (This is not to say that other energy sources such as solar energy or thermonuclear fusion might not eventually become the more important as a supplier of the world's energy needs.)

A more detailed discussion of the U.S. energy trends for the next 20 to 30 years must begin with a clear understanding of where we are now. Figure 7-1, from a Lawrence Livermore Laboratory Report,[3] presents such a comprehensive picture of U.S. energy flow patterns, showing energy sources, energy consuming sectors, and energy use efficiency. In 1970, transportation consumed nearly 25% of U.S. energy. This percentage is expected to decrease insignificantly through 1990. Petroleum accounts for over 95% of transportation fuel, the remainder being natural gas used as fuel for the gas engine compressors which transport natural gas through the pipeline network. Electrical energy generation is currently almost entirely dependent on fossil fuels, coal being the largest source by far. Nuclear energy, in 1970, accounted for less than 2% of all electrical energy generation.

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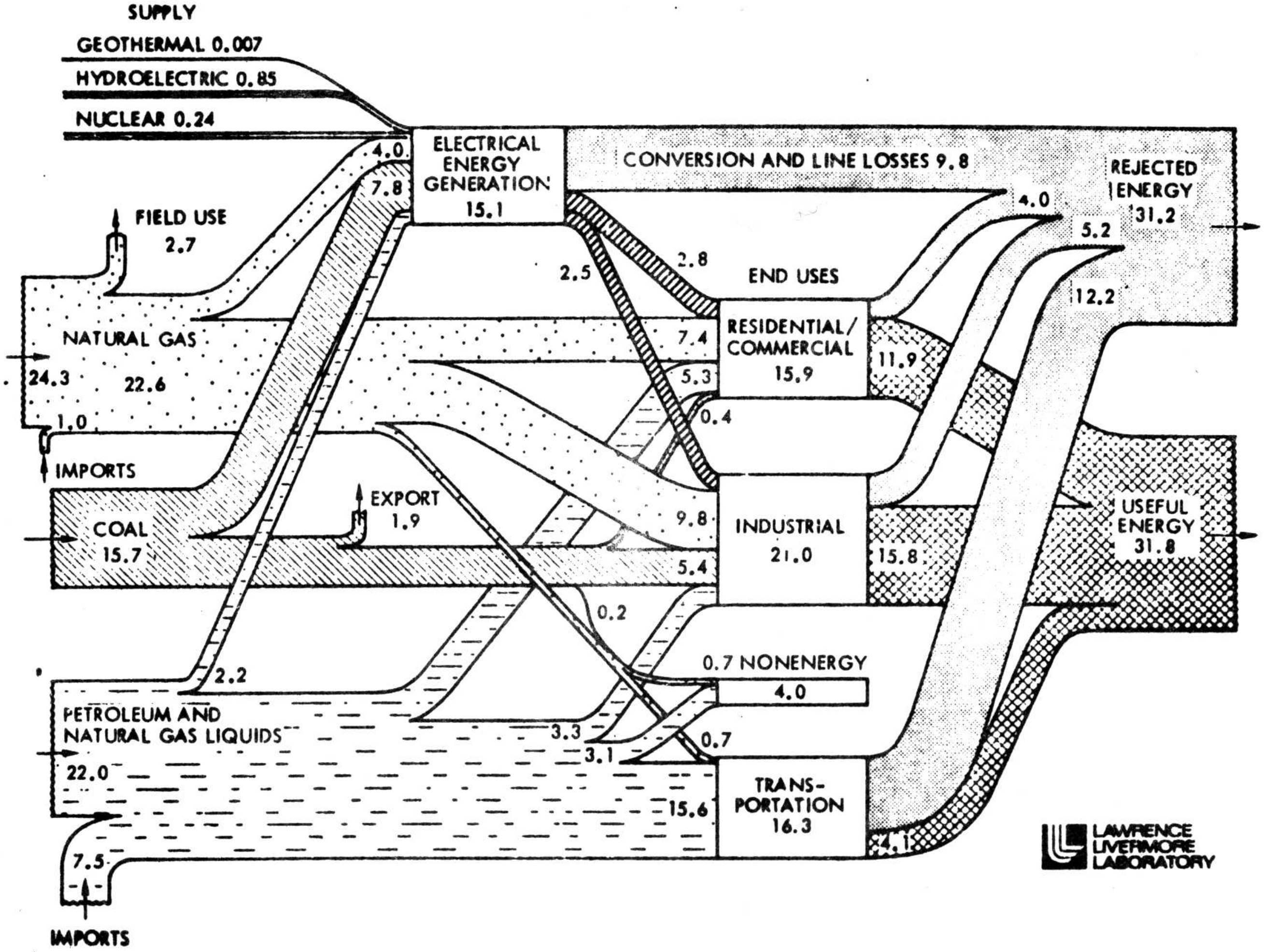
[3] Austin, A. L., et al, Energy: Uses, Sources, Issues, L.L.L. Report UCRL-51221, May 1972.



(From Energy: Uses, Sources, Issues, by A. L. Austin et al, L.L.L. Report UCRL-51221, May 1972)

FIGURE 7-1
ENERGY FLOW PATTERNS IN THE U.S.A.–1970. ALL VALUES ARE IN UNITS OF 10^{15} BTU. TOTAL PRODUCTION = 71.6 x 10^{15} BTU

Figure 7-2, constructed from data supplied by Rice,[4] the Automobile Manufacturers Association [5,6] and Hirst,[7] breaks down the transportation sector for 1970, and shows energy consumption in 1970 for each of the major transportation modes. The bulk of U.S. transportation energy (61% percent) was consumed by the automobile, while passenger rail service consumed only a negligible amount of transportation energy (.1% of the total).

A recently published study[8] by the Office of Emergency Preparedness (OEP) forms the basis for a projection of the most probable U.S. energy trends over the next 20-30 years. The quantitative projections from the OEP study, and other references as noted, are presented graphically in Figures 7-3 to 7-5 and in tabular form in Tables 7-1 to 7-3. Three projections are presented for the period 1970-1990:

- Annual U.S. Energy Consumption - by Source
- Annual U.S. Energy Consumption - by Consuming Sector
- Annual U.S. Energy Consumption for Electric-Power Generation

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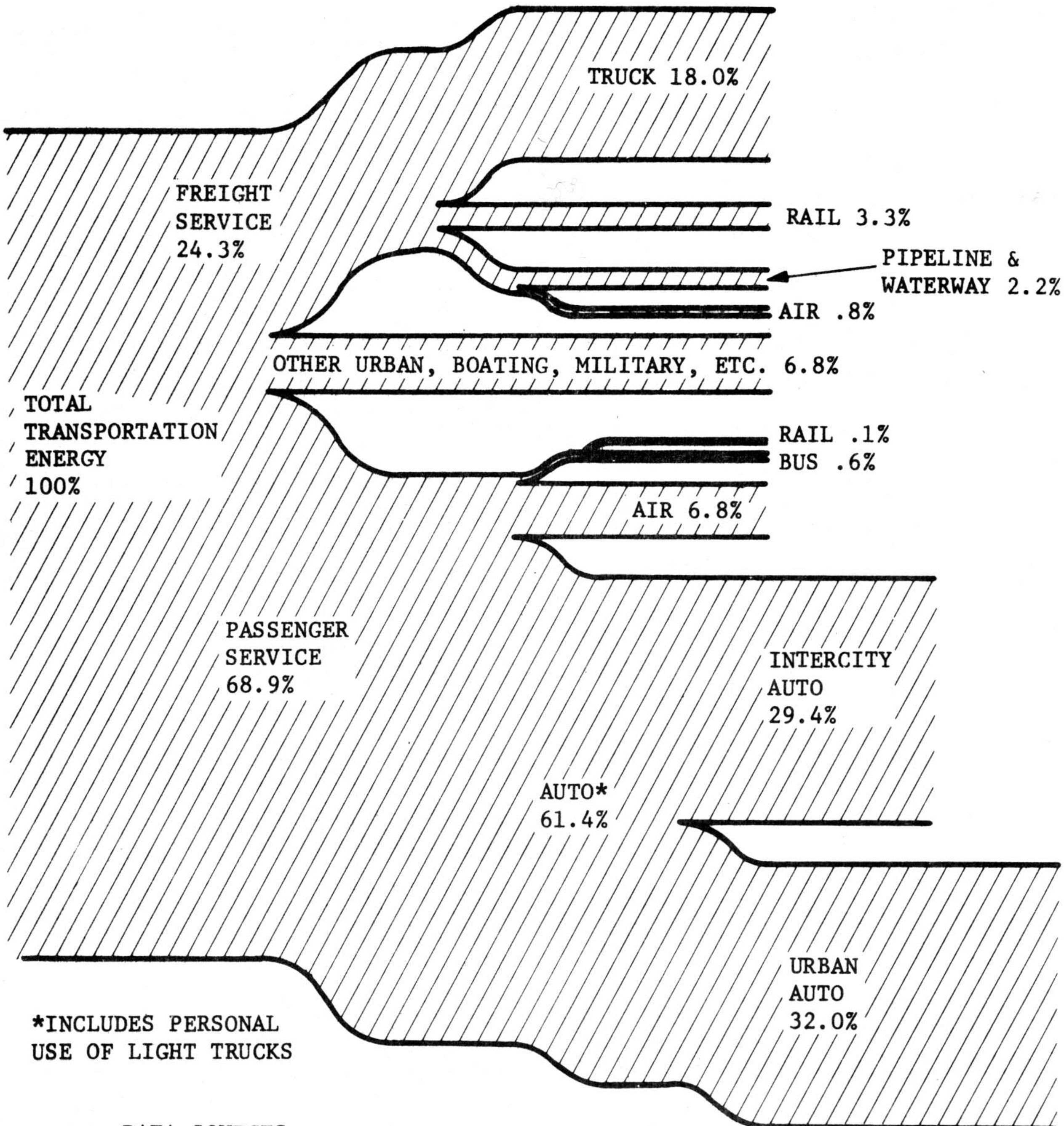
[4] Rice, Richard A., System Energy as a Factor in Considering Future Transportation, ASME Paper 70-WA/Ener-8, November 1970.

[5] Automobile Manufacturers Assoc., 1971 Automobile Facts and Figures.

[6] Automobile Manufacturers Assoc., 1971 Motor Truck Facts.

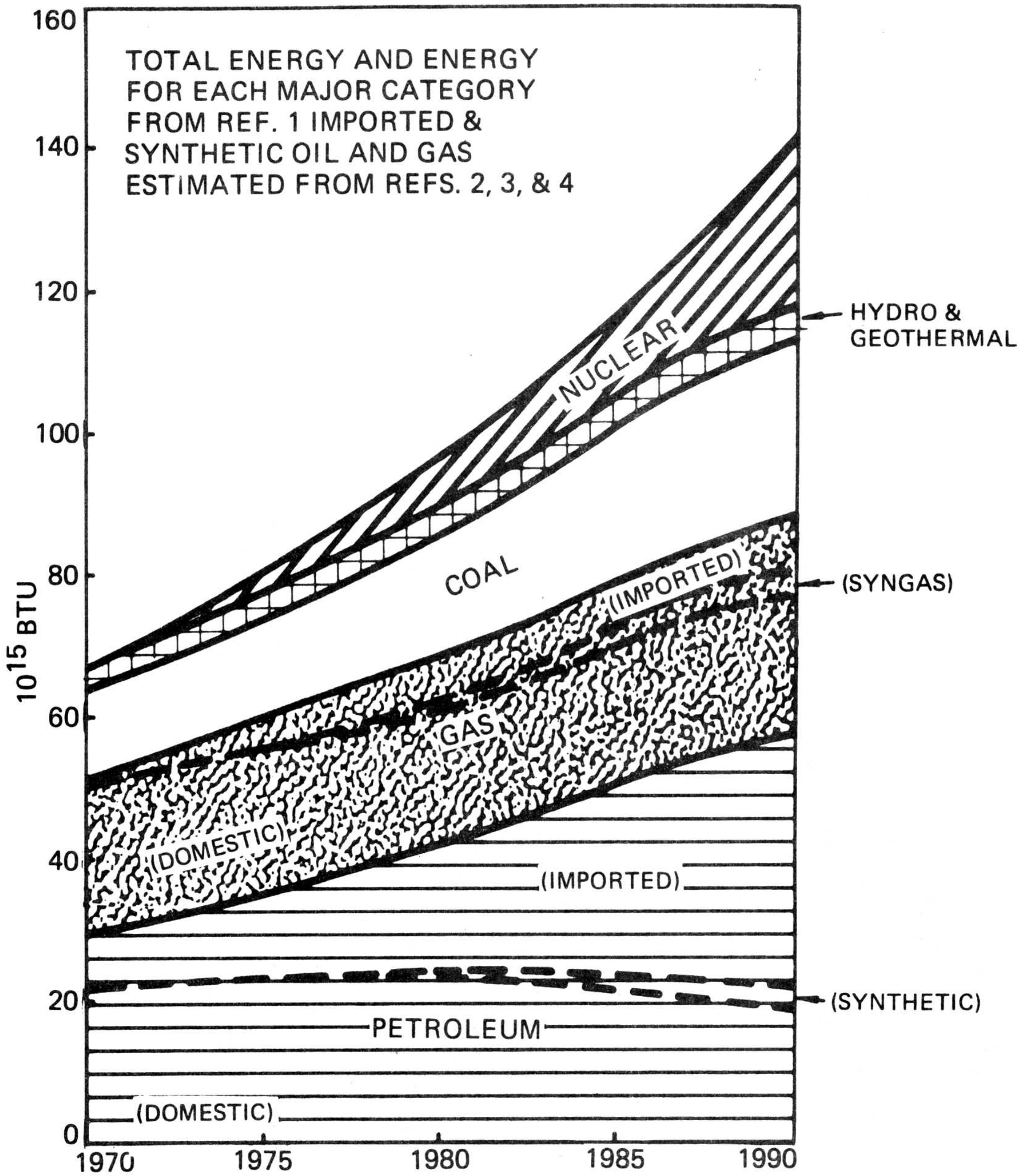
[7] Hirst, Eric, Energy Consumption for Transportation in the U.S., Report ORNL-NSF-EP-15, Oak Ridge National Laboratory, March 1972.

[8] Office of Emergency Preparedness, The Potential for Energy Conservation, October 1972.



DATA SOURCES:
- RICE 1970
- AUTOMOBILE MANUFACTURERS ASSOC. 1971
- HIRST 1972

FIGURE 7-2
U. S. TRANSPORTATION ENERGY DISTRIBUTION
BY MODE (1970)



REFERENCES:

1. OFFICE OF EMERGENCY PREPAREDNESS (OEP), THE POTENTIAL FOR ENERGY CONSERVATION, OCTOBER 1972
2. NATIONAL PETROLEUM COUNCIL, U. S. ENERGY OUTLOOK: AN INITIAL APPRAISAL 1971-1985, JULY 1971
3. AUSTIN, A. L. et al, ENERGY: USES, SOURCES, ISSUES, LAWRENCE LIVERMORE LABORATORY REPORT UCRL-51221, MAY 1972
4. SHELL OIL CO., THE NATIONAL ENERGY POSITION, FEBRUARY 1972

FIGURE 7-3
ANNUAL U.S. ENERGY CONSUMPTION—BY SOURCE

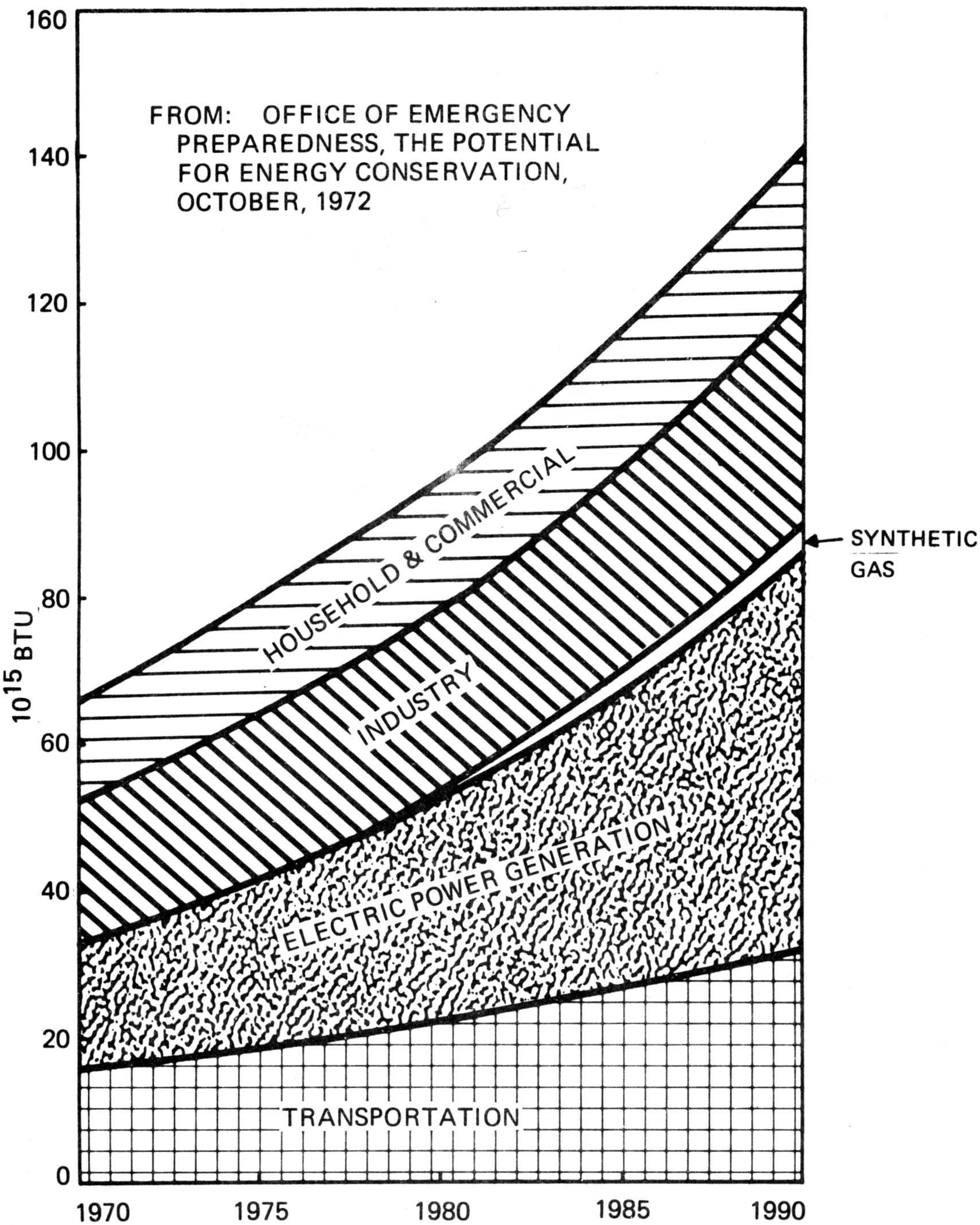


FIGURE 7-4
ANNUAL U.S. ENERGY CONSUMPTION BY CONSUMING SECTOR

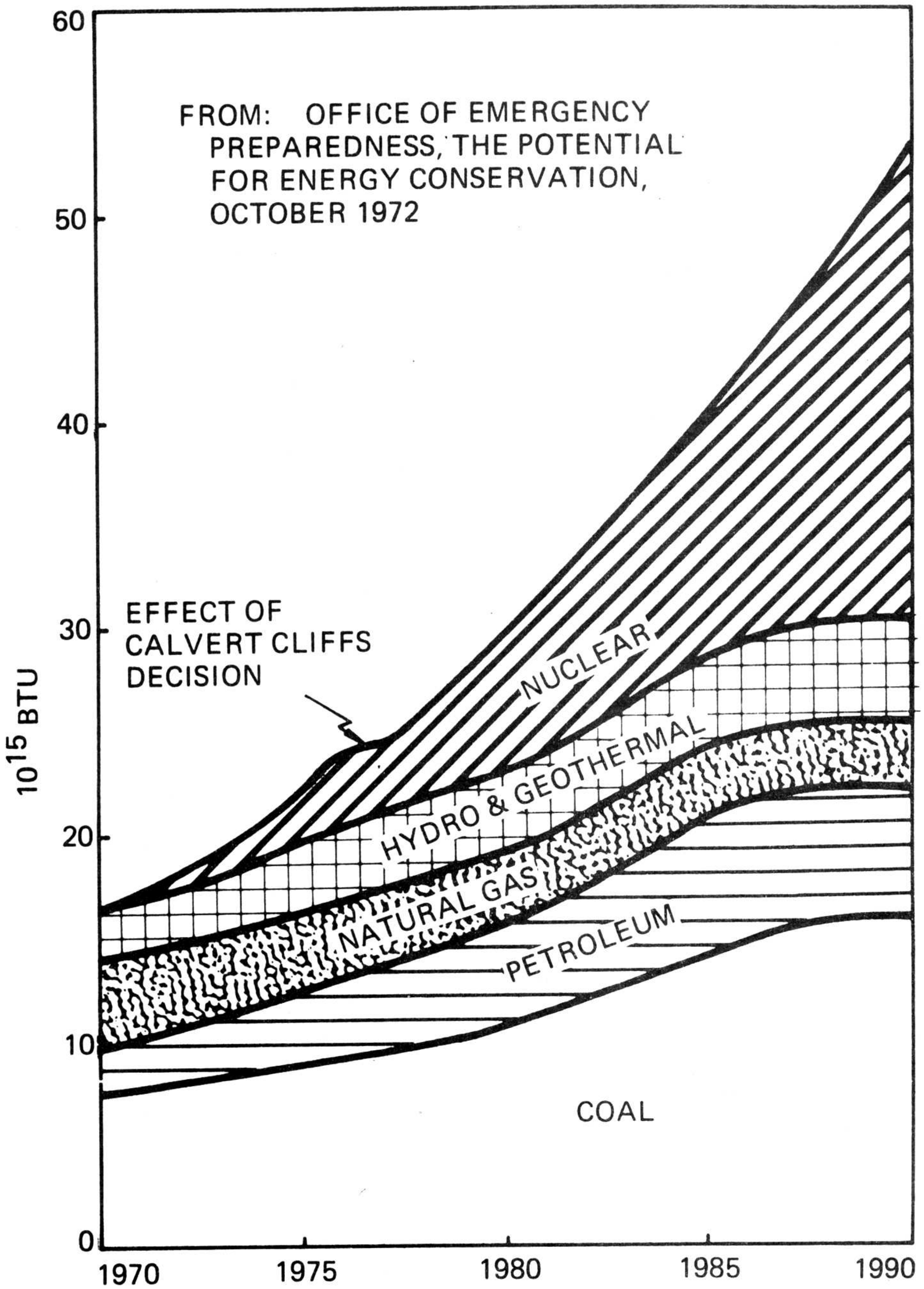


FIGURE 7-5
ANNUAL ENERGY CONSUMPTION FOR
U.S. ELECTRIC POWER GENERATION

TABLE 7-1 ANNUAL U.S. ENERGY CONSUMPTION BY SOURCE

ENERGY SOURCE	1971		1975		1980		1985		1990	
	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%
PETROLEUM:										
DOMESTIC	22.	(32)	23.	(29)	23.5	(25)	22.	(19)	19.	(13)
IMPORTED	8.5	(12)	12.1	(15)	17.7	(18)	26.7	(23)	35.6	(26)
SYNTHETIC					1.	(1)	2.	(2)	3.	(2)
SUBTOTAL	30.5	(44)	35.1	(44)	42.2	(44)	50.7	(44)	57.6	(41)
GAS:										
DOMESTIC	21.2	(31)	20.	(25)	19.	(20)	19.	(16)	19.	(13)
IMPORTED	1.5	(2)	4.7	(5)	7.	(7)	6.4	(5)	7.8	(6)
SYNTHETIC			.5	(<1)	1.	(1)	3.	(3)	3.5	(3)
SUBTOTAL	22.7	(33)	25.2	(31)	27.0	(28)	28.4	(24)	30.3	(22)
COAL	12.6	(18)	13.8	(17)	16.1	(17)	21.5	(18)	24.7	(18)
HYDRO & GEOTHERMAL	2.8	(4)	3.6	(5)	4.	(4)	4.3	(4)	4.9	(3)
NUCLEAR	.4	(<1)	2.6	(3)	6.7	(7)	11.8	(10)	23.	(16)
TOTAL	69.0		80.3		96.0		116.7		140.5	

NOTE:

TOTAL ENERGY AND ENERGY FOR EACH MAJOR CATEGORY FROM REFERENCE 1. IMPORTED AND SYNTHETIC OIL AND GAS ESTIMATED FROM REFERENCES 2, 3, and 4.

REFERENCES:

1. Office of Emergency Preparedness (OEP), The Potential for Energy Conservation, October, 1972.
2. National Petroleum Council, U.S. Energy Outlook: An Initial Appraisal 1971-1985, July, 1971.
3. Austin, A. L. et al, Energy: Uses, Sources, Issues, Lawrence Livermore Laboratory Report UCRL-51221, May, 1972.
4. Shell Oil Company, The National Energy Position, February, 1972.

TABLE 7-2 ANNUAL U.S. ENERGY CONSUMPTION BY CONSUMING SECTOR

CONSUMING SECTOR	1971		1975		1980		1985		1990	
	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%
HOUSEHOLD AND COMMERCIAL	14.3	(21)	15.9	(20)	17.5	(18)	19.0	(16)	20.1	(14)
INDUSTRIAL	20.3	(29)	22.9	(28)	24.8	(26)	27.5	(24)	31.1	(22)
TRANSPORTATION	17.0	(25)	19.1	(24)	22.8	(24)	27.1	(23)	32.2	(23)
ELECTRICAL GENERATION	17.4	(25)	22.4	(28)	30.0	(31)	40.4	(35)	53.3	(38)
SYNTHETIC GAS	--	--	--	--	.9	(1)	2.7	(2)	3.8	(3)
TOTAL	69.0		80.3		96.0		116.7		140.5	

TABLE 7-3 ANNUAL ENERGY CONSUMPTION FOR ELECTRIC POWER GENERATION

ENERGY SOURCE	1971		1975		1980		1985		1990	
	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%	10^{15}BTU	%
PETROLEUM	2.4	(14)	3.6	(16)	5.0	(17)	6.6	(16)	6.3	(12)
NATURAL GAS	4.1	(24)	3.8	(17)	3.6	(12)	3.5	(9)	3.2	(6)
COAL	7.7	(44)	8.9	(39)	10.7	(36)	14.2	(35)	15.9	(30)
HYDRO & GEOTHERMAL	2.8	(16)	3.6	(16)	4.0	(13)	4.3	(11)	4.9	(9)
NUCLEAR	.4	(2)	2.6	(12)	6.7	(22)	11.8	(29)	23.0	(43)
TOTAL	17.4		22.5		30.0		40.4		53.3	

FROM: Office of Emergency Preparedness (OEP), The Potential for Energy Conservation, October 1972.

Using these projections as a base, a most probable forecast of U.S. energy trends can be made for three time periods:

1. Short-term - Now to late 1970's
2. Mid-term - Late 1970's to mid 1980's
3. Long-term - Mid 1980's to 2000

1. Short-term - Now to late 1970's

In the short-term, the following is likely to occur:

- U.S. petroleum refineries, now operating dangerously close to full capacity, are likely to fall behind in meeting the growing demand for gasoline and other refined oil. Recent news articles[9,10] have noted the following aspects of this recently recognized, imminent shortage in refined liquid fuels:

  - the demand for gasoline has recently increased abnormally because of the new low-compression automotive engines which consume 5-10% more fuel than conventional engines

  - the problem will get worse as automotive anti-pollution measures result in further increases in gasoline consumption per vehicle mile, and require a shift to lead-free fuel, which requires more crude oil per gallon of fuel than does leaded gasoline. The shift to lead-free fuel, by itself, will add up to 1 million barrels daily to our petroleum needs by 1980.

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[9] Behind the Sudden Shortage of Gasoline, Business Week, 12 August 1972.

[10] Refining Pinch, Wall Street Journal, 22 August 1972.

oo adding to the demand for refinery products is the growing use of light grade heating oils mixed with heavy industrial fuel oil to make it less polluting; some utilities are also using heating oils in gas turbine units to meet peak summer electricity demand

oo refinery capacity increases are hampered by five factors: uncertainty over the type of refinery to build to meet the unknown fuel requirements of low emission cars of the future; inability of most domestic refineries to process the "sour" (sulfurous, high in metal content) crudes from the Middle East; the 3- to 6-year timetable required for building a new refinery; the high costs, relatively low profits, and siting problems associated with refinery operation; the concern among refiners as to what extent the government may go in allowing expanded imports of refined products

oo gasoline prices will rise rapidly, perhaps as much as 50% over the next 3 years.

o Nuclear power plant start-up schedules will be delayed by 1- to 3-years as a result of the AEC's decision to require environmental impact statements for all new installations (the celebrated Calvert Cliffs decision based on the proposed Calvert Cliffs nuclear plants of the Baltimore G & E Company). This delay, as reflected in Figure 7-5, will aggravate electric power shortages forecast for several urban areas of the U.S. such as California[11] and the Northeast U.S.[12] The Bolduc study projects a five percent deficit in electric generating capacity relative to peak demand for the six New England states and New York over the period 1977-1981. This prediction assumes:

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[11] California Warned to Curb Use of Electricity, N.Y. Times, 17 October 1972.

[12] Bolduc, Pierre, et al, Electrical Energy -- Northeast U.S.A. (New England and New York State), Hydro-Quebec, October 1971.

oo no change in historical demand trends

oo no major change in recent public attitudes and government policies toward environmental protection

oo no early unexpected technological breakthrough

The shortage of electrical power will increase the demand on petroleum and gas for household heating and cooking and for industrial/commercial heating. By 1980, according to current projections, nuclear plants will account for 22% of U.S. electric power generation and 7% of all U.S. energy consumption

o Synthetic gas from coal gasification and naptha reforming processes will be introduced in small quantities, providing no more than 1% of total energy (4% of all gaseous fuel) by 1980

o Synthetic petroleum from shale deposits will also be introduced in small quantity (less than 1% of total energy by 1980)

o If present policies continue, there will be a growing dependence on foreign sources of natural gas, crude petroleum, and, if U.S. refinery capacity is not rapidly increased, petroleum products as well. By 1980, U.S. petroleum imports (mostly crude) will probably reach 40-45% of all U.S. petroleum consumed and 15-20% of all U.S. energy. Natural gas imports (primarily as LNG) will reach 25-30% of all U.S. gas consumption and 5-10% of all U.S. energy by 1980; the proposed gas deal[13] with the Soviet Union would account for 5-7% of all U.S. gas consumption (20-25% of all gas imports) by 1980 at a cost of approximately $1.00 per 1,000 cubic ft. (three to four times the current cost of domestically produced gas). Thus, by 1980, the U.S. will probably depend on foreign sources for 20-30% of its total energy budget.

[13] Soviets, U.S. Near Gas Deal, Washington Post, 3 November 1972.

2. Mid-Term - Late 1970's to mid-1980's

In the mid-term (late 70's to mid-80's), U.S. energy trends will most probably include the following:

- Nuclear power plant environmental issues will be solved and nuclear power generation will account for nearly 30% of U.S. electric power generation (10% of total energy consumption) by 1985. During this time frame the first demonstration-size fast breeder reactor plant will become operational, but the first commercial breeders will not appear until after 1985.

- The short-term refinery capacity problem will be solved, probably by a combination of added domestic capacity and increased product imports. A third factor may be a lessening of petroleum product demand through the introduction of smaller, less powerful automobiles, more efficient use of automobiles (e.g., car pools), and increased use of mass transit -- all shifts that would be encouraged by the short-term gasoline cost increase (up 50% in 3 years) discussed previously

- If present policies continue, U.S. dependence on foreign energy sources will continue to grow. By 1985, 20-25% of all gas and 50-55% of all petroleum consumed in the U.S. will be imported. Imports will provide nearly 30% of total U.S. energy by 1985. This strong dependence on foreign energy sources, especially in the fuels on which transportation is so highly dependent, may well be the most critical feature of the energy picture during the next few decades for the following reasons:

  - by 1985, increases in petroleum demand will have outstripped the rate of discovery so that the current world-wide situation of over-supply will have become one of dependency on the Middle East. However, because of their very comfortable liquidity position (Middle-East oil suppliers may have $30-50 billion liquidity by 1980), the producing nations will have little incentive to increase production, and may prefer to increase price. The result might be a doubling or tripling of petroleum prices over the next decade.[14]

- oo by 1985, the cost of imported petroleum and gas will be $30-40 billion per year (assuming at least a doubling of petroleum prices over current values), a serious load on the U.S. balance of payments. Recent news has suggested this problem may be counteracted by the U.S. plans to export large quantities of enriched uranium to such energy poor countries as Japan

- oo the U.S. energy supply will become highly vulnerable to international hostilities or trade conflicts.

- o The electric power shortage will be relieved through the construction of coal-fired power plants with the application of a very high level of stack emission control technology, and/or through the introduction of total energy systems using fuel cells fed by natural or synthetic gas.[15]

- o Given the projected rise in petroleum prices, synthetic petroleum (probably from shale or coal liquefaction) will become commercially available, supplying three to five percent of the U.S. petroleum demand by 1985. Factors militating against earlier introduction of synthetic petroleum include:

  - oo environmental considerations (surface stripping for coal; residue disposal for shale oil* and coal)
    *(see note next page)

  - oo process development (only at pilot plant stage at present)

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[14] Symposium on Energy, Resources, and the Environment, Kyoto, Japan July 9-12, 1972 (Transcript to be published by The MITRE Corporation in December 1972).

[15] Creating Electricity with Gas, Washington Post, 12 November 1972.

- oo water requirements (most of the water in the Colorado shale oil region is already appropriated).

- oo cost (while current field prices for North African crude are in the range of $3.25 per barrel, not including a $0.40 per barrel transportation cost to the U.S. east coast[16], shale oil, the most nearly at-hand synthetic crude, can be produced for a field cost of between $4.00 and $5.00 per barrel, a cost increment which can be at least partly justified by the fact that shale oil, at this price, is further along the processing line than most crude petroleum. However, this projected cost for shale oil may be optimistic in light of the environmental costs the producers might be forced to pay.*)

  *The National Petroleum Council[17] reports that, as an example of environmental cost, production of just 100,000 bbl. per day of shale synthetic crude (the U.S. currently consumes 16 million bbl. per day of petroleum) requires the daily disposal of shale residual sufficient to cover 40 acres of ground to a depth of one foot.

3. Long-Term - Mid-1980's to 2000

The long term U.S. energy picture will probably include the following:

- o The rate of introducing nuclear power plants will increase markedly during this period (see Figure 7-5) with fast breeder reactors predominating the additions by the end

[16] Stryker, S. H., Options for Clean Energy-Oil, Report WP-8680, Volume XIII, The MITRE Corporation, 12 April 1972.

[17] U.S. Energy Outlook: Initial Appraisal 1971-1985, National Petroleum Council, July 1971.

of the century, providing the awesome problems[18] of plutonium waste product disposal have been solved. By 1990, 15-20% of all U.S. energy and 40-45% of all electric power generation will be derived from nuclear sources. Beyond 1990, all additions to electric power generation capacity will be nuclear.

- If thermonuclear fusion power is ever to be demonstrated as technically and commercially feasible, such demonstrations will occur during this time period (possibly later, but not earlier). If successful, and especially if the more difficult no-Lithium version of the reaction is the one used, fusion power could signal the availability of abundant, low cost electricity having an acceptably small environmental impact.

- In those urban areas where electric power is plentiful and low in cost, the use of hydrogen (H_2) as a transportation fuel and as residential and industrial fuel will likely be introduced. H_2 fueled vehicles will be virtually non-polluting and will have essentially the same performance characteristics as gasoline fueled engines; the only basic problem appears to be the relatively large fuel storage volume required.[19] If the long-term prospects for low-cost and plentiful electric power look bright within this time frame, then the small-scale use of H_2 as a commercially deliverable fuel will probably mark the advent of the so-called "Hydrogen Economy" wherein society's energy needs will be met ultimately by nuclear generated electricity which is stored and transported in the form of electrolytic hydrogen. Ultimately, the energy is released from the hydrogen either in the form of heat (as in combustion processes) or as electricity produced in fuel cells.

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[18] The Energy "Joyride" is Over, Fortune Magazine, September 1972.

[19] Austin, A.L., A Survey of Hydrogen's Potential as a Vehicular Fuel, L. L. L. Report UCRL-51228, 19 June 1972.

- As an alternate to low cost and plentiful electric power, the successful development of coal gasification processes may also lead to a "Hydrogen Economy" wherein the synthetic gas is reformed to hydrogen or to a "Methane Economy" where the energy content of the carbon constituents in the gas is retained. Both hydrogen and methane can be used as transportation fuels and as fuels for individual residential, commercial, and industrial total energy systems.*

  *Total energy systems use a single energy supply (usually gaseous fuel) to provide all energy needs for a particular facility: electricity provided by gas-fed fuel cells and heat provided by combustion of the gas.

- Synthetic petroleum will be available in significant quantities (of the order of 10% of all petroleum consumed) and at high cost (at least 3 times current petroleum product costs).

<u>Most Pessimistic Variations</u>

Using the most probable energy trends, outlined above, as a base, "most pessimistic" and "most optimistic" scenario variations can be constructed. Briefly, the "<u>most pessimistic</u>" outlook would include some or all of the following elements:

<u>In the short- and mid-terms (now to 1985)</u>:

- The liquid fossil-fuel shortage would become acute because of inadequate refining capacity and/or a curtailment in delivery of foreign crude because of competitive worldwide demands and/or international conflicts. Automotive fuel might become rationed and/or gasoline costs would exceed $1.00 per gallon.

- The electric power shortage may become acute as environmental problems plague the introduction of new coal-fired plants for increasing capacity to offset continued delays in nuclear plants. Electric power costs may double or triple

- Synthetic gas processes may fail to reach commercial operation because of economic and/or environmental problems, and environmental pressures concerned with locations of new terminals and pipelines may greatly slow the importation of LNG. The current gas shortage will then be greatly aggravated with the result that the limited petroleum supply may be diverted from less essential transportation modes to the more critical home heating and utility consumers.

In the long term (1985-2000):

- The electric power shortage may become more serious, either because of severe restrictions placed on the siting and radioactive waste disposal aspects of fast breeder reactors, or because of clean fuel shortages affecting the fossil-fueled power plants (which, in the most probable forecast, would still account for roughly 50% of total capacity in 1990), or both

- The shortage of electric power and the lack of a successful synthetic gas process may preclude the introduction of H_2 as a fuel

Most Optimistic Variations

A most "optimistic outlook" for U.S. energy trends would include the following:

In the short term (now to late 1970's):

- The refinery capacity shortage may be eased as:

    - gasoline prices rise sufficiently to encourage domestic investment in new refineries

- oo automotive fuel consumption decreases because of trends toward smaller, more efficient cars, staggered work hours, mass transit, car pools, etc.

- o Nuclear power plant implementation may be accelerated as siting problems are overcome (perhaps through the use of cooling towers) and as environmental objections to coal-fired power plants grow.

- o Synthetic gas from coal may be shown to be commercially attractive.

<u>In the mid term (late 1970's to mid 1980's)</u>:

- o Petroleum prices may stabilize at no more than twice current levels because of:

  - oo successful implementation, in significant quantities, of synthetic petroleum processes (e.g., oil from shale, tar sands, coal, garbage, or plants)

  - oo increasing economic interdependence between producers and consumers, as oil producing nations grow more populous and upgrade their standard of living via industrialization. The dependence of the producing nations on a U.S. market would tend to keep prices low to delay U.S. use of alternative energy sources.

- o Electric power may become abundant and low cost because of:

  - oo successful demonstration and commercial introduction of the fast breeder reactor (not yet in use in significant quantities)

  - oo rapid growth in conventional (light water/enriched uranium) nuclear plants oo reductions in the rate of growth of electric energy demand as consumers (households and industry), through a concerted public education effort, are made aware of ways to reduce electric and total energy consumption without materially altering living standards. (See recommendations of OEP Study[8]).

oo total energy systems, using mostly synthetic gas, may be introduced in significant quantities in selected urban areas to relieve further the demand on electric power and to make more efficient use of energy resources.

<u>In the long term (mid 1980's to 2000)</u>:

- A hydrogen economy may be assured through successful demonstration of a commercially feasible fusion power plant (although a hydrogen economy can just as well be based on a variety of other abundant primary energy sources, such as nuclear fission, solar energy, or purely chemical techniques[20,21]) and through large scale coal gasification. Hydrogen-fueled vehicles may constitute the majority of urban fleet systems by the year 2000. Hydrogen may also fuel non-electric intercity ground transportation as well as home and industrial users of gaseous fuel.

- Electric power will be abundant and low-cost.

- Transportation fuel costs may remain low enough so as not to restrain the use of any mode, thanks to the plentiful supply of synthetic petroleum, synthetic gas, and/or hydrogen.

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[20] <u>When Hydrogen Becomes the World's Chief Fuel</u>, Business Week, 23 September 1972.

[21] Gregory, D. P., et al, "The Hydrogen Economy," Chapter 8 in <u>Electrochemistry of Cleaner Environments</u>, Plenum Publishing Corp., 1972.

B. AIR CONGESTION

Projected Growth of Air Demand

In the pioneering period of air transport, between the two World Wars, growth of certified carrier traffic was erratic, but averaged 35 percent per annum. In the two decades that followed the second World War, growth was more steady and averaged 12 percent per annum.[22] For the decade 1966 through 1975, recorded and forecast growth averaged 13.5 percent per annum. For the period 1976-1983, FAA aviation forecasts[23] show an average annual rate of growth of 11.0 percent for passenger-miles and 10.5 percent per annum for passenger enplanements. Recent DOT studies, concerned with future air congestion, have assumed an average growth in passenger enplanements of 7 to 10 percent per annum for the extended period beyond 1976. Enplaned passenger data shown in the following table were derived from FAA aviation forecasts:[24]

TABLE 7-3

PROJECTED AIR DEMAND

Year	Enplaned Passengers (Millions)	Demand Increase Factor
1970	171	--
1975	230	1.34
1985	475	3.36
1995	1,500	8.77

[22]"Handbook of Airline Statistics," Table 10, 1969 Edition, Civil Aeronautics Board, Washington, D.C.

[23]"Aviation Forecasts," FAA Office of Aviation Economics, 1971.

[24]Op. Cit., Table 1.

Projected Increase in Airport Capacity

Increased airport capacity is necessary to avert increases in airport congestion. Plans for new airports vary with each individual city, and are often subject to community opposition. Generally the greatest opposition to these plans is met where current and forecasted congestion is greatest.

Many solutions to air congestion in the face of public opposition to new airports have been discussed and analyzed. The solutions can be separated into the following categories:

(1) those which attempt to redistribute the demand for air travel or the demand pattern at the airport;

(2) those which attempt to expand the vehicle handling capacity of the system;

(3) those which attempt to expand the passenger handling capacity of aircraft; and

(4) new airports.

The first category includes changes in present procedures which must, in general, be implemented by regulatory action. Four of the more important actions are:

(1) variable landing fees and fares to induce a redistribution of the daily demand profile;

(2) limitation of general aviation at commercial airports;

(3) threshold load factors for landing rights; and

(4) encourage direct flights thereby diverting through and transfer traffic from major hub airports.

The second category of possible actions to reduce congestion at CTOLports are directed toward increasing the system capacity by:

(1) improvements in air traffic control (ATC) capabilities;

(2) expansion and improvement of facilities at existing airports; and

(3) implementation of STOL service at the airport with short runways in areas too small for larger runways.

The third category involves the use of larger aircraft to increase passenger handling per vehicle. Increases of 75 percent in average vehicle size by the 1980's have been forecasted.

Table 7-4 shows that, <u>on the average</u>, the airside capacity, excluding that provided by new airports, can probably keep up with demand growth through the mid '80's. Unless further growth in capacity, which is unforeseen at this time, is developed, capacity growth will begin to be surpassed by demand growth sometime between 1985 and 1990. However, at particular airports such as LaGuardia and O'Hare, this situation may occur much earlier. If the figures in Table 7-4 obtain, congestion delays through 1985 will remain similar to what they are today. Capacity will have to increase <u>faster</u> than demand for delays to decrease.

TABLE 7-4

COMPARISON OF AVERAGE DEMAND AND AIRSIDE CAPACITY INCREASE OVER 1970

Regulatory Changes Increase (by 1985)	1.33
Average Airport Capacity Increase (by 1985)	1.68
Average Aircraft Size Increase (by 1985)	1.75
Total Airside Passenger Handling Increase (by 1985)[1]	3.91
Average Demand Increase (by 1985)	3.36
Average Demand Increase (by 1995)	8.77

[1] Airside capacity may be increased above this figure during the 1985-95 period with next generation air traffic control equipment. However, such re-equipping is not now planned.

Congestion at Major Airports

While the indication is that airport capacity will on the average exceed demand at least through 1985, individual airports may encounter congestion at earlier points in time. Most notably, LaGuardia, Los Angeles International, O'Hare and Washington National have potential for early congestion. Environmental pressures are strong in all cases and, for all except possibly O'Hare, the existing aiport acreage allows little room for runway expansion and the urban surroundings argue strongly against increases in the number of operations unless significant reduction is realized in noise and other sources of community objection.

It is noteworthy that all of these critical airports serve corridors analyzed for high speed ground. The contingency which must be considered is that the airport capacity for the high density corridors may not be able to keep pace with demand, even to 1985.

Obviously, the airport congestion contingency is not likely to occur along with a severe energy shortage. High cost or fuel restrictions would tend to cut down on short haul air travel and work against demand levels leading to congestion. Rather, the congestion contingency is the other horn of the dilemma if the nation is able to avert a major petroleum fuel crisis or if aviation is able to adapt to substitute fuels. If there is no severe fuel crisis and if major improvements in community acceptability of airfields are not forthcoming, then congestion is a threat. The timing would be for localized congestion in the high density corridors by 1985 and more general congestion by 1995.

The Impact of HSGT upon Air Congestion

High-speed ground tranpsortation can be an effective means of replacing short haul air travel along densely populated corridors. Generally, the TLV would provide door-to-door travel times competitive to air service for trips up to 400 miles, although individual access times must be examined for trips over 300 miles. Thus, it would be appropriate for much of the travel in the Northeast Corridor, Chicago area, and California--the market areas where severe airport congestion is expected to occur soonest. It may be noted that the cost-revenue analyses of Chapter V indicated potential economic viability for TLV in these areas even without considering the effects of air congestion. As is true also of IPT, TLV should be able to offer very reliable and high capacity service under almost all weather conditions.

The slower IPT loses in competition with CTOL on trips between 100 and 200 miles in length, again depending upon individual access times. Most travelers whose trips originate and end in Central Business Districts (CBD) should find the IPT more convenient than CTOL near the 200 mile range even though it may take as much as an hour and a half longer for the line haul portion of the trip. Undoubtedly, improved transportation between CBD and the local airport would decrease some of the long access time now attached to air flights; but the IPT gains some service competition when it capitalizes on its inherent ability to maintain a highly dependable time schedule, even at times of peak travel and under most weather conditions. Furthermore, the IPT could usually cover 200 miles in no more than two and one-half hours, which in some cases still qualifies the trip as a one-day trip.

To those cities that must find some form of relief from air traffic congestion, the high-speed ground mode can serve as a back-up mode to short haul air travel. A well managed IPT would divert some air traffic competitively if airport facilities continue to suffer from increased congestion while TLV could offer major diversion.

CHAPTER VIII

SUMMARY EVALUATION

IPT and TLV are not generally competitive in application; rather, they represent more nearly complementary modes likely to be successful under somewhat different conditions of implementation. Nevertheless, many of the same cost-benefit considerations apply to both, and both need to be assessed in relation to the same criteria. Hence, in the overall evaluation, some comparison between the two modes is inevitable - the more so because where quantitative data are lacking, it has been necessary to consider in relative terms the effect which a given criterion has on the evaluation of each mode. Any comparison, whether explicit or implicit, should be construed as directed toward identifying and defining those conditions under which - if a choice had to be made - each alternative system would be most appropriate for implementation.

By way of overall assessment, some general statements should be made at the outset. Both modes meet the criteria established in Chapter II for the applicability of R&D effort. First, the analysis in Chapter V indicates that each system would be viable to the extent that revenues would cover the money costs of operation and maintenance and part or all of the cost of implementation under some reasonable future circumstance. IPT, because of its lower investment cost, requires lower demand for successful operation. It could be implemented in selected areas with expectation of positive net present value (NPV) at an earlier date. However, IPT appears feasible only in corridors where large metropolitan areas are separated by short distances. TLV is not potentially available until a later time than IPT. If implemented in selected corridors, TLV should produce a higher passenger patronage because of its greater speed and resulting capability to compete with air travel over longer distances than IPT. Its greater cost makes its viability more problematical except in the most populous regions. However, the analysis of Chapter V identified a number of markets which combined with highly probable future circumstances (high petroleum prices) would support unsubsidized implementation and operation of each system.

A second criterion for R&D is that there be no insurmountable physical or institutional barriers to implementation. As essentially an extension of an existing mode, IPT should offer fewer problems from environmental impact and societal acceptance. TLV is subject to the possibility of a greater initial resistance because of its higher investment costs and public concern about intrusion of new forms of technology into areas impinging on daily life -- especially if extensive new rights-of-way are required. However, these constraints probably would not prevent eventual implementation in areas where the need for TLV and its benefits - both internal and external - should be demonstrable well before the target date. In fact, as a more innovative development in high-speed transportation, TLV offers in the most highly-urbanized corridors an image which should be more favorable than that of IPT.

Finally, some observations can be made regarding the "insurance criterion." Although it is not possible to quantify the probability that IPT will be vital in the anticipated near term future environment of fuel shortages, the cost of R&D for IPT is so small that it can be safely considered as low-cost insurance that the American public will continue to enjoy adequate transportation. With TLV, whose implementation would be approximately a decade beyond that of IPT, society could avoid disbenefits which could result if potential fuel shortages developed on the one hand, or serious congestion of other modes materialized on the other hand. If no very high-speed mode were available in either contingency, the impact could be so severe that the value of preparing against it would exceed the TLV R&D costs. This assessment takes into account the fact that R&D for TLV will require a much longer time period and that as R&D progresses, the prospect of these contingencies will become clearer and the scope of effort can be scaled accordingly.

Because the time and place of eventual implementation for either mode is unknown, it cannot be evaluated in depth here. The brief tabular assessment of each mode which follows, however, is based on conditions expected to prevail in those areas where analysis has indicated potential markets.

TABLE 8-1

SYSTEM PERFORMANCE

CRITERIA	IPT	TLV
Capacity	10,500 seats each way per day, based on operating only 15 trains per day to avoid freight interference	6000 seats/hour each way for TACV and superconducting MAGLEV 9600 seats/hour for ferromagnetic MAGLEV
Safety	To maintain present high rail safety will require improved signalling, automatic train control and protection of ROW, especially at grade crossings.	Dedicated ROW should ensure improvement over present high rail safety. Requires tradeoff between isolated guideway and automatic system to detect foreign objects. Potential problems of fail-safe device in case of levitation failure or departure from guideway.
Reliability (probability of arriving on schedule)	Impervious to most weather, reliability should be high in absence of significant interference from freight and conventional passenger trains. Not feasible at present to quantify reliability.	With dedicated ROW and relative imperviousness to weather, should achieve very high reliability.
Flexibility (with respect to fluctuating demand on a given route)	Relatively easy to adapt to heavy peak load by increasing train length. Major increase in frequency of schedule subject to possibility of interference from conventional trains.	With dedicated ROW, capability to increase frequency of schedule to meet increased demand limited only by required headway (>3 minutes). Restrictions on maximum train length (5 vehicles) limits ability of TACV and superconducting MAGLEV to adjust to variations in peak demand.
Comfort and Ride Quality	Expected to be fully adequate. Will require increased complexity of suspension system and more rigid maintenance program for hydraulic system. Effect of heavy freight traffic on roadbed may complicate track maintenance.	Expected to be fully adequate. Details of suspension system to achieve necessary level remain to be worked out in R&D, depending on TACV or MAGLEV concept used. Dedicated ROW ensures ease of maintaining guideway tolerances.

TABLE 8-1 (Continued)

SYSTEM PERFORMANCE

CRITERIA	IPT	TLV
Convenience (frequency, accessibility of terminals, ease of intermodal transfer	High. Schedule can be adjusted to provide convenient arrival and departure times, within constraints of possible interference from conventional trains. CBD terminal locations should maximize convenience for most business travel.	High. Ease of schedule adjustment increases expected convenience. Terminals in CBD would maximize convenience for most business travel. If prohibitive costs require terminals only on periphery of metropolitan area (e.g., beltway terminals) convenience would be degraded.
Door to Door Travel Times	CBD - CBD: (2/3 - 3/4) x # miles plus 30 min. CBD - Suburban - add 45 min. to 1 hour.	CBD - CBD: (1/4 - 1/5) x # miles plus 30 min. CBD - suburban: Add 45 - 60 min.
Sensitivity to Number of Stops	At speed of 3/2 - 4/3 mi/min, dwell time of 3 min. at each stop increases travel time by amount equal to an increase $\geq$ 4.5 miles in trip length. Increasing # of stops more likely to promote some increase in demand (than for TLV) because average trip length likely to be short (thus increasing stops provides greater number of possible O - D pairs).	At speed of 4 - 5 mi/min, dwell time of 3 min. per stop increases travel time by amount equal to increase of 12 - 15 miles in length. Demand less likely (than with IPT) to be sensitive to number of stops. TLV is aimed at longer average trips and the increase in time from intermediate stops is negligible but fewer passengers expected to desire intermediate points as origin or destination.
Dependence on Urban Transit	Adequate urban transit would aid IPT in competing with convenience of private cars. Placement of terminals an important factor.	High speeds of TLV and potential ability to reduce door-to-door travel times to less than those achieved by air could be somewhat negated by inadequate urban transit if undue time required to go from TLV terminal to destination in CBD. Greater passenger load required for TLV (than for IPT) would be facilitated significantly by effective urban transit enabling passengers from all geographic subdivisions to be rapidly funneled into or fanned out from terminal.

TABLE 8-2

SYSTEM COST
(1972 dollars)

Elements	IPT: Chicago-Detroit	IPT: San Diego-Los Angeles	IPT: Portland-Seattle	TLV: Washington-Boston	TLV: Portland-Seattle	TLV: San Diego-Los Angeles	TLV: San Diego-Sacramento
Route Preparation (incl. yards & shops, & terminals)	51×10^6	18×10^6	19×10^6	2111×10^6	741×10^6	438-525* $\times 10^6$	2223-2702* $\times 10^6$
Land	0	0	0	557×10^6	62×10^6	57×10^6	210×10^6
Electrification	0	0	0	256×10^6	96×10^6	65×10^6	367×10^6
Control & Communication	8×10^6	4×10^6	4×10^6	80×10^6	30×10^6	21×10^6	115×10^6
Subtotal (Fixed Investments)	59×10^6	22×10^6	23×10^6	3004×10^6	929×10^6	581-668* $\times 10^6$	2915-3394* $\times 10^6$
Vehicles	7×10^6	7×10^6	5×10^6	211×10^6	8×10^6	15×10^6	42×10^6
Total Investment Costs	66×10^6	29×10^6	28×10^6	3215×10^6	937×10^6	596-683 $\times 10^6$	2957-3436* $\times 10^6$
Fixed Annual Operating Costs	5.5×10^6	3×10^6	3.9×10^6	18.0×10^6	7.8×10^6	5.9×10^6	25.9×10^6
Variable Operating Costs, per passenger mile	.038	.038	.038	.031	.031	.031	.031

*-Lower figures represent cost estimates developed in accord with a study performed by The RAND Corporation for DOT.

NOTE: FRA estimated that additional funds required for the IPT development, test, and demonstration program total $24 million which includes $2.0 million in FY 73 (R&D) $5.6 million in FY 74 (purchase equipment); and $16.4 million in FY 75 (upgrade ROW and test). FRA has estimated that R&D funds for TLV, FY 73-78, total approximately $120 million, including $90 million for TACRV and TACV prototype vehicles and $30 million for MAGLEV (FY 73-77 only). Estimates of funds required for later years are not available.

TABLE 8-3

EXTERNAL COSTS

CRITERIA	IPT	TLV
Noise	Comparable to a diesel truck. On existing ROW impact minimized by presence of existing noise sources.	Probably like diesel truck or existing rail freight train. MAGLEV may be quieter than TACV. Noise impact can be abated by policy options (location of ROW and guideway, speed reduction in built-up areas) and/or technology options (vehicle design, use of sound barriers).
Air Pollution	Regenerative Gas Turbine train offers significant reduction in emission of all 5 major pollutants relative to all other modes. Turbotrain and diesel IPT produce sulfur dioxide and particulates at a higher emission rate per seat-mile than automobiles, assuming 4 seats per car. All types IPT offer great reduction in CO over automobile travel especially on basis of 1 or 2 passengers per car. Net impact: overall reduction in pollution possible. Can be quantified on basis of type IPT to be used.	Using electric power, all versions of TLV would produce no UHC or CO, but if uncontrolled fossil-fueled generating stations were employed, significant amounts of NO_x, SO_2 and solid particulates would be emitted. Highly-controlled fossil-fueled plants with or without up to 50% nuclear generation would produce only negligible amounts of the last two pollutants and reduce NO_x emissions to a per-seat rate comparable to that of automobiles carrying only one or two passengers. Net impact: overall reduction in pollution possible but to quantify requires decision as to which TLV will be used and as to power sources.
Relocation and Disruption	Using existing ROW obviates any further relocation or disruption.	May be considerable, with need to acquire land for new ROW and at terminals. Can be quantified only in relation to specific locations using site-specific data.
Esthetics (Visual)	With use of existing ROW, would expect no further impact on esthetics or public opposition based on this issue.	Requirements for new ROW afford opportunity for public opposition based on esthetic considerations. Impossible to quantify impact in this area. If acute, problem should be resolvable by use of buffer zones - possibly also tunneling in urban areas - at increased cost, estimates of which would require site-specific data.

TABLE 8-4

RESOURCE LIMITATIONS

CRITERIA	IPT	TLV
Energy Consumption	Diesel-powered IPT has the lowest energy requirements (per seat-mile), closely followed by regenerative gas turbine. Exact rates depend on train length and cruise speed, but run from 1/3 to 1/2 the rate for automobiles (assuming 4 seats per car). IPT thus offers a considerable potential for energy saving over auto travel.	Energy would be consumed by most versions of TLV at approximately the seat-mile rate of the DC-9-30, which is 2.55×10^3 BTU. This rate is higher per seat-mile than the automobile rate but is about equal to the passenger-mile rate for cars, assuming only 2 passengers per car. However, the ferromagnetic TLV would be expected to consume energy at a lower rate; 1.05×10^3 BTU/seat-mile.
Land Requirements and Availability	Use of existing ROW (with only occasional minor additions as for straightening extreme curves) should obviate any significant problems in this area.	Seem certain to pose a significant constraint. Quantification requires site-specific data.

TABLE 8-5

SOCIOECONOMIC IMPACTS

CRITERIA	IPT	TLV
Enhanced Mobility of Population	Represents a significant benefit of IPT through provision of fast reliable transportation at prices competitive with some auto travel. Increases options available to all of population, especially for transportation between CBD's and provides to some groups (e.g., non-car owners) opportunities for economical travel they might not otherwise have. Especially significant in extreme conditions of adverse weather and if fuel crisis or severe congestion of other modes should develop.	Provides important addition to mobility of that portion of population normally traveling by air in 200 - 400 mile range. Important in weather conditions that curtail flights and in event of fuel crisis or severe congestion of air travel.
Land Use	No effective impact, since no significant additions of land required to that now used in ROW. Some increase in land values in areas served by IPT can be expected. Not likely to involve any significant constraint.	New ROW for TLV can have significant impact on land use patterns - e.g., if ROW serves as barrier between districts, removes land from projected recreational use, etc. Although providing a potential constraint, this consideration is not expected to pose insurmountable obstacle. Greater intensity of land use by TLV than by IPT (because of greater demand requirement) should cause somewhat greater increase in land values in areas served by TLV.
Risk	There is some risk associated with heavy investment in a transportation mode sufficiently different from existing modes to make the economic prospect uncertain. Note that the detailed analysis reported in Chapter V indicates that IPT could have a negative NPV in some corridors.	Considerations cited for IPT essentially apply to TLV. But risk is much greater for TLV because of much higher investment costs and more extreme departure of TLV from existing travel modes.
Flexibility and Responsiveness to Change (of market locations)	To serve added geographical markets major improvements in roadbed and other features of presumably existing ROW would be required.	Less flexible geographically than IPT because moving into new area requires whole new ROW and guideway.

TABLE 8-6

INSTITUTIONAL IMPACTS

CRITERIA	IPT	TLV
Societal Attitudes	As essentially an extension of existing system, IPT is unlikely to arouse significant opposition from non-users. But to acquire active support on a broad geographic basis may require erasing image of passenger train as a losing proposition. Favorable image could be expected from a national network of profitable trains and significant private participation in funding.	Could be significant constraint if present suspicion of large segments of public continues toward new technologic developments as environmentally harmful. High costs could create opposition. Steps that might reduce possible constraint: 1. Use of low noise TLV; 2. Improving access of system to reduce number of non-users; 3. Effective public information program emphasizing advantages of TLV and potential economic success; 4. Private financing support.
Private Financing	Success of auto train and Metroliner suggest potential private financing support could be achieved through loan guarantees or some form of government backing.	Heavy initial investment required is likely to discourage any private financing for establishing TLV. Some private financing for operating system might be induced under arrangements such as suggested for IPT, provided economic viability is sufficiently credible.
Public Financing	AMTRAK's financial condition indicates some public financing will be required for development and implementation. Partial subsidization likely for operating system initially. Trust fund similar to Highway Trust Fund represents one feasible means of public financing. Another is guaranteed loans to be repaid by private sector when some threshold of profitability is passed.	Same considerations apply as cited for IPT but extent of public financing likely to be greater because of higher TLV costs.

TABLE 8-6

INSTITUTIONAL IMPACTS

CRITERIA	IPT	TLV
Management Structure	Heavy Federal involvement in IPT management seems certain through some arrangement (possibly similar to AMTRAK) by a national organization to ensure track improvement. Federal management role likely to be greater in implementation than in operations.	Considerations cited for IPT apply also to TLV.
Political Jurisdictional Factors	Major support must come from Federal government but problem is complicated by fragmentation of responsibility for transportation among local governments.	Considerations cited for IPT apply.
Labor Relations	Can be expected to represent a continuation of present rail labor relations. Increased labor-management cooperation may be critical to economic viability in corridors where cost and revenue are evenly balanced.	New technology offers somewhat more favorable opportunity for negotiating new basis of labor/management agreement and cooperation. Other considerations cited for IPT apply also to TLV.

APPENDIX A

DEMAND PROJECTION METHODOLOGY

A. INTRODUCTION

Appendix A contains descriptions of the methodologies used for:

- preparation of general travel forecasts for a nationwide set of HSGT corridors (Chapter IV);
- estimation of modal shares -- for both a nationwide set of corridors and the selected corridors (Chapters IV and V);
- development of detailed 1970 travel forecasts for selected corridors (Chapter V).

This appendix also includes:

- forecasts of total travel in the selected corridors; and
- tests of the patronage and revenue implications of fares and operating speeds.

Although the basic methodologies used in Chapters IV and V are similar, the purposes of each analysis and therefore the approaches used are different. The analysis of a nationwide set of corridors in Chapter IV is intended to approximately scale the corridors in terms of their patronage potential and not to provide detailed estimates. Therefore, a model rather than actual data was used to estimate travel demands and impedances for all modes other than air. The analysis in Chapter V is intended to provide a more accurate evaluation of the potential viability of high speed ground modes in selected corridors, and, hence, observed travel demands and fares were used, where available, as the basis for developing forecasts.

Results of the Northeast Corridor Transportation Project (NEC) analyses were used directly in this study. Some of the underlying assumptions of the NEC's forecasts are different from those used in this study, inasmuch as it was possible in this study to rely on more recent data and to benefit from the experience gained in producing the NEC forecasts.

It was initially assumed that the ridership of a new high speed ground mode would be diverted from the existing modes and that no additional travel would be induced by the new mode, since, in general, the HSGT mode would not offer a service significantly better in any one attribute than that offered by any other mode. The HSGT mode usually offers a mix of travel time, cost, and service which is not previously available and is intermediate to that offered by the other modes; the HSGT mode generally is not significantly better in any one aspect of service than the existing modes. For example, air is generally the fastest mode for longer distance trips; and, depending on the circumstances, either bus or automobile is generally the lowest "out-of-pocket" cost mode.

In some cases, however, HSGT could be the fastest mode, depending on the individual traveler's terminal access and egress times. Such a situation could quite possibly induce additional travel. No data are available which would clearly indicate the relative impact of such an improved travel service on the volume of travel. Although the NEC travel demand model could be used to estimate induced demand from such an improved travel service, this relationship has not been independently validated. Therefore, neither the market potential analysis of a nationwide set of HSGT corridors nor the initial analysis of the selected corridors consider induced travel, and in this respect they are conservative. Travel forecasts which estimated induced demand using the NEC model formulation were subsequently prepared for several of the selected corridors; these forecasts are also discussed in the results section of this Appendix.

B. TRAVEL FORECASTS FOR A NATIONWIDE SET OF HSGT CORRIDORS

Forecasts of total intercity passenger travel demand used in Chapter IV for the preliminary market potential analysis of a nationwide set of HSGT corridors were based on a previous Peat, Marwick, Mitchell & Co. (PMM&Co.) study for the Department of Transportation.[1] In that study, PMM&Co. developed estimates of the total passenger travel in the U.S. in the year 1967. Then, utilizing the observed historical relationship between growth in travel and growth in population and per capita income, the 1967 travel estimates were combined with projections to prepare forecasts of total travel demand for 1975, 1980, and 1990.

Inasmuch as bus and rail nationally constitute only 4 percent of intercity travel, the assembly of the base period (1967) total person trip table focused on the air and automobile modes. Air demand was estimated from the 10 percent sample of ticket sales obtained in the Civil Aeronautics Board's "Domestic Origin-Destination Survey of Airline Passenger Traffic."[2] Estimates for intercity auto travel were based on a 1962 automobile vehicle trip table prepared by a model developed by the Federal Highway Administration; this trip table was projected to 1967 and converted into an automobile passenger trip table. The volume of bus travel was estimated from factors developed from the 1967 Census of Transportation; these factors relate bus travel to the volume of automobile plus air travel for various distance ranges.

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[1] Peat, Marwick, Mitchell & Co., "National Intercity Travel: Development and Implementation of a Demand Forecasting Framework," prepared for the Office of System Analysis and Information, Department of Transportation, Washington, D.C., 1970.

[2] Civil Aeronautics Board, "Domestic Origin-Destination Survey of Airline Traffic," 1970.

Rail was ignored for noncorridor markets on the assumption that for those markets, rail passenger travel is negligible.

An alternative procedure was employed in certain corridors to estimate 1967, 1975, 1980, and 1990 demands for the automobile, air, bus, and rail modes. Results of other studies, where the NEC demand model had been applied to predict future demands for each of these modes, were adapted by PMM&Co. and appropriately inserted into the trip tables. A constant annual growth rate was assumed to adjust the forecasted 1980 and 1990 demands to 1985 and 1995. Hence:

$$D_{1985} = D_{1980} \left(\frac{D_{1990}}{D_{1980}} \right)^{0.5}$$

and

$$D_{1995} = D_{1990} \left(\frac{D_{1990}}{D_{1980}} \right)^{0.5}$$

where D equals the total travel demand between two cities.

To facilitate use of the available air data, the following Standard Metropolitan Statistical Areas (SMSAs) were merged and considered as air hubs:

- o New York, N.Y., Jersey City, N.J., Newark, N.J., Patterson, N.J., Stamford, Conn., Norwalk, Conn.;
- o Harrisburg, Pa., Lancaster, Pa.;
- o Scranton, Pa., Wilkes-Barre, Pa.;
- o Raleigh, N.C., Durham, N.C.;

- Hartford, Conn., Springfield, Mass.;
- Akron, Ohio, Canton, Ohio;
- Dallas, Texas, Ft. Worth, Texas;
- Los Angeles, Calif., Anaheim, Calif.
- W. Palm Beach, Fla., Lauderdale, Fla., Miami, Fla.;
- Seattle, Wash., Tacoma, Wash.;
- Chicago, Ill., Hammond-Gary, Ind.

C. MODAL SHARES

The Modal Split Model

IPT and TLV modal shares for both the preliminary market potential analysis of a nationwide set of HSGT corridors (Chapter IV) and the more detailed patronage and revenue analyses of selected corridors (Chapter V) were estimated using a version of the Cross-Elasticity Modal Split Model[3] which was calibrated using data from the Northeast Corridor.[4] This version of the model estimates modal shares as a function of the following modal attributes: time, cost, and frequency of service. The general form of the model which was used is:

$$\omega_m = e^{\alpha_m} T_{ijm}^{-1.9135} C_{ijm}^{-0.8555} \left(1 - e^{-0.007F_{ijm}}\right)^{0.5536}$$

$$S_m = \frac{\omega_m}{\sum_m \omega_m}$$

where:

S_m = modal share for mode m;

T_{ijm} = door-to-door travel time between cities i and j via mode m;

C_{ijm} = door-to-door travel cost between cities i and j via mode m;

F = average daily one-way frequency of service between cities i and j via mode m; and

αm = modal constant.

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[3] J. M. McLynn, et al., "Analysis and Calibration of a Modal Allocation Model," prepared for the National Bureau of Standards, U.S. Department of Commerce, Washington, D.C., 1967.

[4] "National Bureau of Standards Modeling for the NECTP," prepared for Office of High Speed Ground Transportation, U.S. Department of Transportation, Report No. NECTP-211, Washington, D.C., 1969.

The modal constant reflects the behavior of travelers in choosing among modes with identical times, costs, and frequencies. The constants used in this study are:

Mode	Modal Constant α_m
Air	0.641
HSGT	0.641 and 1.000
Bus	0.127

Automobile was used as the base or reference mode and consequently had a coefficient of e^0 or 1.000 (i.e., $\alpha_m = 0$ for auto). Two modal constants for HSGT were used in the analysis. Although the calibrated rail constant in the NEC model was about twice that of air, the NEC model was calibrated using 1965 travel data, a period of considerable transition in mode choice. More recent and reliable data indicates that the value of rail's modal constant should be closer to that of air. Therefore, the air constant was generally used for the HSGT mode. A series of sensitivity runs using a constant of 1.000 for the HSGT mode were also prepared; this latter value corresponds to that used in the final NEC model.

Frequency was assumed to be infinite for automobile, since the traveler can depart at his convenience. Efforts to calibrate the frequency term for bus suggest that this variable is of little consequence in influencing ridership, assuming that this basic service is available. Therefore, the frequency term for bus was omitted, and the constant for this mode was adjusted to account for the average frequency used to calibrate the NEC model.

Estimation of Modal Attributes

Time, cost and frequency attributes of the four modes were estimated for each city or city pair. The estimation equations were developed from examinations of modal attributes for a number of areas within the country, or, in the case of the HSGT mode, from the performance specifications for the mode. The modal attributes used in Chapter IV (for ranking) and Chapter V (detailed analysis) are described separately below; in general, more accurate estimates were used in the Chapter V analyses of the selected corridors.

Modal Attributes for Chapter IV

Line-Haul Travel Time

Air. Air travel times were those developed in PMM&Co.'s study of national intercity travel.[5] The general form of the equation for travel time, T_{ij}, in minutes between cities i and j is:

$$T_{ij} = (TTF)(21 + d_{ij}/8.33)$$

where:

TTF = travel time factor for indirectness of service; and

d_{ij} = the CAB airline distance between the cities.

For d_{ij} less than 200 miles, it was assumed that flights are nonstop (i.e., that TTF = 1). For d_{ij} greater than 200 miles, the directness of air service depends on the two-way annual travel demand, D_{ij}, as follows:

$$TTF = 4 \text{ when } D_{ij} < 5700$$

[5]"National Intercity Travel. . .," op. cit., pp. 2.30-2.32.

$$TTF = \frac{60}{(D-3,000)^{0.3439}} \text{ when } 5700 < D_{ij} < 20,000$$

$$TTF = 2.7 - \frac{1.7D_{ij}}{60,000} \text{ when } 20,000 < D_{ij} < 60,000$$

$$TTF = 1 \text{ when } D_{ij} > 60,000$$

where D_{ij} is the two-way annual air travel demand between i and j as estimated for the previous analysis period. Actual 1970 air travel was used as an estimate of D_{ij} for the 1975 analysis.

Automobile. Total automobile travel time was estimated as a function of the highway distance. For all forecast periods, interstate standard highways will connect virtually all city pairs in the national HSGT network; therefore, an average speed of about 55 mph or 1.1 minutes per mile was used. This assumes travel on the interstate highways at 60-65 mph with some time loss for access to the true end points of the trip within metropolitan areas. No increase in highway speed was anticipated, and it was assumed for this analysis that increased highway capacity would accommodate increased demand without a degradation of service levels.

Bus. Bus travel times were also estimated as a function of highway mileage. Based on an analysis for this study of scheduled trip times for a number of intercity routes in the 75- to 400-mile range, an average speed of 51 mph of 1.17 minutes per mile was assumed.

HSGT. The analysis of a nationwide set of HSGT corridors considered one Improved Passenger Train (IPT) and two Tracked Levitated

Vehicle (TLV) systems. One alternative TLV system analyzed would be constructed over existing rail rights-of-way. Hence, the mileage for this system was estimated as the current rail mileage, and an average station-to-station speed of 175 mph was assumed. The other TLV system studied was assumed to be constructed on an entirely new right-of-way directly connecting the two cities. Hence, for this system, the mileage was assumed to be 1.05 times the airline distance, and an average speed of 300 mph between stops was assumed.

High-speed ground transportation times were estimated as a function of the anticipated route distance, the nominal average speed, and the time loss associated with intermediate stops. The equations used to estimate the line-haul portion of the trip time for the three options analyzed for the nationwide HSGT network are:

- IPT (80 mph nominal speed)
  $T_{ij} = (0.75 \text{ min./mile})(R_{ij}) + 4.0\ S_{ij}$
- TLV (175 mph nominal speed, use of existing rights-of-way)
  $T_{ij} = (0.34 \text{ min./mile})(R_{ij}) + 6.0\ S_{ij}$
- TLV (300 mph nominal speed, use of new rights-of-way)
  $T_{ij} = (0.20 \text{ min./mile})(1.05\ A_{ij}) + 6.0\ S_{ij}$

where:

T_{ij} = travel time (minutes) between i and j;

R_{ij} = the current rail mileage;

S_{ij} = the number of intermediate stops; and

A_{ij} = the airline mileage

For the analyses of selected corridors, specific average speeds were developed for each IPT mode tested. Those speeds and results are presented in Chapter V. Only the 300 mph TLV mode was examined in selected corridors.

Access and Egress Times

Additional time for access and egress to and from the terminal were added to the air, bus, and HSGT line-haul travel times. The access times also included a terminal time which allowed for the time required for parking, processing, and boarding, and for the uncertainty of access travel time.

Air. For air travel, access and terminal times were computed as follows for the current airport locations:[6]

$$T_i = (2.0 \text{ min./mile})D_i + A_i + 10 \text{ minutes}$$

where:

T_i = access and terminal time for city i;

D_i = distance from CBD to airport, in miles;

$A_i = 6.875 \log_{10}\left(\frac{P_i}{10^5}\right) + 2.75$, $A_i \geq 0$; and

P_i = population of SMSA i.

Bus and HSGT. Three alternative policies for locating HSGT terminals were considered in this study. Many cities are served by rail terminals located only in the CBD, hence continuation of this policy was the first alternative. Suburban railroad stations located adjacent to the beltways in Washington, New York, and Boston have

[6] "National Intercity Travel. . .," op. cit., pp. 2.25-2.26.

attracted significant patronage. Hence, a policy of CBD and beltway terminals was the second alternative, and was the one used for the analyses of Chapter V. Finally, it may be questioned whether the additional cost of constructing TLV on a new right-of-way from the beltway to the CBD is warranted by the additional ridership and revenue resulting therefrom. Hence, a terminal located only at the beltway was the third terminal policy alternative considered in this study.

Based on data collected for the NEC, a relationship was developed for access to bus and HSGT terminals. Access and terminal times were estimated as a function of SMSA population and the terminal location, as follows:

- for CBD terminal only:

$$T_i = 20.0 \log_{10}\left(\frac{P_i}{10^6}\right) + 28.5$$

- for beltway terminal only:

$$T_i = 21.6 \log_{10}\left(\frac{P_i}{10^6}\right) + 29.5$$

- for CBD and beltway terminals:

$$T_i = 23.3 \log_{10}\left(\frac{P_i}{10^6}\right) + 11.5$$

where T_i is the access plus terminal time in minutes, and P_i is the population of SMSA i. Bus access and terminal times were estimated assuming only a CBD terminal, while HSGT times were also computed for the latter two alternative terminal policies.

Line-Haul Trip Cost

Intercity trip costs were adjusted to a 1970-1971 base year cost for use in the modal split model.

Air. Air fares were estimated from 1971 fares (including tax) as follows:

$$F_{ij} = 1080 + 6.7¢/\text{mi.}\ (A_{ij})$$

where F_{ij} is the fare, and A_{ij} the airline mileage between cities i and j.

Automobile. Automobile "perceived" costs were developed from the NEC (1.5¢/passenger mile + tolls), but were revised to reflect inflation occurring since these estimates were developed. Links for which significant tolls are charged were specially identified and a higher cost was used:

- no tolls:

$$F_{ij} = 2.0¢/\text{mile}(d_{ij})$$

- with tolls:

$$F_{ij} = 2.9¢/\text{mile}(d_{ij})$$

where F_{ij} is the cost and d_{ij} is the highway mileage between i and j. These relationships assume a perceived operating cost of 4 cents per vehicle-mile, a toll cost of 1.8 cents per vehicle-mile, and an average occupancy for intercity travel of two persons (driver and one passenger).

__Bus.__ Bus fares were computed using the average revenue per passenger-mile for intercity motor carriers as reported to the Inter-State Commerce Commission for 1970. An examination of bus fares in the various corridors under study indicated that fares were about 0.4 cents per mile higher for routes involving tolls roads; therefore, bus fares were estimated using a procedure similar to that used to compute automobile costs:

- o no tolls:

$$F_{ij} = 3.6¢/\text{mile}(d_{ij})$$

- o with tolls:

$$F_{ij} = 4.0¢/\text{mile}(d_{ij})$$

where F_{ij} and d_{ij} are as defined above.

__HSGT.__ High-speed ground fares were developed using the same pricing policy as was used by the NEC:

- o high-speed rail:

$$F_{ij} = 150 + 7.5¢(1.05\ A_{ij})$$

- o tracked levitated vehicles:

$$F_{ij} = 300 + 8.5¢(1.05\ A_{ij})$$

where F_{ij} and A_{ij} are as defined above. The current rail mileage was not used to estimate IPT fares, since, in some cases, this would result in fares greater than TLV fares because of the circuitous rail routes in some corridors.

Access and Egress Costs

Access and egress costs are generally small as compared to line-haul costs. Because airports are generally farther from the final origins and destinations of travelers within cities and are not as readily accessible by public transportation, a penalty of $2.50 was added to air costs to account for extra cab fares or airport parking. For HSGT and bus modes the access and egress costs were taken as negligibly small, and no corresponding penalty was added to the line haul costs for those modes.

Line-Haul Service Frequencies

Line-haul service frequencies are required by the model only for air and HSGT.

Air. Air frequencies were estimated using a function which related frequency to the air travel demand between the two cities:[7]

$$W_{ij} = 0.0264(D_{ij})^{0.62}$$

where W_{ij} is the two-way frequency of service, and D_{ij} is the estimated annual two-way air travel between i and j.

HSGT. Because of the sensitivity of the modal split model to frequency, it was necessary to choose a hypothetical frequency for HSGT. An experimental frequency of 14 trips per day each way on the national network was assumed; this represents basically an hourly service. If insufficient patronage is generated at 14 trips per day to maintain a reasonable load factor, a corridor will likely have little potential for HSGT service.

[7] "National Intercity Travel. . .," op. cit., pp. 2.32-2.35.

The strong correlation between trip frequency and demand is not unreasonable, since it can readily be observed in actual experience. Individual airlines have increased their share of a market by increasing their frequency, and recent Metroliner experience confirms this relationship. A schedule policy was tested in the analyses of the selected corridors in which frequency was allowed to increase to equilibrium when load factors above 50 percent were generated at a 14 trip per day frequency.

<u>Modal Attributes for the Patronage and Revenue Analyses of Selected Corridors</u> (Pertains to analysis described in Chapter V)

The modal attributes described above were used for both analyses except as noted below. Because of the more detailed analyses conducted in the selected corridors, the following refinements were made to the modal attributes for these corridors:

- <u>Line-Haul Travel Time</u>

  - <u>HSGT</u> - For the analyses of Chapter V, the average speed to be used for IPT in each corridor was determined by site-specific analyses performed for FRA. The site-specific analysis considered the conditions of existing track and facilities and produced estimates of investments required for upgrading and estimates of average speeds attainable. Those estimates and corresponding demand estimates are shown in Chapter V. In addition, as described in Section G of this appendix, three alternate average speeds were used for IPT in each corridor to examine the sensitivity of demand to speed. Since overall average speeds were used which included acceleration and deceleration times and dwell time at stops, the 4 minutes-per-intermediate-stop was eliminated. There was no change in TLV line-haul travel time.

- <u>Air</u> - Travel times for air trips of less than 200 miles were increased by 20 percent to better represent typical travel times in the selected corridors under analysis.

- <u>Auto</u> - No change.

- <u>Bus</u> - No change.

- <u>Access and Egress Times</u>

  All Modes - No Change. HSGT was assumed to have CBD and beltway terminals.

- <u>Line-Haul Trip Cost</u>

  - Air and Bus - Air and bus fares for all markets were changed to the one-way regular or coach fare in effect on August 1, 1972. Intrastate air carrier fares were used where appropriate in California.

  - Auto - No Change.

  - HSGT - IPT and TLV fares were varied according to the fare policies shown in Table A-5.

- <u>Access and Egress Costs</u>

  All Modes - No Change.

- <u>Line-Haul Service Frequencies</u>

  - Air - No Change.

  - HSGT - There was no change from the previously assumed 14 trips per day, except for a series of eight runs designed to test the effects of higher HSGT frequencies. These tests and the frequencies used are summarized in Table A-8.

D. DETAILED 1970 TRAVEL ESTIMATES FOR SELECTED CORRIDORS

Introduction

The reliability of patronage estimates for a future HSGT system is highly dependent on the accuracy of the total travel forecast. For specific regions where recent travel survey data exists, a more reliable estimate of total travel between cities can be obtained by a careful projection of current travel than by using a parametric model. This Section describes the development of 1970 intercity person travel data; Section E describes the methodology that was developed to project the total intercity travel for 1975, 1985, and 1995; and Section F presents the application of the methodology in the selected corridors.

Need for Improved Demand Estimates

The most accurate estimates of intercity passenger travel used in the preliminary HSGT market potential analysis in Chapter IV are those for air travel. The estimates of travel on the other modes, including auto, were demand model estimates and were not generally considered to be as reliable as surveys of observed travel. Since auto ordinarily represents from 75 to 95 percent of a typical intercity travel market, it is vital that auto travel be accurately estimated. Therefore, to obtain more accurate estimates of current total travel in the markets being studied in detail, PMM&Co. examined available local data sources for three corridors:

- o Chicago-Detroit corridor;
- o California corridor; and
- o Seattle-Portland corridor.

The following describes the preparation of detailed 1970 travel estimates for these three corridors.

Chicago-Detroit Corridor

Sources of data available for the Chicago-Detroit are as follows:

- o Data for outbound auto travel from Detroit in 1965 were obtained from the Southeast Michigan Council of Governments (SEMCOG).

- o Similar 1967 auto travel data was obtained from the Detroit Transportation and Land-Use Study (TALUS).

- o Auto travel data from a 1967 screen line survey conducted along a north-south axis through central Michigan between Jackson and Kalamazoo were obtained from the Michigan State Highway Department.

- o Air data were obtained from the 10 percent CAB sample.

- o Bus and rail data for 1967 were obtained from a survey conducted by the Interagency Transportation Council of Michigan of outbound passengers at Detroit bus and rail terminals.

The above data were for travel between the Detroit and Chicago areas only, except for the TALUS data which also included Detroit-Toledo travel. Estimates of travel obtained from the three sets of auto data were within 5 percent of each other.

To estimate travel demands for other city pairs in the Chicago-Detroit corridor, a gravity model was calibrated using 1967 travel between Chicago and Detroit, the 1967 populations of the Chicago and Detroit SMSAs, and the auto distance separating the two cities. The model was validated using Detroit-Toledo auto data and provided an estimate of auto travel which was within 5 percent of the estimate obtained from the TALUS survey. (Air, bus, and rail travel combined between Detroit and Toledo only amount to 4.4 percent of this market.) The model was then used to predict 1967 total travel for all the other city pairs in the corridor. Finally, the 1967 total travel was projected to 1970, utilizing the travel demand projection methodology described in the next section.

California Corridor

County-to-county 1966 auto travel was obtained from a study performed by the California Division of Highways to develop a statewide transportation model for estimating future travel demands.[8] The report contains model estimates of county-to-county auto volumes as well as actual origin-destination counts from the various comprehensive metropolitan area transportation studies throughout the state.

The estimates provided by the model were generally in agreement with actual counts. Where the two numbers were not in agreement, the actual counts were usually selected. Where the numbers differed significantly, however, a more careful examination was necessary. A common pattern of disagreement between the actual count and the model's estimate was the model's underprediction of trips between adjacent counties. Inasmuch as this is believed to be the result of a large

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[8] California Division of Highways, "California Statewide Transportation Study - 1966 Base Year Calibration Report," Sacramento, California, 1972.

number of short trips "just over the boundary," the lower model estimate was selected instead of the actual number. An occupancy factor of 1.7, recommended by the Division of Highways, was used to convert passenger car and pickup truck trips to person trips.

Air data for 1970 was obtained from the following sources:

- The 10 percent CAB sample was used for federally regulated interstate carriers.

- A 1972 rate increase petition filed by Pacific Southwest Airlines (PSA) was obtained from the California Public Utilities Commission (PUC), which regulates intrastate carriers in California. Data were taken from a supporting document filed by PSA which contained historical traffic data for PSA routes.

- Commuter taxi carrier volumes were estimated assuming a 50 percent load factor on all flights. The number of flights in each market and the type of aircraft were obtained from the July 1, 1970, Official Airline Guide.[9]

Bus data were estimated, where possible, from summary tabulations of passenger traffic by route which were provided by Western Greyhound Lines. In some cases, it was impossible to estimate city-to-city travel because traffic was summarized for a long route which served a number of cities. Bus traffic for these city pairs was estimated to be approximately 5 percent of the total of auto and air traffic, a figure derived from an analysis of observed Greyhound traffic for markets in which

[9] Reuben H. Donnelly Corp., Official Airline Guide, July 1, 1970.

the ratio of bus travel to total travel could be identified. Trailways data were not considered because it is not a major carrier in California.

The only rail data available were total passenger counts in the Los Angeles-San Diego market: those were provided from Amtrak's records. Rail patronage is assumed to be negligible elsewhere in comparison with auto, air, and bus travel.

Travel data for all of the above modes was converted to 1970 estimates using the travel demand projection methodology described in the next section.

Seattle-Portland Corridor

Estimates of travel by all modes for the Seattle-Portland corridor are available from studies conducted by PMM&Co. and Wilbur Smith and Associates for the Federal Railroad Administration.[10,11] Automobile travel was estimated by Wilbur Smith and Associates from a screen line survey conducted in 1971 and from average daily traffic counts. Air travel estimates were obtained by PMM&Co. from the 1970 CAB 10 percent survey. Rail travel was estimated by PMM&Co. from 1969 railroad on-line origin-destination passenger counts; these were adjusted to exclude passengers traveling beyond Portland or Seattle. Bus travel was estimated by PMM&Co. from a 1971 Greyhound origin-destination study and from Greyhound and Trailways operating statistics.

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[10] Peat, Marwick, Mitchell & Co., Survey to Determine the Potential for Improved Rail Advanced Vehicle Service - Common Carrier Historical and Survey Data, prepared for the Federal Railroad Administration, Department of Transportation, Washington, D.C., April 1972.

[11] Wilbur Smith and Associates, A Study of the Potential for Improved Rail Advanced Vehicle Service: Highway Analysis, prepared for the Federal Railroad Administration, Department of Transportation, Washington, D.C., July 1972.

E. DEVELOPMENT OF RELATIONSHIPS FOR FORECASTING TOTAL TRAVEL IN SELECTED CORRIDORS

This section describes mathematical functions relating miles of travel per capita to income per capita in the U.S., and relating the number of intercity trips per capita to the miles of travel per capita. In Section F, the mathematical functions are combined with projections of population and income growth to develop forecasts of travel demand in the corridors selected for detailed analysis.

Relationship Between Per Capita Passenger Miles and Per Capita Income

Part of the approach to forecasting total travel was to examine the relationship between per capita intercity passenger miles of travel and per capita personal income (Table A-1). A graph of historical per capita national intercity travel and per capita income in constant dollars is shown in Figure A-1. A least squares fit of the data yielded the relationship:

$$y = 1.77\ x - 203$$

where:

y = per capita passenger-miles of intercity travel; and

x = per capita personal income.

The correlation coefficient (r^2) for this equation was 0.97; the standard error of estimate was 226.

TABLE A-1

PER CAPITA TRAVEL AND INCOME BY YEAR

Year	Per Capita Income Constant 1967 Dollars	Per Capita Passenger Miles of Intercity Travel
1929	1,458	2,140
1940	1,483	2,500
1950	2,065	3,336
1955	2,350	4,320
1960	2,500	4,345
1965	2,820	4,750
1969	3,360	5,570

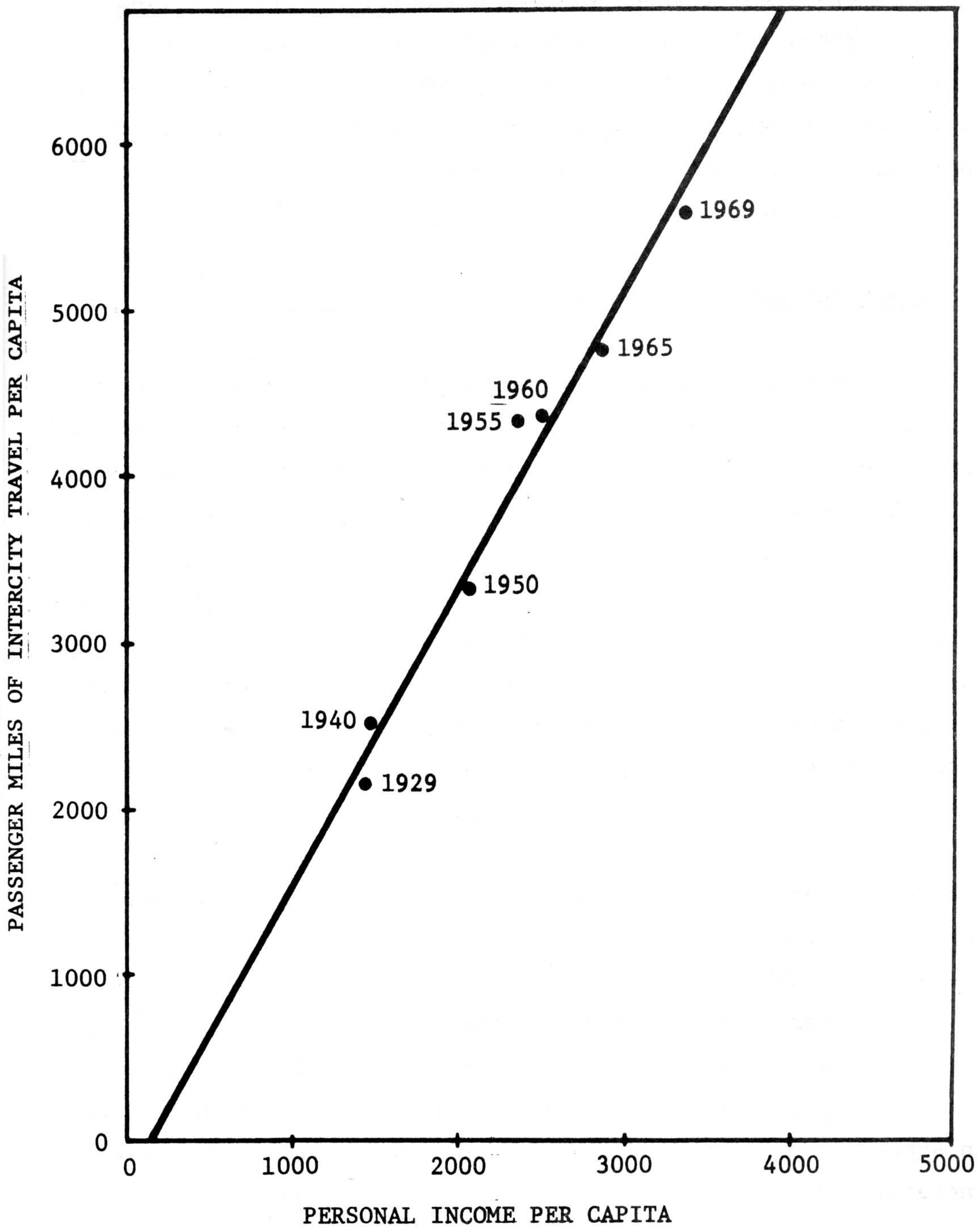

FIGURE A-1

RELATIONSHIP BETWEEN TRAVEL AND INCOME

The correlation of these two variables appears quite strong. Much of the remaining variance may possibly be explained with a variable describing the state of the economy. Because of the difficulty in predicting the timing and severity of future cycles, no attempt was made to incorporate a business cycle variable in the forecasting expression.

Relationship Between Passenger Miles and Passenger Trips

The relationship between per capita passenger-miles of intercity travel and per capita incomes is based on 40 years of observation and appears to predict quite accurately the total intercity passenger miles. The average trip length, however, has also increased during this period, so that the number of per capita intercity trips has increased at a lower rate than the per capita passenger-miles. Therefore, a projection of travel between low-to-medium-length city-pairs based only on the growth in per capita passenger-miles of travel would probably overstate the growth in the number of trips. Hence, the projection of trips between cities based on the growth of per capita passenger-miles must be corrected for the growth in trip length.

Data on average trip length, unfortunately, is not as complete as that on total intercity passenger miles of travel. Two data points are available from the 1957 and 1967 Censuses of Transportation.[12] The average intercity trip length by all modes, as reported by the Censuses of Transportation, increased from 203.7 miles in 1957 to 233.4 miles in 1967, an increase of 14.6 percent in 10 years, or an annual average increase of 1.36 percent per year. This rate of increase was projected into the future, as follows:

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[12] U.S. Bureau of the Census, Census of Transportation, 1967; National Travel Survey TC67-N1. U.S. Government Printing Office, Washington, D.C., 1969.

- 5 years - 7.6 percent;
- 15 years - 22.6 percent; and
- 25 years - 40.5 percent.

These factors were used accordingly to reduce the projected growth in per capita passenger-miles intercity travel to projections which are believed to be more indicative of the projected growth in the number of intercity trips in the markets studied.

F. FORECASTS OF TOTAL TRAVEL IN THE SELECTED CORRIDORS

Population and income forecasts were used in conjunction with the 1970 travel estimates to project intercity passenger travel in the Chicago-Detroit, Seattle-Portland, and California corridors to the years 1975, 1985, and 1995.

Population Forecasts

Population forecasts by metropolitan area were obtained from Alternative Policies on Growth Centers,[13] an unpublished report of the Commission on Population Growth and the American Future. These forecasts were prepared for the years 1980, 1990, and 2000, using the Bureau of the Census Series B and Series E projections. Population forecasts were obtained for each metropolitan area by averaging the metropolitan area forecasts based on Series B with those based on Series E. On a national basis, this is approximately the same as averaging Series C and D. A constant annual growth rate was assumed during each decade to adjust the forecasted 1980, 1990, and 2000 populations to 1975, 1985, and 1995. Hence:

$$P_{1975} = P_{1970}\left(\frac{P_{1980}}{P_{1970}}\right)^{0.5}$$

$$P_{1985} = P_{1980}\left(\frac{P_{1990}}{P_{1980}}\right)^{0.5}$$

$$P_{1995} = P_{1990}\left(\frac{P_{2000}}{P_{1990}}\right)^{0.5}$$

where P is the metropolitan area population.

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13 Commission on Population Growth and the American Future, "Alternative Policies on Growth Centers," 1972.

Income Forecasts

Per capita income forecasts by state for 1980 and 1990 were obtained from Table 5 of "State Projections of Income, Employment, and Population".[14] These forecasts are expressed in constant 1967 dollars and assumed the Series C population forecast levels. Table 5 of this publication was also the source of historical per capita income estimates used to calibrate the relationship between per capita passenger miles of intercity travel and per capita income. Therefore, the forecast income data are consistent with the data used to calibrate the relationship.

Incomes for the mid-decade years of 1975, 1985, and 1995 were interpolated from the forecast decennial years in a manner similar to the interpolation of population, above. Income was assumed to grow at a uniform annual rate between decennial years. Also, the average annual growth rate in income between 1980 and 1990 was assumed to remain constant between 1990 and 1995. The passenger-mile travel growth factors, as related to income growth, for 1975, 1985, and 1995 are determined as follows:

$$FI_{75} = \frac{1.77(I)_{75} - 203}{1.77(I)_{70} - 203}$$

$$FI_{85} = \frac{1.77(I)_{85} - 203}{1.77(I)_{70} - 203}$$

$$FI_{95} = \frac{1.77(I)_{95} - 203}{1.77(I)_{70} - 203}$$

[14] Bureau of Economic Analysis, Department of Commerce, and Economic Research Service, Department of Agriculture, "State Projections of Income, Employment, and Population", Table 5, p. 35, 1972.

where I is the per capita personal income, and $FI_{75,\ 85,\ 95}$ are the per capita passenger-mile travel growth factors estimated for 1975, 1985, and 1995, respectively.

Trip Length Forecasts

To forecast the number of trips, the per capita passenger-miles of travel must be divided by the average trip length. Hence:

$$\frac{\text{passenger-miles forecast year/trip length forecast year}}{\text{passenger-miles 1970/trip length 1970}}$$

or

$$\frac{\text{passenger-miles forecast year}}{\text{passenger-miles 1970}} \times \frac{\text{trip length 1970}}{\text{trip length forecast year}}$$

or, simply, the growth in travel divided by the growth in trip length. For the forecast years, the trip length factors are:

$$FL_{75} = \frac{1}{1.076} = 0.92$$

$$FL_{85} = \frac{1}{1.226} = 0.82$$

$$FL_{95} = \frac{1}{1.405} = 0.71$$

where $FL_{75,\ 85,\ 95}$ is the inverse of the forecast relative increase in trip length for 1975, 1985, and 1995 respectively.

Development of Demand Factor

Combining the three projection factors gives, for example, for 1975:

$$D_{1975} = (D_{1970}) \left(\frac{(P_1 + P_2)_{75}}{(P_1 + P_2)_{70}}\right)\left(\frac{1.77(I)_{75} - 203}{1.77(I)_{70} - 203}\right) (0.92)$$

where P_1 and P_2 are the populations of the two cities of an interchange, and D is the travel demand. Based on the forecasts of population and income, Table A-2 summarizes the relative increase in travel demand from 1970 to 1975, 1985, and 1995 for the major corridors considered in this study.

Forecasts of 1975, 1985, and 1995 Total Demands for the Selected Study Corridors

The 1970 total intercity travel demands estimated for the three study corridors were projected to the years 1975, 1985, and 1995 using the demand projected factors presented in Table A-2. Table A-3 presents the 1975, 1985, and 1995 estimated total travel demands by city pair for the Chicago-Detroit, California, and Seattle-Portland corridors.

By far the greatest travel volume occurs in the California corridor. The total amount of travel in the Chicago-Detroit corridor is about 10 percent of the total travel in the California corridor. Further, the volume of travel in the Seattle-Portland corridor is half of the travel in the Chicago-Detroit corridor and 5 percent of the travel in the California corridor.

Over half of the total trips in the California corridor - 27,000,000 trips in 1970 - is in the Los Angeles - San Diego market. Other major markets in this corridor include San Francisco - Los Angeles and San Francisco - Sacramento, and there are several other markets of over 1,000,000 annual person trips. In contrast, there are only two markets of over 1,000,000 trips in the Chicago - Detroit corridor via Toledo (Toledo - Detroit and Chicago - Detroit) and only one such market in the Seattle - Portland corridor.

TABLE A-2

SUMMARY OF DEMAND PROJECTION FACTORS

Corridor	Year	(A) Population	(B) Income	(C) Trip Length	(A) & (B) & (C) COMPOSITE FACTOR
Chicago-Detroit	1975	1.04	1.19	.92	1.14
	1985	1.18	1.56	.82	1.47
	1995	1.30	1.98	.71	1.82
Seattle-Portland	1975	1.10	1.19	.92	1.20
	1985	1.36	1.57	.82	1.75
	1995	1.65	1.98	.71	2.32
Los Angeles-San Diego	1975	1.15	1.19	.92	1.26
	1985	1.50	1.54	.82	1.89
	1995	1.91	1.95	.71	2.64
Los Angeles-San Francisco	1975	1.13	1.19	.92	1.24
	1985	1.44	1.54	.82	1.82
	1995	1.80	1.96	.71	2.50
San Francisco-Sacramento	1975	1.12	1.19	.92	1.23
	1985	1.39	1.54	.82	1.76
	1995	1.71	1.95	.71	2,37

TABLE A-3

ESTIMATED TOTAL TRAVEL DEMAND BY CORRIDOR, CITY-PAIR, AND YEAR

Corridor	City-Pair	Year 1970	1975	1985	1995
Chicago-Detroit (292 route miles)	Chicago-Detroit	1,386,000	1,566,180	2,037,420	2,578,000
	Chicago-South Bend	955,000	1,079,150	1,403,850	1,776,300
	Chicago-Toledo	332,000	375,000	488,000	617,500
	South Bend-Toledo	31,500	35,600	46,300	58,600
	South Bend-Detroit	93,000	105,090	136,700	173,000
	Toledo-Detroit	2,672,000	3,019,360	3,927,800	4,970,000
		5,469,500	6,180,380	8,040,070	10,173,400
Seattle-Portland (186 route miles)	Seattle-Portland	2,612,600	3,108,300	4,440,400	5,772,500
California (638 route miles)	Sacramento-San Francisco	5,087,600	6,206,870	8,700,000	11,500,000
	Sacramento-Stockton	1,289,600	1,573,300	2,205,200	2,915,000
	Sacramento-Fresno	264,600	325,468	468,342	630,000
	Sacramento-Bakersfield	51,700	63,591	91,500	123,000
	Sacramento-Los Angeles	1,374,220	1,690,290	2,432,400	3,270,000
	San Francisco-Stockton	3,023,550	3,688,700	5,170,300	6,833,000
	San Francisco-Fresno	607,800	662,500	1,075,800	1,446,600
	San Francisco-Bakersfield	205,200	252,400	363,200	448,400
	San Francisco-Los Angeles	8,200,000	10,086,000	14,500,000	19,516,000
	Stockton-Fresno	152,750	187,882	270,400	363,545
	Stockton-Bakersfield	36,680	32,816	47,200	63,500
	Stockton-Los Angeles	590,500	726,300	1,045,200	1,405,400
	Fresno-Bakersfield	512,700	630,600	907,500	1,220,200
	Fresno-Los Angeles	1,042,650	1,282,500	1,845,500	2,481,500
	Fresno-San Diego	54,400	66,900	96,300	129,500
	Bakersfield-Los Angeles	3,252,400	4,000,500	5,756,700	7,740,700
	Bakersfield-San Diego	68,250	83,950	120,800	162,400
	Los Angeles-San Diego	27,000,000	33,750,000	49,680,000	68,040,000
		52,804,600	65,310,567	94,776,342	128,328,745

G. RESULTS OF THE MARKET POTENTIAL TEST IN SELECTED CORRIDORS

Market Potential Tests

Parametric tests were conducted with the modal split model described above to estimate modal shares under alternative future conditions. These tests, summarized in Tables A-4 through A-6, examined variations in IPT line-haul speed; different pricing policies, sensitivity to the modal constant, α; sensitivity to HSGT trip frequency, and the impact of increases in energy costs.

The average IPT speeds assumed for each corridor are presented in Table A-4. Since these are average terminal-to-terminal speeds, no additional time was allowed for intermediate stops. For the TLV tests, travel time was estimated assuming a cruising speed of 300 mph between stops and six minutes of lost time for each intermediate stop. These assumptions yielded average speeds of 200 to 240 mph. The alternative fare policies tested are summarized in Table A-5. The extra low HSGT fares in the California corridor were designed to be lower than current intrastate air fares.

Two assumptions regarding increased energy cost were made: 1.5 times and 3.0 times current prices. The assumed impact of the increased energy cost on the total cost of travel for each of the modes is presented in Table A-6. The impact of increased energy can be calculated as:

$$C_T = C_n + F_e(C_e)$$

where C_T = total cost factor;

TABLE A-4

IPT TEST SPEEDS

Speed	Chicago-Detroit	Seattle-Portland	Los Angeles-San Diego
High	105 mph	95 mph	95 mph
Medium	90 mph	80 mph	80 mph
Low	75 mph	65 mph	65 mph

TABLE A-5

TEST FARES

IPT

Fare	Chicago-Detroit	Seattle-Portland	Los Angeles-San Diego
A	\$1.72+8.6¢/Pas.Mi.	\$1.72+8.6¢/Pas.Mi.	\$1.72+8.6¢/Pas.Mi.
B			\$1.25+5¢/Pas. Mi.

TLV

Fare	Seattle-Portland	Sacramento-San Diego
A	\$3.44+9.7¢/Pas. Mi.	\$3.44+9.7¢/Pas. Mi.
B		\$2.51+5.7¢/Pas. Mi.
C		\$1.25+5.0¢/Pas. Mi.

TABLE A-6

ENERGY CRISES COST FACTORS

	Cost of Travel		Total Cost Factor (C_T) Energy Crisis Equals: (F_e)	
Mode	Non-Energy Related Portion (C_n)	Energy Related Portion (C_e)	1.5	3.0
Auto	0%	100%	1.5	3.0
Air	90	10	1.05	1.20
Bus	95	5	1.025	1.10
IPT	97.5	2.5	1.0125	1.05
TLV	95	5	1.025	1.10

C_n = non-energy related portion of cost of travel;

C_e = energy related portion of cost of travel; and

F_e = energy cost factor.

Since the preponderance of the perceived costs (p. A-16) for automobile travel are for fuel (there are no significant tolls in these corridors), it was assumed that a 100% increase in automobile fuel cost would result in a 100% increase in the automobile travel cost.

Test Results

Patronage and revenue forecasts for the IPT and TLV systems described above are presented in Tables A-7 and A-8 respectively. Revenue passenger-miles were calculated on a different basis than operating passenger miles because of the desire for IPT fares to be lower than TLV fares for the same routes. As explained previously (p. A-17), use of the current rail mileage to calculate the IPT fares might result in a higher IPT fare than TLV fare on some routes. Both IPT and TLV fares and revenues were therefore calculated using 1.05 times the air mileage. To estimate certain aspects of operating costs, operating passenger-miles for IPT were calculated using current rail mileage.

IPT achieved its largest market share in the Seattle-Portland corridor. Under similar conditions of speed, fare, modal constant, and energy crises, IPT achieves about a 50% greater penetration in the Seattle-Portland market than in Chicago-Detroit. Even when a lower fare structure was assumed between Los Angeles and San Diego, with all other conditions remaining equal, a greater market penetration was achieved in the Seattle-Portland market. In general, the modal split model is

TABLE A-7

IMPROVED PASSENGER TRAIN MARKET SHARE SENSITIVITY TESTS

Corridor	Parameters: Speed (mph)	Parameters: Fare	Parameters: Rail Mode Constant	Parameters: Energy Crisis	IPT Market Share (%)	Average Trip Length	1975 Passengers (000)	1975 Revenue Passenger Miles (000,000)	1975 Operating Passenger Miles (000,000)	1985 Passengers (000)	1985 Revenue Passenger Miles (000,000)	1985 Operating Passenger Miles (000,000)
Chicago-Detroit	90	A	0.641	no	5.2	160.5	323.9	52.0	51.9	429.8	69.0	68.9
	105	A	0.641	no	6.1	165.3	380.5	62.9	62.8	504.7	82.6	82.4
(292 route miles)	75	A	0.641	no	4.4	156.6	272.0	42.6	42.5	360.9	56.5	56.3
	90	A	1.000	no	7.2	160.8	452.2	72.7	72.6	601.6	96.5	96.3
	105	A	1.000	no	8.4	165.4	521.9	86.3	86.2	692.5	114.4	114.4
	75	A	1.000	no	6.1	156.4	381.7	59.7	59.5	506.4	79.2	79.0
	90	A	0.641	1.5	6.6	159.1	413.5	64.2	64.1	548.6	85.2	85.0
	90	A	0.641	3.0	9.6	145.4	598.9	87.1	86.7	794.5	115.5	115.0
Portland-Seattle	80	A	0.641	no	6.4	162.8	200.9	32.7	37.4	292.7	47.6	54.4
	95	A	0.641	no	7.9	162.8	248.0	40.3	46.1	361.3	58.8	67.2
(186 route miles)	65	A	0.641	no	4.9	162.8	153.8	25.0	28.6	224.1	36.5	41.7
	80	A	1.000	no	8.9	162.8	282.5	45.9	52.5	411.6	66.9	76.5
	95	A	1.000	no	11.1	162.8	348.5	56.7	64.8	507.7	82.6	94.4
	65	A	1.000	no	6.9	162.8	216.6	35.3	40.3	315.6	51.4	58.7
	80	A	0.641	1.5	7.9	162.8	248.0	40.4	46.1	361.3	58.8	67.2
	80	A	0.641	3.0	10.5	162.8	329.6	53.6	61.3	480.2	78.2	89.3
San Diego-Los Angeles	80	B	0.641	no	5.7	113.0	1,942.9	220.3	246.8	2,916.7	330.8	370.4
	95	B	0.641	no	6.8	113.0	2,317.9	262.8	294.4	3,479.6	394.6	441.9
	65	B	0.641	no	4.6	113.0	1,568.0	177.8	199.1	2,353.8	266.9	298.9
(127 route miles)	80	A	0.641	no	3.8	113.0	1,295.3	146.9	164.5	1,944.5	220.5	246.9
	80	B	1.000	no	8.8	113.0	2,761.0	313.1	350.7	4,144.8	470.0	526.4
	95	B	1.000	no	9.5	113.0	3,238.3	367.2	411.3	4,861.2	551.3	617.4
	65	B	1.000	no	7.6	113.0	2,215.7	251.3	281.4	3,326.1	377.2	422.4
	80	B	0.641	1.5	7.2	113.0	2,454.3	278.3	311.7	3,684.3	417.8	467.9
	80	B	0.641	3.0	10.1	113.0	3,442.8	390.4	437.2	5,168.2	586.1	656.4

A = $1.72 + $0.086 per mile
B = $1.25 + $0.050 per mile

slightly inelastic to fare when total demand is held constant. Consequently, revenue tends to increase when fares are increased. Assumption of a higher modal constant for HSGT yields about 40% greater traffic in all cases, while the three-fold increase in energy costs improves IPT's market share by as much as 80%. While the most optimistic case of highest speed, lowest fare, a modal constant of 1.0, and a three-fold increase in energy costs was not tested, it might yield IPT market shares as high as 16 to 17% in the Seattle-Portland corridor.

Because of the significant differences in total travel, an examination of passengers and passenger-miles suggests a different ranking of corridors. For similar conditions, Portland-Seattle has the lowest number of passengers and passenger-miles, while Los Angeles-San Diego has by far the largest volumes. Of the three corridors examined, Portland-Seattle apparently has the optimum stage length for IPT in terms of attracting the largest market share, but the greatest volumes of travelers are attracted in the Los Angeles-San Diego corridor.

Results of the TLV tests in selected markets are presented in Table A-8. The entire California Corridor was examined instead of the Chicago-Detroit Corridor. Inasmuch as the market penetration was substantial, and since TLV was assumed to have a lower train capacity than IPT (700 passengers per IPT train versus 500 passengers per TLV train) several additional tests were conducted based on the assumption that TLV train frequencies would be greater than 14 per day to properly serve the demand.

TLV generally achieves a greater market share than IPT because of its greater speed and in spite of its greater cost. The highest market

TABLE A-8

TRACK LEVITATED VEHICLE MARKET SHARE SENSITIVITY TESTS

Corridor	Frequency no/day	Fare	Energy Crisis	TLV Market Share (%)	Average Trip Length	1985 Passengers (000)	1985 Passenger Miles (000,000)	1995 Passengers (000)	1995 Passenger Miles (000,000)
Portland-	14	A	no	23.0	162.8	1,051.9	171.2	1,394.1	226.9
Seattle	14	A	1.5	26.6	162.8	1,216.6	198.0	1,612.3	262.4
(166 route miles)	14	A	3.0	32.4	162.8	1,481.9	241.2	1,963.8	319.6
San Diego-Los Angeles	14	B	no	9.3	113.0	4,758.8	539.7	6,644.1	753.4
(114 route miles)	14	C	no	11.3	113.0	5,782.3	655.7	8,072.9	915.5
	14	B	1.5	11.4	113.0	5,833.4	661.5	8,144.4	923.6
	14	B	3.0	14.0	113.0	6,955.2	788.7	10,001.9	1,134.2
	27	B	no	12.6	113.0	6,448.5	731.3	9,001.7	1,020.8
	47	B	3.0	25.1	113.0	12,469.7	1,456.5	17,931.9	2,033.5
	27	A	no	8.7	113.0	4,451.8	504.8	6,215.5	704.8
	47	A	3.0	18.2	113.0	9,313.0	1,056.1	13,002.4	1,474.5
San Diego-Sacramento	14	B	no	12.5	168.7	12,238.3	2,064.9	16,824.6	2,835.4
	14	C	no	15.0	164.9	14,609.9	2,410.3	20,086.1	3,310.4
(638 route miles)	14	B	1.5	15.0	162.6	14,600.2	2,373.6	20,072.7	3,250.9
	14	B	3.0	18.4	155.7	17,954.2	2,795.9	24,990.0	3,890.6
	23	B	no	16.0	166.5	15,615.5	2,600.4	21,479.8	3,572.5
	32	B	3.0	28.3	151.6	27,602.5	4,183.2	38,002.2	5,753.9
	23	A	no	11.3	166.3	11,046.8	1,836.9	15,191.1	2,522.8
	32	A	3.0	20.9	165.1	20,473.6	3,380.0	28,179.0	4,646.8

A = $3.44 + 0.097 per mile
B = $2.51 + 0.057 per mile
C = $1.25 + 0.050 per mile

penetrations, up to 32.4% under energy crisis conditions, were achieved in the Seattle-Portland corridor. In spite of lower fares and higher frequencies in the San Diego-Los Angeles corridor, TLV's market penetration in this corridor is generally lower than in the Seattle-Portland corridor. With a high frequency, a lower fare, and a three-fold increase in energy costs, TLV captures a significant 25% of the San Diego-Los Angeles market. In the complete California corridor, TLV generally captures a somewhat higher market share than it does in the Los Angeles-San Diego segment. It should be noted that the San Diego-Los Angeles corridor is a subset of the complete California corridor, and that the frequency indicated for the complete California corridor was not assumed for this shorter segment. Because of the higher density of traffic achieved on the Los Angeles-San Diego segment, a higher service frequency was assumed for this segment than was assumed for the remainder of the California corridor: 27 instead of 23 and 47 instead of 32 daily trips. Traffic density in the Portland-Seattle corridor was never sufficient to warrant increased service.

The corresponding modal shares for all modes for each of the tests summarized in Tables A-7 and A-8 are presented in Tables A-9 and A-10, respectively. When IPT is the competing high speed ground mode, automobile always receives the largest share of, and usually dominates, the markets. In the Chicago-Detroit market, it never receives less than 60% of the trips. Air attracts the second largest share, except in the Seattle-Portland corridor, where bus ranks second. Energy crises cause a significant shift away from automobile and to the common carrier modes, approximately in proportion to their shares. A similar pattern appears

TABLE A-9

MARKET SHARES

IPT TESTS[15]

Corridor	Parameters				Market Share (%)			
	Speed (mph)	Fare	Rail Mode Coefficient	Fuel Price Factor	IPT	Air	Bus	Auto
Chicago-Detroit (292 route miles)	90	A	0.641	no	5.2	9.7	7.5	77.6
	105	A	0.641	no	6.1	9.7	7.7	76.5
	75	A	0.641	no	4.4	9.7	7.7	77.9
	90	A	1.000	no	7.2	9.4	7.3	76.0
	105	A	1.000	no	8.4	9.3	7.2	75.2
	75	A	1.000	no	6.1	9.6	7.4	76.8
	90	A	0.641	1.5	6.6	11.7	9.8	71.8
	90	A	0.641	3.0	9.6	13.4	13.3	63.7
Portland-Seattle (186 route miles)	80	A	0.641	no	6.4	14.1	18.2	61.4
	95	A	0.641	no	7.9	13.8	17.7	60.5
	65	A	0.641	no	4.9	14.3	18.4	62.4
	80	A	1.000	no	8.9	13.6	17.7	59.8
	95	A	1.000	no	11.1	13.4	17.2	58.4
	65	A	1.000	no	6.9	14.1	18.0	61.1
	80	A	0.641	1.5	7.9	16.7	21.8	53.6
	80	A	0.641	3.0	10.5	20.5	28.3	40.7
San Diego-Los Angeles (127 route miles)	80	B	0.641	no	5.7	16.2	9.2	68.9
	95	B	0.641	no	6.8	16.1	9.1	68.0
	65	B	0.641	no	4.6	16.4	9.3	69.7
	80	A	0.641	no	3.8	16.6	9.4	70.2
	80	B	1.000	no	8.8	15.8	9.1	67.0
	95	B	1.000	no	9.5	15.6	8.8	66.1
	65	B	1.000	no	7.6	16.1	9.1	68.2
	80	B	0.641	1.5	7.2	19.7	11.4	61.6
	80	B	0.641	3.0	10.1	25.4	15.5	49.0

A = \$1.72 + \$0.086 per mile
B = \$1.25 + \$0.050 per mile

15. Market shares shown in the table apply to 1975 and following years. For comparison, based on somewhat incomplete data, the rail share of the San Diego-Los Angeles market in 1970 was less than 1%. The rail share of the Chicago-Detroit city-pair in 1967 was 4.7%; and that of Portlant-Seattle in 1970 was 2.2% The modal share model was calibrated on data from the Northeast Corridor; and when applied to other corridors, the model appears to overestimate the bus share of the market. No attempt was made to correct that feature of the model because the effect on the HSGT share of the market is minor. The major changes would be to the auto and bus shares of the market, and those systems were not being examined.

TABLE A-10

MARKET SHARES

TLV TESTS[16]

Corridor	Parameters: Frequency No./Day	Fare	Fuel Price Factor	Market Share (%): TLV	Air	Bus	Auto
Portland-Seattle (166 route miles)	14	A	no	23.0	13.4	14.2	49.4
	14	A	1.5	26.6	15.3	16.6	41.5
	14	A	3.0	32.4	17.7	20.2	29.6
San Diego-Los Angeles (114 route miles)	14	B	no	9.3	15.6	8.5	66.5
	14	C	no	11.3	15.3	8.3	65.0
	14	B	1.5	11.4	18.9	10.5	59.2
	14	B	3.0	14.0	23.9	15.6	46.5
	27	B	no	12.6	15.1	8.3	64.1
	47	B	3.0	25.1	21.2	12.5	41.2
	27	A	no	8.7	15.8	8.6	66.9
	47	A	3.0	18.2	23.2	13.7	44.9
San Diego-Sacramento (638 route miles)	14	B	no	12.5	21.0	8.1	58.4
	14	C	no	15.0	20.4	7.8	56.2
	14	B	1.5	15.0	23.5	9.8	51.7
	14	B	3.0	18.4	27.4	13.8	40.4
	23	B	no	16.0	20.3	7.8	55.8
	32	B	3.0	28.3	24.5	11.4	35.9
	23	A	no	11.3	21.4	8.3	59.0
	32	A	3.0	20.9	26.7	12.8	39.5

A = \$3.44 + 0.097 per mile
B = \$2.51 + 0.057 per mile
C = \$1.25 + 0.050 per mile

16. Market shares shown in the table apply to 1985 and following years. For comparison, the rail share of the Portland-Seattle market in 1970 was 2.2%.

The modal share model was calibrated on data from the Northeast Corridor; and when applied to other corridors, the model appears to over-estimate the bus share of the market. No attempt was made to correct that feature of the model because the effect on the HSGT share of the market is minor. The major changes would be to the auto and bus shares of the market, and those systems were not being examined.

in Table A-10, except that TLV has a greater market penetration in each corridor than IPT. Under conditions of a three-fold increase in energy costs, TLV captures the largest market share of any of the modes in the Seattle-Portland corridor.

Implications of the NEC Demand Model on Total Forecast Travel

The analyses discussed above are predicated on the assumption that for the range of alternatives being considered, the total demand for intercity travel is essentially invariant with the supply. Hence, it was assumed that users of a new HSGT service would be diverted from the existing modes and that the new service would not induce any additional travel. Similarly, it was assumed that increases in energy costs would divert travel from automobile to other modes and not result in a decrease in the total volume of travel. This section examines the implications of relaxing the assumption of invariant demand and applying the NEC demand forecasting model to estimate travel induced by a new mode or suppressed by an energy crisis.

The NEC demand model is formulated such that the addition of a new mode, such as HSGT, increases total travel as a function of the new mode's attributes. Conversely, increasing the impedance attributes (such as cost) of any mode decreases total travel as a function of the increase in the impedance.

The NEC model formulation for total demand, D_t, is:

$$D_t = f(P_1 P_2)\left(\sum_{m=1}^{k} \omega_m{}^2 \right)^{.34}$$

where $f(P_1 P_2)$ is a socio-economic function which is constant for the purposes of estimating induced demand, and ω_m is the modal attributes characteristic as explained above in Section C of this appendix.

Total demand under a new set of conditions, D_t', can be obtained from the projected demand, D_p, estimated in Section F as follows:

$$D_t' = \frac{\left(\sum_{m=1}^{n} \omega_m'^2\right)^{.34}}{\left(\sum_{m=1}^{k} \omega_m^2\right)^{.34}} D_p$$

where the ω_m' s are the new characteristics of the modes, and k and n are the numbers of modes for the original and new sets of conditions, respectively.

Travel induced by a new mode, then, can be determined by adding the ω^2 for the new mode to the sum for the existing modes:

$$\left(\sum_{m=1}^{n} \omega_m'^2\right) = \left(\sum_{m=1}^{k} \omega_m^2\right) + \omega_n^2$$

where n = k + 1.

Accordingly, the magnitude of the induced travel depends not only on the attributes of the new mode (from which ω_n is calculated), but also on the distrubution of travel among the original modes. An approximate relationship can be developed, based on the tests conducted, between the proportional increase in total travel and the resultant share of the market which the new mode attracts (Figure A-2). It can be seen that the new mode must penetrate 12 to 15% of a market before a significant amount of additional travel is induced. When the new mode captures about 40% of the market, induced travel accounts for half or more of the new mode's volume.

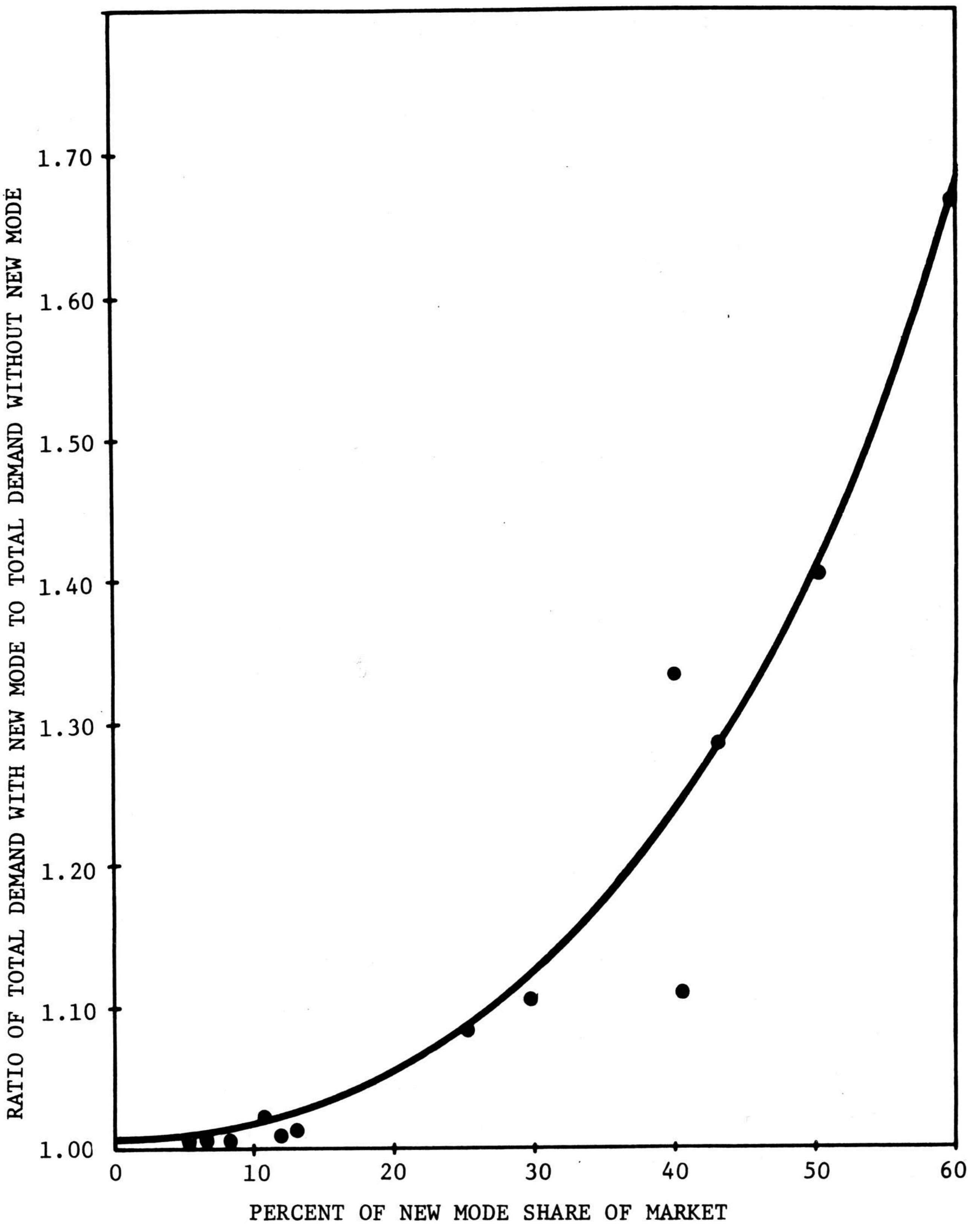

FIGURE A-2

ESTIMATED IMPACT OF NEW MODE ON TOTAL DEMAND
(NEC MODEL)

A similar analysis of the impact of increased energy cost on total travel can be developed by considering the sensitivity of modal costs to energy costs. It can be seen from Table A-6 that the sensitivity of auto cost to changes in energy cost is an order of magnitude greater than that of other modes. Since the cost impact on total demand is felt through the cost term, $(C)^{-.855}$, of the ω calculation (p. A-8), the resulting change in ω is almost linear with cost, and the ratio of demand with the energy crisis to that without is:

$$\frac{D_t'}{D_P} = \frac{\left(\sum_{m=1}^{n} \omega_m'^{2}\right)^{.34}}{\left(\sum_{m=1}^{n} \omega_m^{2}\right)^{.34}}$$

where $\omega_m' = \omega_m \left(\frac{C^1}{C}\right)^{-.855}$ and $\left(\frac{C^1}{C}\right) = C_T$ (total cost factor for appropriate energy crises from Table A-6), or $\omega_m' = \omega_m (C_T)^{-.855}$.

Since the change in total demand is dominated by the change in auto cost, an approximate relationship can be developed between the ratio of demands and automobiles' share of the market (Figure A-3). When the automobile share is small, the decline in total demand is controlled by the relatively small increases in common carrier fares; when the automobile share is large, the decline in travel is dominated by the decline in auto travel. The overall implication of the demand model is that travel volumes for other modes do not increase significantly when the impedance of a heavily used mode increases substantially; rather the total volume of travel is suppressed. Thus, under conditions of a severe energy crises, HSGT's market share is increased; but the overall volume of travel is so reduced as to nearly offset the effect of the increased HSGT share.

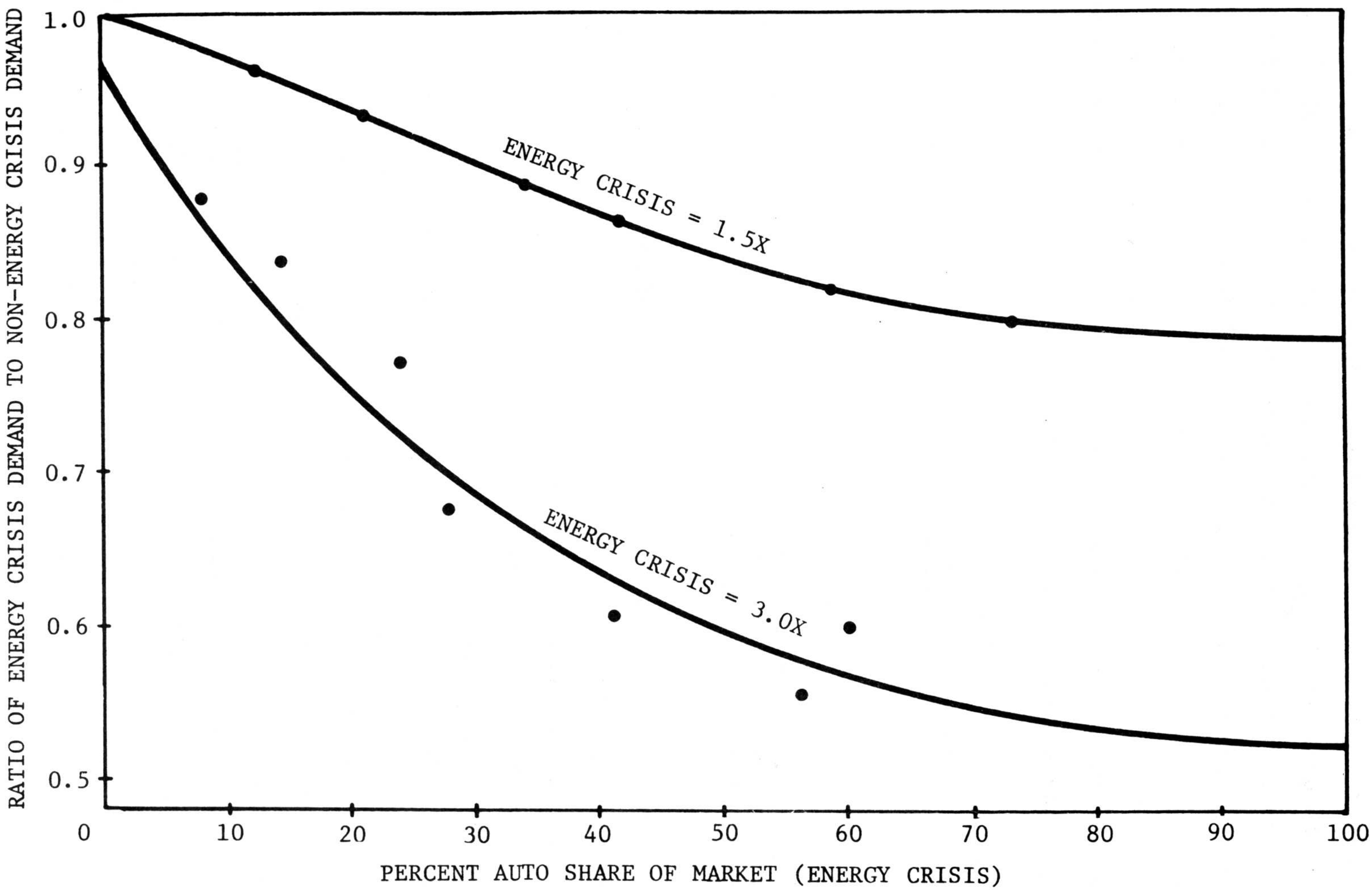

FIGURE A-3

ESTIMATED IMPACT OF ENERGY CRISIS ON TOTAL DEMAND (NEC MODEL)

For the combined effect of the induced increase in demand due to improved HSGT impedance and lower total demand due to fuel crisis we could expect the following:

- IPT, which has only a modest market penetration, would induce little wholly new demand. Tht total volume, dominated by auto, would be strongly sensitive to the high fuel cost. The combined effect could mean that fuel crisis enhancement of IPT would be largely negated.

- TLV, which penetrates the market more strongly, can induce greater demand than IPT and, by decreasing the auto share, reduces the overall demand loss under the high fuel cost. As a result, the combined effect for TLV could be an improvement in the non-fuel-crisis demand for TLV over that estimated without allowing for induced demand, compled with only a modest decrease in the enhancement of TLV demand due to the fuel crisis.

The discussions of induced demand effects should be viewed in the contest that no unambiguous data exists to verify the demand model indications. In particular, we have no documented instances of the effects of either a sudden radical improvement in a mode or of a drastic deteıioration such as an energy crisis might create. We might speculate that habit and long-term travel commitments would introduce a lag into the drop in total demand if auto were to become much less attractive. Over the short term, therefore, the estimation technique of modal split of projected demand might be valid. For the long term, changes in the organizations and operations of geographically widely dispersed businesses and relocations of both residence and business might be necessary to permit the very drastic drop in total demand indicated by Figure A-3.

APPENDIX B

NET PRESENT VALUE AND BREAKEVEN ANALYSIS

Two measures of the potential economic viability of a new system such as IPT or TLV are the net present value (NPV), and the breakeven demand (or breakeven fare, for a given demand). Values of these measures are presented in Chapter V for a variety of possible systems and conditions, and corresponding inferences are drawn as to system viability.

The purpose of this appendix is to develop the mathematical relationships from which NPV and breakeven demand are estimated.

Net Present Value

Suppose A dollars are borrowed at an interest rate i compounded annually. After one year the debtor owes $A(1+i)$ dollars. If no payment is made, the debtor owes $A(1+i)^2$ dollars after two years. After n years, the debtor owes $A(1+i)^n$ dollars. Thus A dollars today are worth $A(1+i)^n$ dollars n years from now. Conversely, the "present value" of A dollars receivable n years in the future is $A(1+i)^{-n}$ dollars.

When an IPT or TLV system is implemented, a cash flow, A_n, will be generated in each year n during the life of the system. The cash flow, A_n, will be made up of positive components resulting from revenues, and negative components resulting from costs. Any particular A_n can therefore be either positive or negative.

Each A_n can be regarded as a payment receivable from the system (or payable to the system, if A_n is negative) in year n. Thus each A_n has a present value, as of the start of system operation (defined as year n=0), of $A_n(1+i)^{-n}$. The present value of the entire sequence of cash flows, A_n, taken over the system life of N years, is therefore

$$\sum_{n=1}^{N} A_n (1+i)^{-n}$$

Since the A_n are net flows of revenues minus costs, the above sum is called the net present value (NPV) of the system. It is occasionally desirable (as in Chapter V) to use a reference date for NPV other than the starting date of system operation. If the reference date is taken as M years prior to the start of system operation (n=0), the NPV is given by:

$$NPV = \frac{1}{(1+i)^M} \sum_{n=1}^{N} A_n (1+i)^{-n}$$

or equivalently, by

$$NPV = \sum_{n=1}^{N} A_n (1+i)^{-(n+M)}$$

From the foregoing, it follows that the NPV is an amount equal to that lump sum payment, receivable as of the reference date (n=-M), which would be interchangeable with the entire sequence of cash flows generated by the system. The NPV appears, therefore, to be a fair measure of the economic viability of a system.

If each A_n is comprised of components of revenue and cost, A_{jn}, where

$$A_n = \sum_j A_{jn}$$

it is often computationally more convenient to evaluate the NPV via the components, since

$$NPV = \sum_{n=1}^{N} (\sum_{j} A_{jn}) \ (1+i)^{-(n+M)}$$

$$= \sum_{j} \left[\sum_{n=1}^{N} A_{jn} (1+i)^{-(n+M)} \right]$$

$$= \sum_{j} PV_{j}$$

where PV_j is the present value of the jth component of the A_n's.

For an IPT or TLV system, the significant components are: Revenue; Land Purchase Cost (zero for IPT); Right-of-Way Investment Cost; Vehicle Purchase Cost; Fixed Operating Cost; Variable Operating Cost.

In what follows, relationships will be derived for computing the present values of each of these components. Since revenue makes a positive contribution to NPV and costs make negative contributions, the NPV will therefore equal the present value of the revenue minus the sum of the present values of the costs.

Revenue

Let
- r = revenue per passenger mile (\$)
- D_n = demand (passenger miles) in year n of system operation
- g = annual growth rate of demand

Then $D_n = D_1 \ (1+g)^{n-1}$

Assume that the effective use of revenue accumulated in any year does not start until the end of that year.

Then the present value of revenue accumulated in year n is

$$rD_1 (1+g)^{n-1} (1+i)^{-(n+M)}$$

The present value of revenue accumulated over the life of the system is thus

$$\sum_{n=1}^{N} rD_1 (1+g)^{n-1} (1+i)^{-(n+M)}$$

which can be expressed as

$$PV_{revenue} = \frac{rD_1}{(i-g)(1+i)^M} \left[1- \left(\frac{1+g}{1+i}\right)^N \right]$$

Land Purchase Cost

Let L be the initial investment cost for land, for the TLV system. (No land is to be purchased for IPT.) It is assumed that L is obligated in K equal amounts, $\frac{L}{K}$, at the end of each of the K years preceding the start of system operation. The interest owed on these obligations, as of the first day of system operation, is thus

$$\sum_{j=0}^{K-1} \left(\frac{L}{K}\right)(1+i)^j - L$$

which can be expressed as

$$\left(\frac{L}{K}\right)\frac{(1+i)^K-1}{i} - L$$

It is assumed that land does not depreciate (i.e., has an infinite economic life). The present value of land cost must therefore equal the accumulated interest to be paid off, referenced to n=-M, plus interest for the continued use of L dollars throughout the life of the system.

Thus

$$PV_{land} = \frac{1}{(1+i)^M}\left[\left(\frac{L}{K}\right)\frac{(1+i)^K-1}{i} - L\right] + \sum_{j=1}^{N} iL(1+i)^{-(j+M)}$$

$$= \frac{L}{(1+i)^M}\left\{\frac{(1+i)^K-1}{iK} - \frac{1}{(1+i)^N}\right\}$$

Right-of-Way Investment Cost

Let G be the initial investment cost for right-of-way construction. It is assumed that G is obligated in K equal amounts, $\frac{G}{K}$, at the end of each of the K years preceding the start of system operation. (K=1 for IPT).

The present value of these obligations is thus

$$PV_{row} = \sum_{j=0}^{K-1}\left(\frac{G}{K}\right)(1+i)^{j-M}$$

$$= \frac{G}{K}\frac{(1+i)^K-1}{i(1+i)^M}$$

For the IPT systems, K=1 and the above expression reduces to

$$PV_{row} = \frac{G}{(1+i)^M}$$

Vehicle Purchase Cost

Based on the NECTP estimate of TACV demand and vehicle requirements, it was determined that each annual passenger trip requires a vehicle investment of V, given as data. The annualized cost per passenger trip, annualized over the life of the vehicles is thus

$$V\left[\sum_{j=1}^{N_v}(1+i)^{-j}\right]^{-1}$$

where N_v is the economic life (in years) of the vehicles.

Let T = average trip length (miles).

Then the number of passenger trips in year n of system operation will be

$$\frac{D_1(1+g)^{n-1}}{T}$$

The annualized cost for vehicles in year n is thus

$$\frac{D_1(1+g)^{n-1}V}{T}\left[\sum_{j=1}^{N_v}(1+i)^{-j}\right]^{-1}$$

The present value of these costs over the life of the system is therefore

$$PV_{vehicles} = \frac{D_1V}{T}\left[\sum_{j=1}^{N_v}(1+i)^{-j}\right]^{-1}\left[\sum_{n=1}^{N}(1+g)^{n-1}(1+i)^{-(n+M)}\right]$$

$$= \frac{D_1V}{T(1+i)^M}\left(\frac{i}{i-g}\right)\frac{\left[1-\left(\frac{1+g}{1+i}\right)^N\right]}{\left[1-\frac{1}{(1+i)^{N_v}}\right]}$$

Fixed Operating Cost

Let F be the fixed annual operating cost of the system. The present value of these annual costs is

$$PV_{foc} = \sum_{n=1}^{N} F(1+i)^{-(n+M)}$$

$$= \frac{F}{i(1+i)^M}\left[1- \frac{1}{(1+i)^N}\right]$$

Variable Operating Cost

Let B be the variable operating cost, on a per passenger mile basis. Then the variable operating cost for year n of system operation is

$$BD_1(1+g)^{n-1}$$

The present value of these costs is

$$PV_{voc} = \sum_{n=1}^{N} BD_1(1+g)^{n-1}(1+i)^{-(n+M)}$$

$$= \frac{BD_1}{(1+i)^M(i-g)}\left[1-\left(\frac{1+g}{1+i}\right)^N\right]$$

This completes the derivation of relationships for computing net present value.

Breakeven Analysis

A useful indicator of possible economic viability of a system is breakeven demand; that is, the demand, at an assumed fare structure, required to recover all costs. Breakeven demand can be compared against projected demands, and against total demand in the corridor.

A related measure of potential economic viability is the fare required to break even, given any particular demand estimate. The feasibility of this fare can then be determined by comparing it with those of competitive modes.

The system costs can be categorized into four components:

1. Fixed Annualized Investment (FAI), to account for land investment cost (TLV only) and guideway construction cost.
2. Fixed Operating Cost (FOC)
3. Variable Operating Cost (VOC), reduced to a per passenger mile basis.
4. Annualized Investment for Vehicles (AIV), on a per passenger trip basis.

Of these, FOC and VOC are readily computable, and AIV is computable on the basis of first year demand as the annualized equivalent over vehicle life of

$$\frac{VD_1}{T}$$

Thus

$$AIV = \frac{VD_1}{T}\left[\sum_{n=1}^{N_v} \frac{1}{(1+i)^n}\right]^{-1}$$

$$= \frac{VD_1 i}{T}\left[1 - \frac{1}{(1+i)^{N_v}}\right]^{-1}$$

$$\equiv CD_1$$

where C is defined in the obvious manner, and is readily computable from system parameters, as indicated.

The quantity FAI is computed from

$$FAI = FAI_{land} + FAI_{guideway}$$

where

$$FAI_{land} = 0 \text{ for IPT.}$$

Referring to the preceding section which presents the computation of PV_{land}, it can be seen that the amount of accumulated interest on the loan for land purchase, to be paid over the life of the system, has a value as of the first day of system operation of

$$\frac{L}{K}\left[\frac{(1+i)^K - 1}{i}\right] - L$$

since the amount L will eventually be recovered from the sale of the land (assumed not to depreciate). The annual payment to pay off this interest is therefore

$$\frac{\frac{L}{K}\left[\frac{(1+i)^K-1}{i}\right] - L}{\sum_{n=1}^{N} \frac{1}{(1+i)^n}}$$

To this must be added the quantity iL, as interest for the continued use of L dollars throughout the life of the system. Thus

$$FAI_{land} = L \frac{\left[\frac{(1+i)^K-1}{K} - \frac{i}{(1+i)^N}\right]}{\left[1- \frac{1}{(1+i)^N}\right]}$$

after some algebraic manipulation.

The amount of the loan for guideway construction, as of the first day of system operation is

$$\frac{G}{K} \frac{(1+i)^K-1}{i}$$

This is to be paid off in full during the life of the system, since the guideway investment is assumed to depreciate to zero at the end of system life.

The annualized payment for guideway construction is thus

$$\frac{\left(\frac{G}{K}\right)\frac{(1+i)^K-1}{i}}{\sum_{n=1}^{N} \frac{1}{(1+i)^n}}$$

which reduces to

$$FAI_{guideway} = \frac{G}{K}\left[\frac{(1+i)^K - 1}{1 - \frac{1}{(1+i)^N}}\right]$$

Having computed the quantities FAI, FOC, VOC, C, the annual system costs are

$$FOC + FAI + CD_1 + (VOC)\ D_1$$

based on first year demand. The fare, f, per passenger mile which recovers these costs is given by

$$f = \frac{FOC + FAI}{D_1} + C + VOC$$

and it is this relationship which is used to generate the breakeven results presented in Figures 5-1 and 5-2.

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