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AN ANALYSIS OF FUEL CONSERVATION THROUGH AIRCRAFT TOWING

A. N. SINHA

FEBRUARY 1975

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16. Abstract

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This analysis indicates that no towing scheme is economically feasible unless the price of fuel increases by at least 150% to 200% more (over 1974 prices) without any increase in crew costs. If, however, future conditions require that fuel be conserved at all costs, then towing schemes would yield a savings of 0.7% to 1.3% of the total air carrier fuel usage at an additional net annual cost of $21 million to $90 million.

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ABSTRACT

This paper presents an analysis of aircraft towing at the top twenty air carrier airports in the United States. The study of towing aircraft analyzes the economic feasibility of two towing scenarios: towing arrivals and departures, towing departures only. The analysis has been conducted under assumptions which yield an upper bound (high estimates) of fuel savings and a lower bound (low estimates) of the costs involved. A number of operational factors which would reduce the fuel savings and further increase the cost of towing have been identified but not explicitly accounted for in the analysis. The environmental benefits (noise and pollution reductions) of aircraft towing have not been considered in this analysis.

This analysis indicates that no towing scheme is economically feasible unless the price of fuel increases by at least 150% to 200% more (over 1974 prices) without any increase in crew costs. If, however, future conditions require that fuel be conserved at all costs, then towing schemes would yield a savings of 0.7% to 1.3% of the total air carrier fuel usage at an additional net annual cost of $21 million to $90 million.

If towing vehicles with faster acceleration and towing speeds could be designed to lower the increase in tow time to 20% over taxiing time, the breakeven price of fuel would reduce to 25¢/gallon for towing departures only at ORD and LAX. Another possible way to make towing economically feasible would be for the airlines to negotiate crew contracts such that they did not charge the extra time due to towing against their flight hours. In both cases, however, a number of operational problems must be overcome before any towing scheme can be made feasible for implementation.

RESULTS AND CONCLUSIONS

This study was conducted under assumptions which provide high estimates of fuel savings and low estimates of costs. The results of the study indicate that no towing scheme is economically feasible unless the price of fuel increases by at least 150% to 200% more (over 1974 prices) without any increase in crew costs. In addition, there are a number of economic and operational factors, identified but not explicitly considered in this analysis, which would further increase the costs and decrease the fuel savings, thus adding further to the impracticality of towing aircraft. This study has not analyzed the environmental benefits (noise and pollution reduction) of aircraft towing.

If, however, future conditions require that fuel be conserved at all costs, then towing arrivals and departures at the top twenty air carrier airports in the United States will provide a moderate savings of no more than 6,065 barrels/day (1.3% of the total air carrier usage) at an additional net annual cost of $90 million. By comparison, towing departures only is a relatively better economic proposition yielding a savings of 3,047 barrels/day (0.7% of the total air carrier usage) at an additional net annual cost of $21 million; however, this would still represent a considerable economic loss to the airlines at today's jet fuel prices.

If faster towing vehicles could be developed such that the increase in towing time relative to taxiing time was 20% rather than 50%, then the breakeven cost of fuel for towing departures only would be about 25¢/gallon at LAX and ORD. It should be noted that this reduction in towing time would require an increase in the average towing speed of 2 to 4 knots which would require faster acceleration capability in the towing vehicle and higher maximum towing speeds than currently available. Another possible way of making towing economically feasible would be for the airlines to negotiate crew contracts such that they did not charge the extra time due to towing against their flight hours. In either case, there would be a number of operational problems which would have to be overcome before any towing scheme can be considered feasible for implementation.

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1. INTRODUCTION

The two main studies regarding aircraft towing have been done by Lockheed Aircraft Service Company (Reference 1) and the Oak Ridge National Laboratory (Reference 2). The former presents a very brief analysis of aircraft towing at Los Angeles International Airport. There are, however, some important aspects that have not been considered in that analysis. The latter report considers a number of fuel conservation strategies with only a very brief first-cut analysis of towing aircraft. No specific airports have been studied and the analysis is based on a general aircraft fleet rather than an aircraft mix at an airport.

This report presents an analysis which estimates the fuel savings achievable and the economic feasibility of towing aircraft at the top twenty air carrier airports in the United States. Table 1-1 gives a list of these airports. Each of the twenty airports has been analyzed for the two towing scenarios of towing both arrivals and departures and towing departures only. The analysis has been conducted under some general assumptions which are outlined in Sections 1.1 and 1.2.

Section 2 describes the values of the various parameters used in this study. The details of the methodology employed are described in Appendix A. The analysis described in Section 4 extends the results of Section 3 to study the effects of taxi time and towing speed at LAX and ORD.

1.1 Study Assumptions

This analysis provides first level estimates of the effects of towing aircraft. The physical layout, the modes of operation and the ability of the current system of taxiways and aprons to sustain a towing scenario have not been examined in detail for each of the twenty airports. The environmental benefits (noise and pollution reduction) of aircraft towing have not been analyzed in this study. The analysis is based on nominal arrival and departure taxi times for each airport. The following general assumptions have been made for this study:

1. In a no-tow situation, arriving aircraft taxi on reduced engines as appropriate. (Section 2.2)

2. While under tow, aircraft provide their own power (APU or engine) for the aircraft support systems.

TABLE 1-1

TOP 20 AIR CARRIER AIRPORTS IN THE UNITED STATES

ATL	Atlanta Hartsfield International, Atlanta, Georgia
BOS	Boston Logan International, Boston, Massachusetts
ORD	Chicago O'Hare International, Chicago, Illinois
CLE	Cleveland Hopkins International, Cleveland, Ohio
DFW	Dallas-Ft. Worth Regional, Dallas, Texas
DEN	Denver Stapleton International, Denver, Colorado
DTW	Detroit Metro Wayne County, Detroit, Michigan
IAH	Houston Intercontinental, Houston, Texas
MCI	Kansas City International, Kansas City, Missouri
LAX	Los Angeles International, Los Angeles, California
MIA	Miami International, Miami, Florida
JFK	JFK International, New York, New York
LGA	La Guardia, New York, New York
EWR	Newark International, Newark, New Jersey
PHL	Philadelphia International, Philadelphia, Pennsylvania
PIT	Greater Pittsburgh International, Pittsburgh, Pennsylvania
STL	St. Louis Lambert International, St. Louis, Missouri
SFO	San Francisco International, San Francisco, California
SEA	Seattle-Tacoma International, Seattle, Washington
DCA	Washington National, Washington, D.C.

3. Departures must have full engines on for two minutes before takeoff.

4. A nominal increase in taxi times of 50% is assumed under towing scenarios. (Based on 15 knots average taxiing speed vs. 10 knots average towing speed.) Table 1-2 gives the speeds of some of the existing towing vehicles. It shows maximum towing speeds of 3 to 9 knots in general. Hence, an average speed of 10 knots for towing is quite high.

5. The number of vehicles required for each airport is based on its busy hour operations.

6. Cost of fuel in 1974 is assumed to be 22.5¢/gallon.

In general, the assumptions and the values of the parameters have been chosen so as to be favorable to aircraft towing. Subsequently, the results provide an upper bound for the fuel savings (high estimates) and a lower bound for the costs (low estimates).

1.2 Towing Scenario

Two towing scenarios have been analyzed in this study, namely arrivals and departures, and departures only. Due to the more complex operational problems and the less desirable economic implications, an analysis of arrivals only would not likely yield any useful information and hence is not analyzed.

Figure 1-1 shows the scenario for towing arrivals and departures. The taxi times for aircraft under tow are assumed to increase by 50%. The cycle time for a tow vehicle after bringing an arrival in is assumed to be 5 minutes (Reference 1) which includes unhooking from the arrival, travel to a departure and hookup to the departure. After towing a departure, the cycle time is 10 minutes (Reference 1) and consists of 5 minutes of travel time and 5 minutes of maneuver and hookup time for an arrival.

Figure 1-2 shows the towing scenario for departures only. The tow time is again assumed to be 50% higher than the nominal departure taxi time. The cycle time back to service, including the unhook and hookup time, is conservatively assumed to be the nominal departure taxi time.

TABLE 1-2

CAPABILITIES OF SOME EXISTING TOW VEHICLES

MANUFACTURER	MODEL	MAXIMUM DRAWBAR PULL	MAXIMUM SPEED NO-LOAD MODE	MAXIMUM TOWING SPEED
F. L. Douglas Equipment Ltd. Arle, Cheltenham, U.K.	DC 12/4 MK11	47,200 lbs	16 knots	N/A
	DC 11	34,000 lbs	16 knots	3 knots for a B727
	DC 6	12,000 lbs	18 knots	N/A
	DC 4	6,000 lbs	17 knots	N/A
International Harvester Melrose Park, IL, U.S.A.	T-800S	80,000 lbs	16 knots	12 knots for a B727 5 knots for a B747
	T-500S	50,000 lbs	17 knots	N/A
	T-300SL	30,000 lbs	16 knots	9 knots for a B727
	T-225SL	25,000 lbs	16 knots	9 knots for a B727
Konrad Wiedemann Allerhop, West Germany	DS 75	6,600 lbs	9 knots	N/A
	DS 45	5,500 lbs	14 knots	N/A
Reliance Mercury Ltd. Halifax, Yorks, U.K.	RM 450	57,000 lbs	16 knots	N/A
	RM 300	30,000 lbs	19 knots	N/A
Schopt Maschinenbau Stuttgart, West Germany	F 356	52,900 lbs	16 knots	8 knots for a B747
Secmafer Mantes, France	SF 800	75,500 lbs	16 knots	N/A
	SF PO	50,000 lbs	6 knots	N/A

N/A: Not Available

NOTE: o Average weight of a B727 assumed as 175,000 lbs.
o Average weight of a B747 assumed as 700,000 lbs.

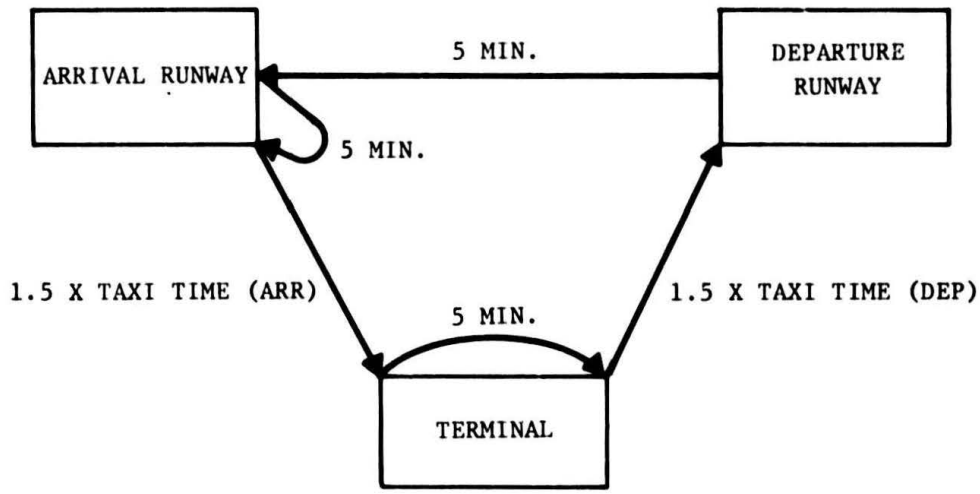

FIGURE 1-1
TOWING SCENARIO
(ARRIVALS AND DEPARTURES)

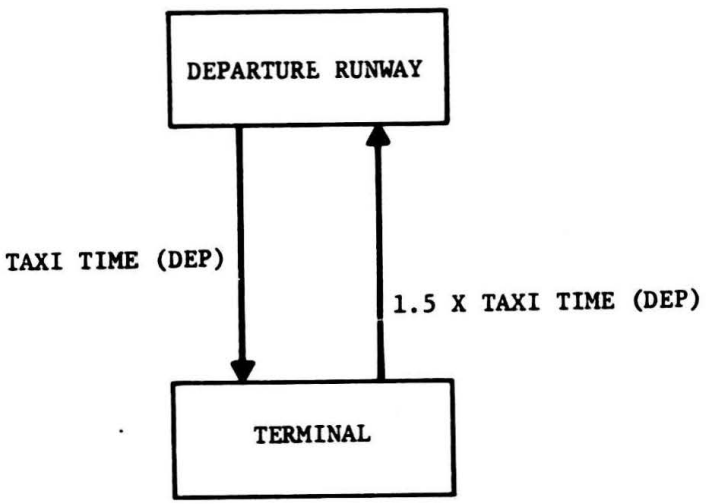

FIGURE 1-2
TOWING SCENARIO
(DEPARTURES ONLY)

2. INPUT VARIABLES

The input variables required in this analysis fall into three categories that are tow vehicle, aircraft and airport related. The next three subsections present the assumed values of the input parameters for each of these categories together with their sources.

2.1 Tow Vehicle Related

The source of data for parameter values related to the tow vehicle is Reference 1. The cycle time to return to service and the increase in taxi time due to towing have already been discussed in Sections 1.1 and 1.2.

An annual cost of $55,000 per tow vehicle is used in this analysis. In addition to the operating and maintenance cost, it is assumed to include the amortized capital cost and the cost of manpower to run the vehicle but does not include its fuel cost. The figure used is rounded down from the lowest figure of $1.26 million for 22 vehicles cited in Reference 1.

The fuel consumption rate for the tow vehicle in the unloaded mode is 0.7 gallons per minute for those used for heavy aircraft and 0.5 gallons per minute for smaller vehicles (Reference 1). In this analysis, the fuel consumption rate is assumed to remain the same while towing aircraft, since no adequate data is available on tow vehicle fuel consumption under loaded conditions. This assumption tends to bias the results towards providing a higher estimate of fuel savings and a lower estimate of costs.

2.2 Aircraft Related

Table 2-1 gives the values of the aircraft related parameters used in this analysis. The classification of aircraft into six groups is based on CAB classes employed in Reference 3. The crew costs for 1974 have been obtained by increasing the 1972 costs, available in Reference 3, by 18%.

The fuel consumption rates are based on data provided by the Air Transport Association (ATA) (Reference 4). The consumption rate for taxiing shown in Table 2-1 does not include support system requirements. The rates for reduced engine operations are based on two engines-on for four engine aircraft (except B747) and three engine aircraft (except DC10, L1011). This is in conformance with the current FAA recommended procedure for arrivals to taxi on reduced engines (Reference 5). B747's are

TABLE 2-1

AIRCRAFT DATA

CLASSES	CREW COST $/MIN (1974 COSTS)	FUEL CONSUMPTION RATE (LBS/MIN)		
		TAXI ON ALL ENGINES*	TAXI ON REDUCED ENGINES*	SUPPORT SYSTEM
1. TURBO-FAN, 4 ENGINE WIDE BODY (B747)	$5.63	125	125	24
2. TURBO-FAN, 4 ENGINE REG. BODY (B707,DC8)	$4.10	80	50	20
3. TURBO-FAN, 3 ENGINE WIDE BODY (DC10,L1011)	$4.55	60	60	15
4. TURBO-FAN, 3 ENGINE REG. BODY (B727)	$3.64	55	40	5
5. TURBO-FAN, 2 ENGINE (BAC 111,B737,DC9)	$3.07	38	38	4
6. TURBO-JET, 4 ENGINE (B707,B720,DC8,CV880)	$3.97	95	50	20

*DOES NOT INCLUDE REQUIREMENTS OF SUPPORT SYSTEM

not recommended to taxi on reduced engines because of problems with their hydraulic braking systems and the DC10's and L1011's under current configurations require a certain amount of idle running before engine shut-off. It should be noted that taxiing on reduced engines does not linearly decrease the fuel consumption. This is due to the need of a higher thrust when taxiing on reduced engines.

2.3 Airport Related

Table 2-2 gives the values of the airport related data for each of the twenty airports. The annual operations and the air carrier mix are for calendar year 1973 (Reference 6). The busy hour operations are obtained as a ratio of the annual operations based on the operations profile of the airports given in Reference 7.

The taxi time estimates are based on data from Civil Aeronautics Board (CAB File ERS 586), (Reference 8), United Airlines and MITRE estimates.

Table 2-3 gives the weighted crew costs and the fuel consumption rates for each of the twenty airports. These are calculated from the aircraft mix in Table 2-2 and the fuel consumption rate of the six classes of aircraft given in Table 2-1.

TABLE 2-2
AIRPORT OPERATIONS DATA

AIRPORT		ATL	BOS	ORD	CLE	DFW	DEN	DTW	IAH	MCI	LAX	MIA	JFK	LGA	EWR	PHL	PIT	STL	SFO	SEA	DCA
ANNUAL OPERATIONS (CY1973)		421770	195434	566980	131366	266350	198658	180456	119854	105064	443122	193794	295690	249338	142268	166300	192696	164488	317974	107292	222206
BUSY HOUR OPERATIONS (ESTIMATED)		100	48	129	47	66	60	47	30	32	109	66	77	65	43	40	53	42	78	28	51
TAXI TIME (MINS)	ARRIVALS	9	6	9	5	4	6	8	5	4	7	4	7	6	4	1	4	4	7	4	3
	DEPARTURES	7	5	7	5	6	3	6	5	6	8	3	7	7	4	2	4	5	5	6	4
AIR CARRIER MIX (%)	CLASS 1 B747	1.2	1.6	3.5	0.3	1.2	0.2	2.7	0.0	0.0	6.2	3.0	11.2	0.0	0.0	0.0	0.2	0.0	4.3	6.0	0.0
	CLASS 2 B707,DC8 (HEAVY)	10.7	11.7	19.4	11.9	21.1	10.5	23.3	15.5	10.3	24.3	14.7	37.0	0.0	17.6	15.6	3.8	10.8	25.0	33.7	0.0
	CLASS 3 DC10,L1011	1.0	2.6	7.1	4.9	2.8	7.2	6.1	5.3	0.3	6.1	9.7	7.0	5.0	2.4	3.8	1.2	1.2	2.8	3.7	0.0
	CLASS 4 B727	30.8	37.1	39.0	43.6	51.8	42.7	39.0	52.7	62.3	32.4	52.1	30.8	60.1	36.6	31.3	25.4	36.7	33.0	37.9	55.0
	CLASS 5 BAC111, B737,DC9	51.2	42.1	23.1	35.2	21.0	29.8	26.8	24.9	21.7	27.9	17.0	8.4	34.9	36.5	42.7	65.0	48.4	30.7	10.6	45.0
	CLASS 6 B707,B727, DC8,CV880	5.1	4.9	7.9	4.1	2.1	9.6	2.1	1.6	5.4	3.1	3.5	5.6	0.0	6.9	6.6	4.4	2.9	4.2	8.1	0.0

TABLE 2-3
AIRPORT FUEL CONSUMPTION AND CREW COST DATA

AIRPORT		ATL	BOS	ORD	CLE	DFW	DEN	DTW	IAH	MCI	LAX	MIA	JFK	LGA	EWR	PHL	PIT	STL	SFO	SEA	DCA
CREW COST (1974 BASE) $/MIN.		3.45	3.53	3.78	3.56	3.67	3.62	3.71	3.62	3.58	3.77	3.77	4.07	3.49	3.56	3.52	3.31	3.43	3.70	3.91	3.38
TOW VEHICLE FUEL CONSUMPTION LBS/MIN		3.6	3.6	3.8	3.6	3.8	3.7	3.9	3.7	3.6	3.9	3.8	4.2	3.5	3.7	3.7	3.5	3.6	3.9	4.0	3.4
AIRCRAFT FUEL CONSUMPTION LBS/MIN	TAXI ON FULL ENGINES	52	54	62	54	59	57	59	55	56	62	60	73	49	56	54	47	51	61	69	47
	TAXI ON REDUCED ENGINES	42	43	47	42	43	43	47	42	41	49	.6	55	40	42	42	40	41	47	50	39
	SUPPORT SYSTEM	7.2	7.6	10.2	7.6	8.8	8.5	9.7	7.8	7.2	10.6	8.4	14.1	5.1	8.5	8.3	5.7	6.7	10.2	12.7	4.5

NOTE: EACH FIGURE IS WEIGHTED BY THE APPROPRIATE AIRPORT TRAFFIC MIX.

3. RESULTS

Table 3-1 shows the aggregate results of the twenty airports studied. The details of the methodology are described in Appendix A.

3.1 Towing at All Airports

Towing arrivals and departures at the 20 airports is estimated to have potential savings of 6065 barrels of fuel per day at an additional yearly cost of $111 million. To make this proposition economically feasible for the 20 airports as a whole the price of fuel must rise to at least $1.20/gallon without any increase in the crew cost. At 1974 price of fuel of 22.5¢/gallon the annual cost of fuel saved amounts to $21 million at an additional annual operations cost to the airlines of $111 million (additional crew costs $93 million, towing vehicle costs $18 million).

Towing departures only is a relatively better economic proposition, although it still results in a substantial net loss. This procedure would save 3,047 barrels of fuel per day at an additional yearly cost of $32 million. The comparatively lower cost of departures only is partially due to the assumptions of the towing scenario for departures only. No hookup and unhook time has been assumed.* In addition, it is assumed that the cycle time to return to service is equivalent to the taxi time of the aircraft. Under these assumptions, an increase in the cost of fuel to $0.69/gallon, without any increase in the crew cost, is the breakeven point for the economic feasibility of towing departures at all airports. Using 1974 prices of fuel, the additional annual cost of $32 million (additional crew costs $24 million, towing vehicle costs $8 million) saves $11 million worth of fuel annually.

3.2 Towing at Selected Airports

Tables 3-2 and 3-3 show the results of the individual airports. Figures 3-1 to 3-4 show graphical depictions of the breakeven price and the additional net annual cost of towing (1974 base) for both the towing scenarios for all the airports. For the scenario of towing arrivals and departures the breakeven price of fuel ranges from $0.80 to over $3.00 per gallon and the net

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* At certain airports, current operations already include push back and unhook time. Therefore, no additional hookup and unhook time for departures was considered.

TABLE 3-1

AGGREGATIVE RESULTS OF THE TOP 20 AIRPORTS

	ARRIVALS & DEPARTURES	DEPARTURES ONLY
TOTAL FUEL SAVED (BARRELS/DAY)	6,065 (6,237)	3,047 (3,113)
ADDITIONAL ANNUAL COST OF TOWING	$111M ($111M)	$32M ($32M)
ADDITIONAL CREW COST	$93M	$24M
TOWING VEHICLE COST	$18M	$ 8M
BREAKEVEN PRICE OF FUEL	$1.20/GALLON ($1.17/GALLON)	$0.69/GALLON ($0.68/GALLON)
1974 COST OF FUEL SAVED (@ 22.5¢/GALLON)	$21M ($21M)	$11M ($11M)
ADDITIONAL NET ANNUAL COST OF TOWING (1974 BASE)	$90M ($90M)	$21M ($21M)

NOTE:
- IN THIS ANALYSIS AIRCRAFT CLASSES 1, 2, & 3 ARE ASSUMED TO REQUIRE HEAVY TOW VEHICLES
- THE NUMBERS IN PARENTHESES ARE THE RESULTS IF ONLY CLASSES 1 & 3 ARE ASSUMED TO REQUIRE HEAVY TOW VEHICLES

TABLE 3-2
RESULTS FOR THE 20 AIRPORTS
(ARRIVALS AND DEPARTURES)

AIRPORT	ATL	BOS	ORD	CLE	DFW	DEN	DTW	IAH	MCI	LAX	MIA	JFK	LGA	EWR	PHL	PIT	STL	SFO	SEA	DCA
NUMBER OF TOW VEHICLES	33	13	42	12	17	14	14	8	8	34	14	23	19	10	7	12	10	21	7	11
FUEL SAVED (BARRELS/DAY)	813	211	1223	118	262	122	306	106	104	922	70	606	363	70	-67*	99	118	411	117	91
ADDITIONAL ANNUAL COST OF TOWING ($ MILLIONS)	11.3	4.3	16.2	3.0	5.8	4.2	4.8	2.6	2.4	12.3	3.8	8.5	6.1	2.8	2.3	3.5	3.2	7.6	2.5	3.8
BREAKEVEN COST OF FUEL ($/GALLON)	0.90	1.34	0.87	1.66	1.45	2.24	1.02	1.60	1.45	0.87	3.61	0.91	1.09	2.62	**	2.31	1.78	1.21	1.38	2.72
1974 COST OF FUEL SAVED (@ 22.5¢/GALLON)	2.8	0.7	4.2	0.4	0.9	0.4	1.1	0.4	0.4	3.2	0.2	2.1	1.3	0.2	-0.2*	0.3	0.4	1.4	0.4	0.3
ADDITIONAL NET ANNUAL COST OF TOWING-1974 BASE ($ MILLIONS)	8.5	3.6	12.0	2.6	4.9	3.8	3.7	2.2	2.0	9.1	3.6	6.4	4.8	2.6	2.5	3.2	2.8	6.2	2.1	3.5

* DUE TO SHORT TAXI TIMES TOWING AIRCRAFT RESULTS IN A LOSS OF FUEL (REFER TO SECTION 4).

** DUE TO A NET LOSS IN FUEL THE BREAKEVEN PRICE IS NOT CALCULATED.

TABLE 3-3
RESULTS FOR THE 20 AIRPORTS
(DEPARTURES ONLY)

AIRPORT	ATL	BOS	ORD	CLE	DFW	DEN	DTW	IAH	MCI	LAX	MIA	JFK	LGA	EWR	PHL	PIT	STL	SFO	SEA	DCA
NUMBER OF TOW VEHICLES	15	5	19	5	8	4	6	3	4	18	4	11	9	3	2	4	4	8	3	4
FUEL SAVED (BARRELS/DAY)	346	91	562	61	194	16	128	57	74	532	17	341	197	39	-21*	31	72	165	91	54
ADDITIONAL ANNUAL COST OF TOWING ($ MILLIONS)	3.4	1.1	4.8	0.9	2.1	0.8	1.3	0.7	0.8	4.3	0.8	2.7	2.0	0.6	0.4	0.9	0.9	1.9	0.8	1.0
BREAKEVEN COST OF FUEL ($/GALLON)	0.64	0.81	0.56	0.91	0.70	3.16	0.68	0.81	0.69	0.53	2.87	0.52	0.67	1.11	**	1.83	0.84	0.76	0.57	1.17
1974 COST OF FUEL SAVED (@ 22.5c/GALLON)	1.2	0.3	1.9	0.2	0.7	0.1	0.4	0.2	0.3	1.8	0.1	1.2	0.7	0.1	-0.1*	0.1	0.2	0.6	0.3	0.2
ADDITIONAL NET ANNUAL COST OF TOWING-1974 BASE ($ MILLIONS)	2.2	0.8	2.9	0.7	1.4	0.7	0.9	0.5	0.5	2.5	0.7	1.5	1.3	0.5	0.5	0.8	0.7	1.3	0.5	0.8

*DUE TO SHORT TAXI TIME TOWING AIRCRAFT RESULTS IN A LOSS OF FUEL (REFER TO SECTION 4).

**DUE TO A NET LOSS IN FUEL THE BREAKEVEN PRICE IS NOT CALCULATED.

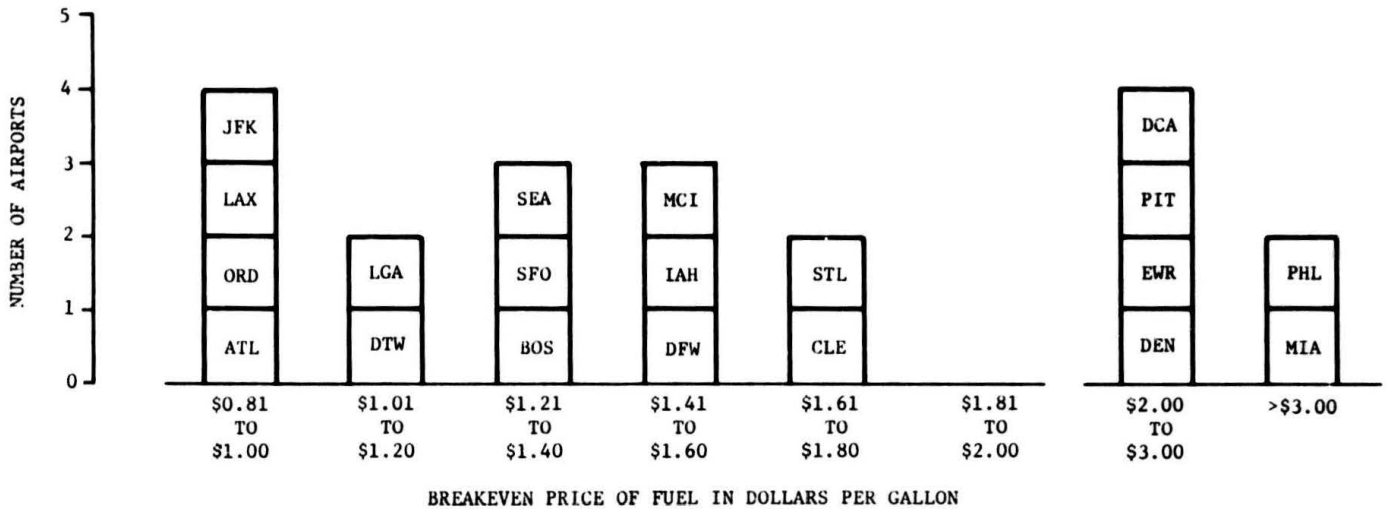

FIGURE 3-1
BREAKEVEN PRICE OF FUEL FOR TOWING AIRCRAFT
(ARRIVALS AND DEPARTURES)

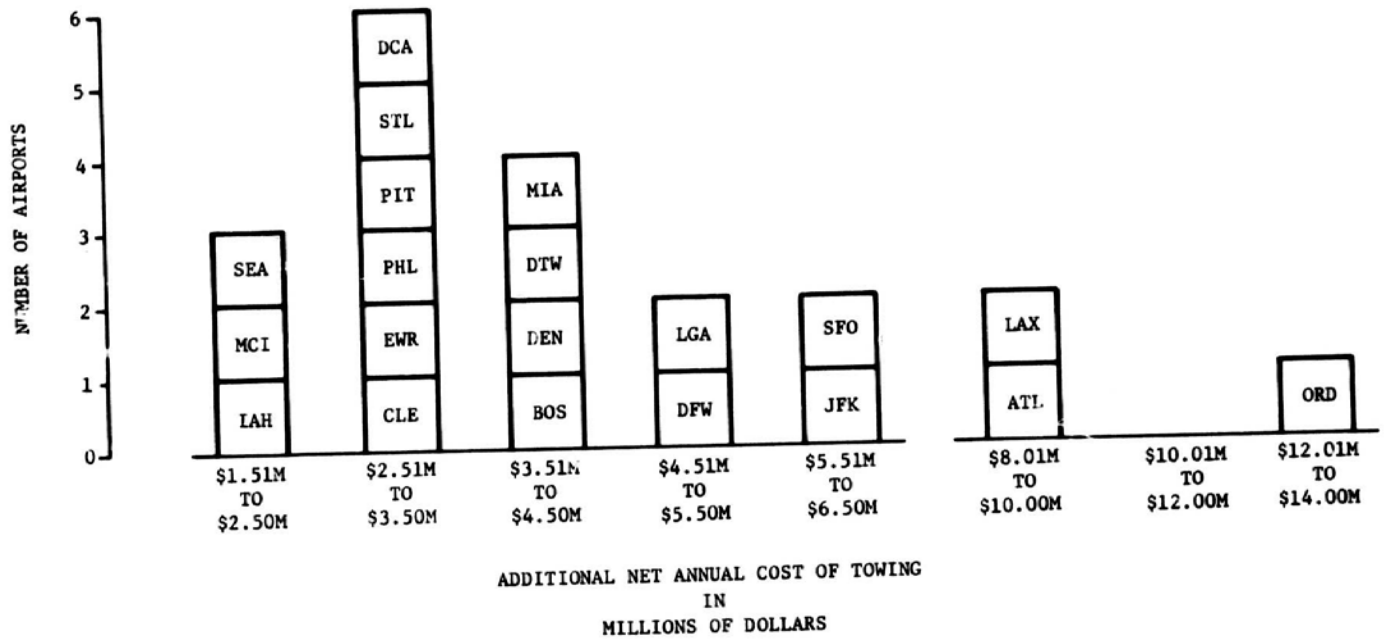

FIGURE 3-2
ADDITIONAL NET ANNUAL COST OF TOWING–1974 BASE
(ARRIVALS AND DEPARTURES)

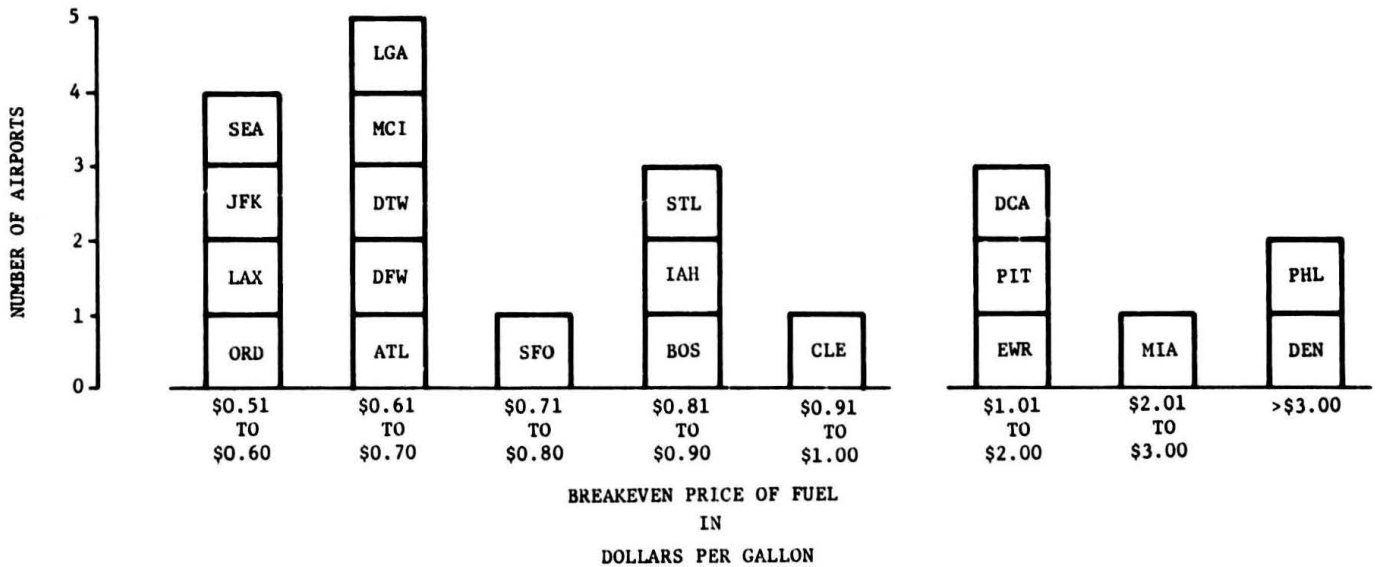

FIGURE 3-3
BREAKEVEN PRICE OF FUEL FOR TOWING AIRCRAFT
(DEPARTURES ONLY)

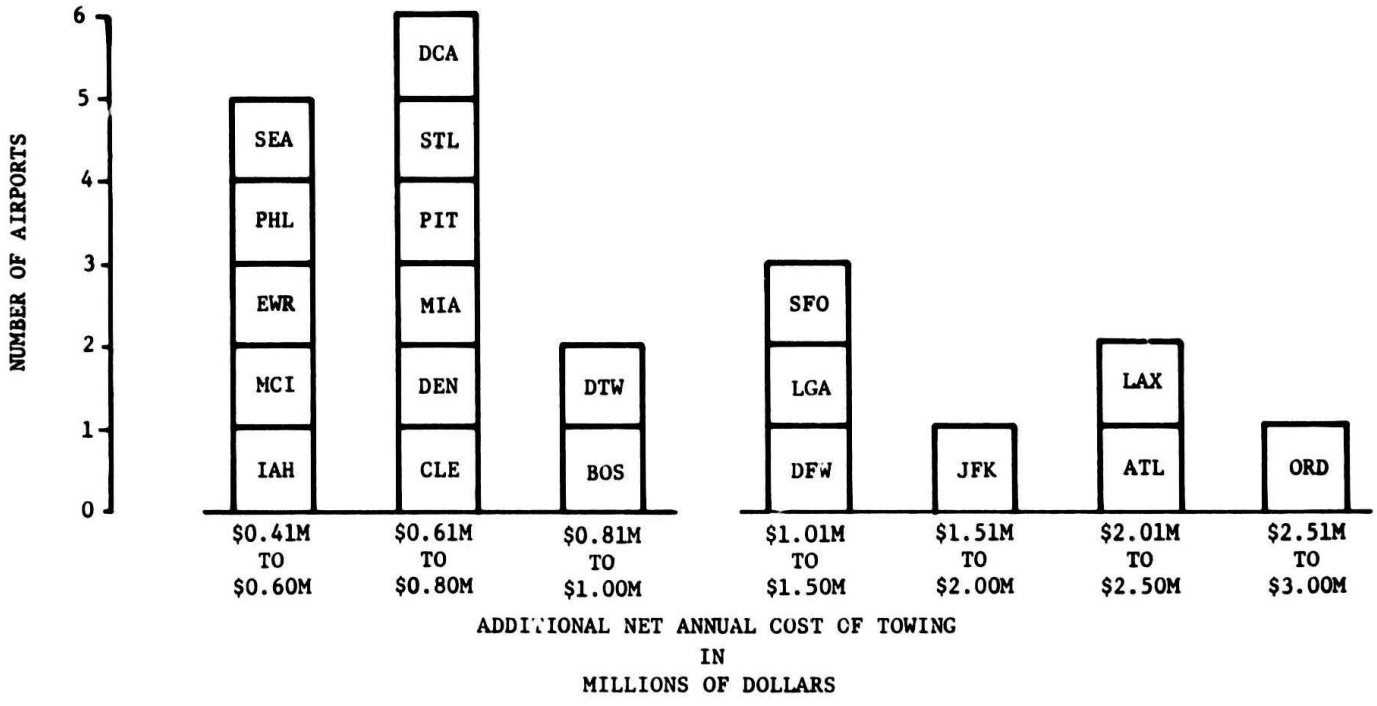

FIGURE 3-4
ADDITIONAL NET ANNUAL COST OF TOWING—1974 BASE
(DEPARTURES ONLY)

annual cost from $1.5 million to $12 million. The corresponding ranges for towing departures only are from $0.50 to over $3.00 per gallon and $0.4 million to $3 million respectively. It should be noted that the breakeven prices are calculated on the assumption of no increase in the crew costs above the 1974 salary levels.

In both towing scenarios, the four major airports (ATL, ORD, LAX, JFK) have a relatively low breakeven price of fuel. The additional net cost of towing, however, at these airports is the highest. This results from the high operations rates of these airports.

4. FURTHER ANALYSIS OF LOS ANGELES INTERNATIONAL AND CHICAGO O'HARE INTERNATIONAL

Taxi time and the speed of towing are the two main elements of this analysis. Since towing departures at LAX and ORD were identified as the most economically viable propositions, Sections 4.1 and 4.2 describe a parametric study of taxi and towing speeds for these two airports.

4.1 The Effect of Taxi Time

Figure 4-2 shows the effect of departure taxi time on the breakeven price of fuel at LAX and ORD for the scenario of towing departures only. Although the analysis is done for LAX and ORD, the results are valid for all airports.

For taxi times of two minutes or less there is no savings in fuel due to the two minute engine warmup assumptions for departures. The breakeven price of fuel drops rapidly from about $2.50 - $3.00 per gallon for 3 minutes taxi time to about $0.64 per gallon for 6 minutes taxi time. It stabilizes rather rapidly at $0.45 to $0.50 per gallon for taxi times up to 15 minutes.

This would indicate that even though the breakeven price is sensitive to low taxi times, the proposal of towing departures only is not economically feasible unless the price of fuel rises to at least $0.50 to $0.60 per gallon without any concurrent increases in crew costs.

4.2 The Effect of the Speed of Towing

Figure 4-2 shows the effect of towing speed on the breakeven price of fuel for ORD and LAX when towing departures only. An increase in towing time of 50% (nominal value used in the analysis) yields a breakeven price of fuel at $0.50 - $0.55 per gallon. If the speed of towing were increased so as to require only 25% more time during tow, the price of fuel in the range of $0.30 per gallon would be the breakeven price. As shown in Table 1-2, the existing tow vehicles have a <u>maximum</u> towing speed of 3 to 9 knots in general. Hence, the assumption of an <u>average</u> increase in towing time of only 50% is not feasible through existing vehicles. To be able to further reduce the increased time of towing to 20% above taxiing time, tow vehicles with much higher maximum speeds and faster acceleration capabilities would be required. In addition, it should be noted that a faster tow vehicle would,

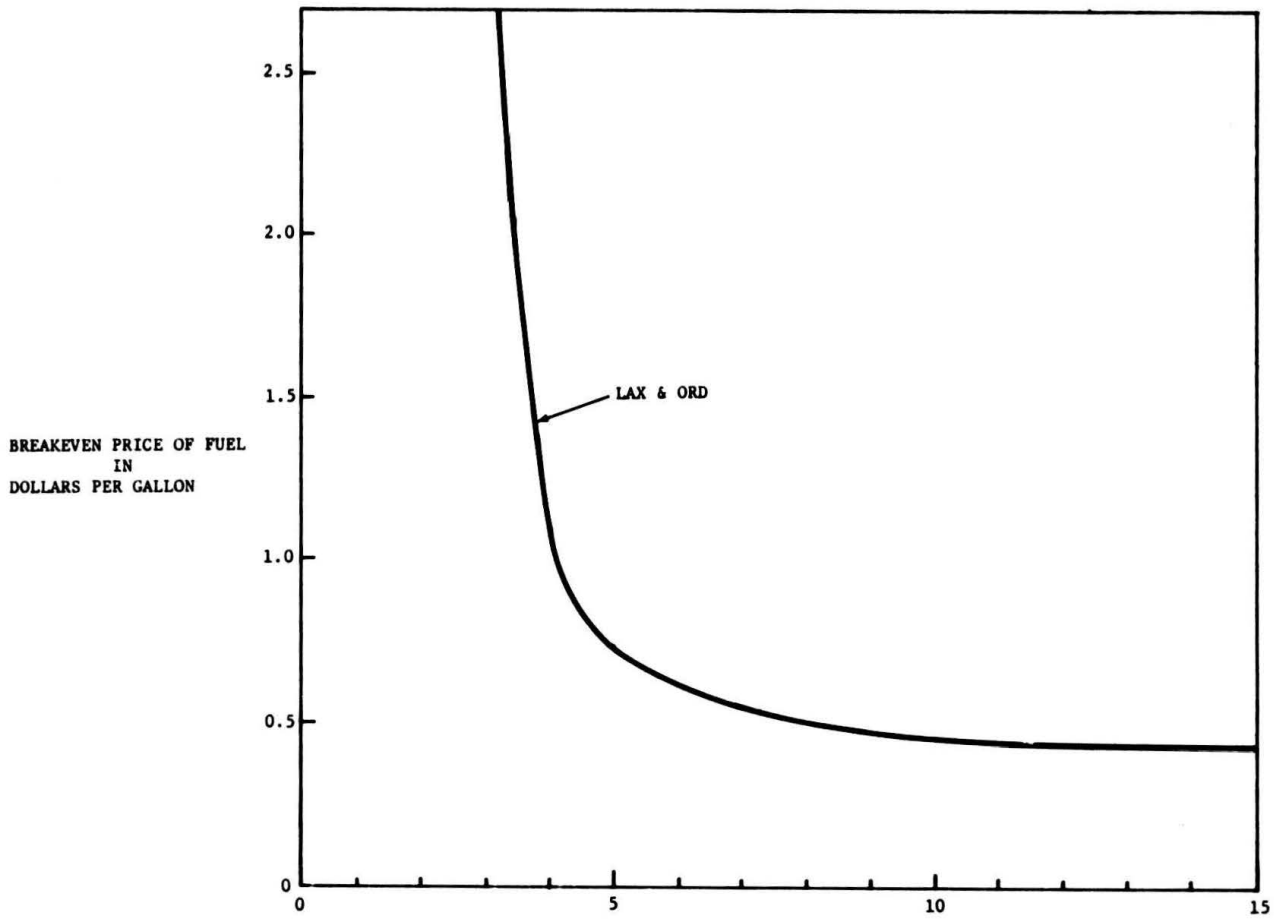

FIGURE 4-1
THE EFFECT OF TAXI TIME ON THE BREAKEVEN PRICE OF FUEL
(DEPARTURES ONLY)

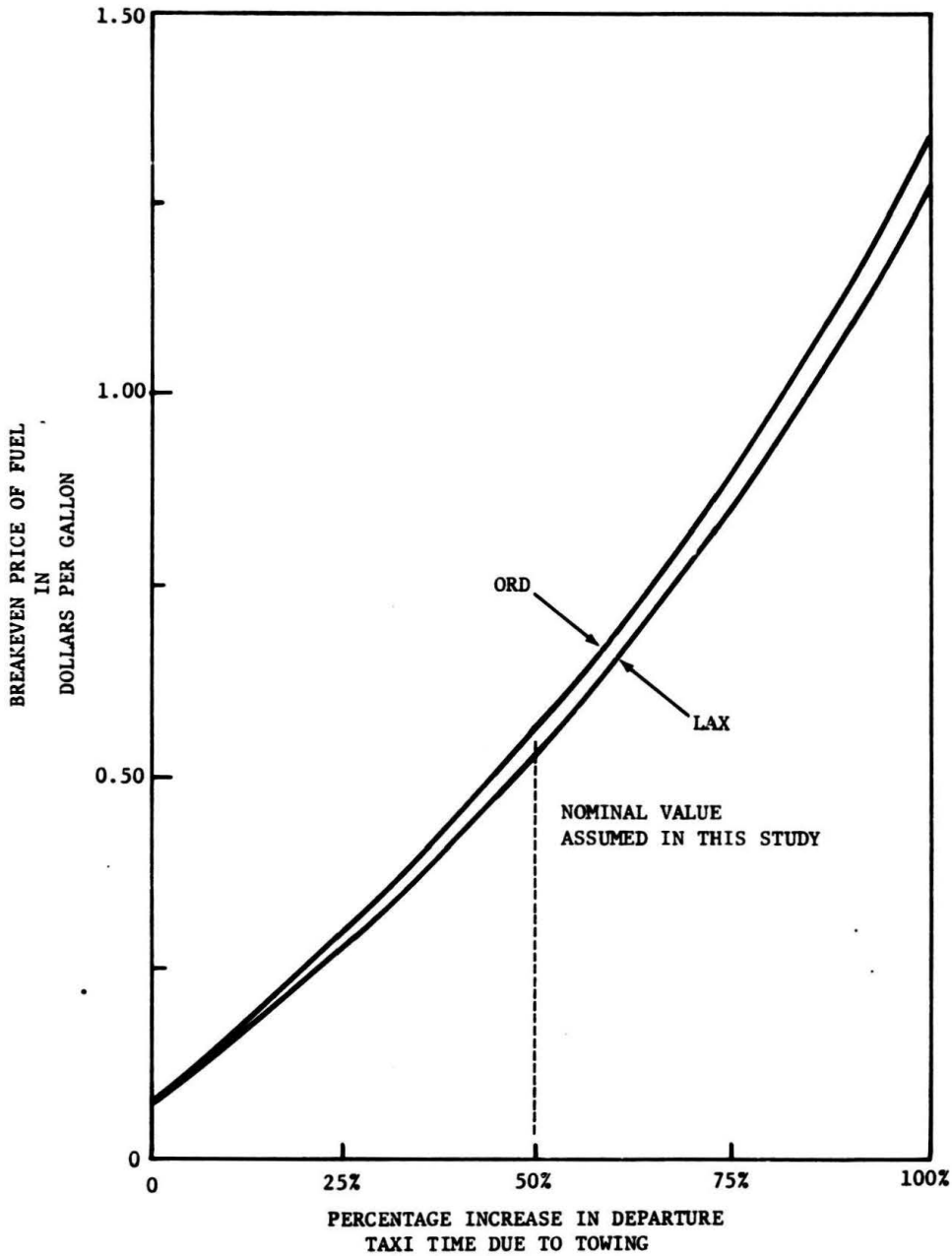

FIGURE 4-2
THE EFFECT OF TOW VEHICLE SPEED ON THE BREAKEVEN PRICE OF FUEL (DEPARTURES ONLY)

generally, have a higher operating and maintenance cost with higher per minute fuel consumption, and this would tend to increase the breakeven price. In addition, it is assumed that the crew cost remains constant at the 1974 base. In practice, however, the crew costs can be expected to rise with time and hence the breakeven price will be further increased.

5. SUMMARY AND CONCLUSIONS

This analysis has been conducted under assumptions which provide higher estimates of the fuel savings and lower estimates of costs and breakeven prices. Even under such assumptions, the cost of conserving fuel through towing substantially exceeds the market price.

Total air carrier fuel consumptions in the U.S. of 450,000 barrels/day constitutes only 2.25% of the total national fuel consumption of 20 million barrels/day. An upper bound on the maximum amount of fuel saved by towing arrivals and departures is 6,065 barrels/day (1.3% of the total air carrier usage). Towing departures only will yield a maximum savings of 3,047 barrels/day (0.7% of the total air carrier usage), but at a lower net cost to the carriers.

Although towing departures only is a relatively better economic proposition than towing arrivals and departures, no towing scheme is economically feasible unless the price of fuel increases by 150% to 200% without any increase in crew costs. One possible way of achieving economic feasibility for towing is for airlines to negotiate crew contracts so that they did not charge the extra time due to towing against their flight hours. Even under those conditions, a number of operational problems must be overcome before any towing scheme can be considered feasible.

It should be noted that the cost of towing is sensitive to towing speeds. The performance of tow vehicles presently on the market would indicate that the assumption of an increase of 50% in the overall taxi time for aircraft under tow is a reasonable estimate. To be able to better the average speed performance with aircraft under tow, the tow vehicle should have a greater acceleration capability under load, and present vehicles are not designed for this type of operation.

There are a number of variables, not considered in this analysis, that would tend to increase the cost of towing as well as the breakeven price of fuel. Spare tow vehicles would be required at the airports for an efficient operation. Furthermore, no operational system would have perfect dispatching to provide a tow vehicle where and when it is needed. Tow vehicle dispatcher cost and the cost of resource management (tow vehicle and driver scheduling) would further increase the costs. The need for constructing holding pads for arrivals and tow vehicle roads would require additional capital investments. In the analysis of towing departures only, hookup and unhook times have not been considered and the tow vehicle fuel consumption under load may also be higher than the numbers used in this analysis.

In addition, a number of airfield operational difficulties will have to be overcome before any towing scheme can be implemented. Special holding areas may be required for hookup operations of arrivals. Towing aircraft would increase surface traffic congestion and delays. The control of the tow vehicles' movement would present additional operational difficulties. The airport surface traffic control would worsen considerably under low visibility conditions and might decrease the acceptance rate of the airport. If aircraft are required to cross active runways, the low acceleration capability of the vehicles under load may be detrimental to the runway acceptance rate.

In general, therefore, from an economic and operational viewpoint towing of aircraft is not a desirable proposition. However, if future conditions require that fuel be conserved at all costs, then towing aircraft would provide some moderate savings of fuel--about 1% of the air carrier usage, which represents 0.0225% of the total national fuel consumption.

APPENDIX A

METHODOLOGY OF TOWING ANALYSIS

1. INTRODUCTION

This appendix provides details of the methodology used in the towing analysis. The calculations have been divided into three categories: fuel savings, number of tow vehicles required and the cost calculations. Table A-1 gives a list of the notations used.

2. FUEL SAVINGS

To estimate the fuel savings at an airport due to aircraft towing, calculations were made to determine the fuel consumption under no-tow conditions and under towing scenarios given in Section 1.2 of this report.

Table A-2 gives the equations for estimating the fuel savings achievable. It should be noted that for the scenario of towing departures-only an operation refers to a departure only.

The calculations of aircraft fuel consumption per operation under no-tow conditions is based on the taxi times (arrival and departure) and the fuel consumption rate of the aircraft and its support system.

The aircraft consumption per operation under towing scenario depends on the fuel consumption of the support system during the increased taxi times and the increase in block-to-block times for arrivals and the fuel consumption of the aircraft during the 2 minutes engine run up time for departures.

The tow vehicle fuel consumption per operation depends on the cycle time of the tow vehicle and its fuel consumption rate.

The fuel savings per operation and the annual operations of the airport give the net fuel savings.

The transformation to barrels per day is based on 365 days in a year, 6.84 lbs. to the gallon and 42 gallons to the barrel.

TABLE A-1

NOTATIONS

AO	Annual operations.
BHO	Busy hour operations.
TD	Average departure taxi time (minutes).
TA	Average arrival taxi time (minutes).
CC	Weighted* crew cost (dollars per minute).
RT	Weighted* fuel consumption rate of aircraft taxiing under own power (lbs. per minute).
RR	Weighted* fuel consumption rate of aircraft taxiing on reduced engines (lbs. per minute).
RL	Weighted* fuel consumption rate for the support system of an aircraft (lbs. per minute).
RV	Weighted* fuel consumption rate of the tow vehicle (lbs. per minute).
NV	Number of tow vehicles required.

*The weighting is done with respect to the aircraft mix of the airport.

TABLE A-2

CALCULATIONS TO ESTIMATE FUEL SAVINGS

SYMBOL	ELEMENT	TOWING ARRIVALS AND DEPARTURES	TOWING DEPARTURES ONLY
A	AIRCRAFT FUEL CONSUMPTION PER OPERATION UNDER NO-TOW CONDITIONS (LBS.)	$\frac{TD*(RT+RL)+TA*(RR+RL)}{2}$	TD*(RT+RL)
B	AIRCRAFT FUEL CONSUMPTION PER OPERATION UNDER TOWING SCENARIO (LBS.)	$\frac{1.5*TD*RL+2*RT+(1.5*TA+5)RL}{2}$	1.5*TD*RL+2*RT
C	TOW VEHICLE FUEL CONSUMPTION PER OPERATION UNDER TOWING SCENARIO (LBS.)	$\frac{[1.5*(TA+TD)+15]*RV}{2}$	2.5*TD*RV
D	FUEL SAVINGS PER OPERATION UNDER TOWING SCENARIO (LBS.)	A-(B+C)	A-(B+C)
E	DAILY FUEL SAVINGS UNDER TOWING SCENARIO (BARRELS/DAY)	D*AO/(6.84*42*365)	$D*\frac{AO}{2}/(6.84*42*365)$

NOTE: IN THE CASE OF TOWING DEPARTURES ONLY, AN OPERATION REFERS TO A DEPARTURE.

3. NUMBER OF TOW VEHICLES

The number of tow vehicles (NV) required at an airport is based on the busy hour operations (BHO) assuming a 100% efficient dispatching system of placing a vehicle when and where required.

For the case of towing arrivals and departures the equation is:

$$NV = [1.5*(TD + TA) + 15]* \frac{BHO}{120}$$

In the case of towing departures only it becomes:

$$NV = 2.5* TD * \frac{BHO}{120}$$

4. COST ESTIMATES

All cost estimates are in 1974 dollars and are based on a fuel cost of 22.5¢/gallon and a crew cost which is 18% more than 1972 costs.

Table A-3 gives the equations used for the cost estimates. The annual cost of tow vehicles is based on $55,000 per vehicle per year which includes capital costs and the manpower to run the vehicles.

The additional crew cost per operation is based on the increase in the block-to-block time of an operation.

The additional cost of towing per year is made up of the annual cost of the tow vehicles and the annual crew cost. The breakeven price of fuel is then calculated on the basis of the additional annual cost of towing and the annual savings in fuel. The additional net annual cost of towing is simply the additional annual cost of towing less the 1974 cost of fuel saved.

TABLE A-3

CALCULATIONS TO ESTIMATE COSTS OF TOWING

SYMBOL	ELEMENT	TOWING ARRIVALS AND DEPARTURES	TOWING DEPARTURES ONLY
F	ANNUAL COST OF TOW VEHICLES	$55,000*NV	$55,000*NV
G	ADDITIONAL CREW COST PER OPERATION	$[0.5(TD+TA)+5]*CC/2	$0.5*TD*CC
H	ADDITIONAL COST OF TOWING PER YEAR	$[G*AO+F]	$[G*$\frac{AO}{2}$+F]
J	COST OF FUEL SAVED PER YEAR	$\frac{\$0.225}{6.84}$*D*AO	$\frac{\$0.225}{6.84}$*D*$\frac{AO}{2}$
K	BREAKEVEN PRICE OF FUEL ($/GALLON)	$[H/(D*AO)]*6.84	$[H/(D*$\frac{AO}{2}$)]*6.84
I	ADDITIONAL NET COST OF TOWING PER YEAR	$ H-J	$ H-J

NOTE: 1. ALL COSTS ARE IN 1974 DOLLARS.

2. 1974 COST OF FUEL IS 22.5¢/GALLON.

APPENDIX B

REFERENCES

1. Lockheed Aircraft Service Company, Systems for Transporting Aircraft on the Ground, Report No. FAA-RD-74-92, December 1973.

2. Oak Ridge National Laboratory, Airplane Energy Use and Conservation Strategies, Report No. ORNL-NSF-EP-69, May 1974.

3. Civil Aeronautics Board, Aircraft Operating Cost and Performance Report, Vol. VII, July 1973.

4. Air Transport Association, Correspondence dated May 21, 1974.

5. Federal Aviation Administration, Advisory Circular AC 91-41, March 12, 1974.

6. Federal Aviation Administration, Airport Activity Statistics of Certificated Route Air Carriers, 12 Months Ended December 31, 1973.

7. Federal Aviation Administration, Profiles of Scheduled Air Carrier Airport Operations, Top 100 U.S. Airports (November 2, 1973), March 1974.

8. Federal Aviation Administration, Report on Phase I Effort to Use New Data Source - CAB File ERS 586, QSATS Office, January 1973.

APPENDIX C

COMPARISON WITH OTHER STUDIES

The two main studies regarding aircraft towing have been done by Lockheed Aircraft Service Company (Reference 1) and the Oak Ridge National Laboratory (Reference 2). The latter does not study any specific airports and it presents a very brief analysis of aircraft towing based on a general aircraft fleet rather than an aircraft mix at an airport.

The Lockheed analysis is primarily directed toward movement of disabled aircraft. In addition, their analysis considers the case of towing both arrivals and departures at LAX. The results of the Lockheed study and the analysis presented in this report have a substantial disparity. Although all the reasons for this disparity were not identifiable, some basic differences in the assumptions, as given in Table C-1, account for the major differences in the results. The estimate of fuel savings in the Lockheed study is a high upper bound. The MITRE study estimates the fuel savings more closely by considering additional factors such as two minute warm-up for departures, arrivals taxiing on reduced engines (except wide body and 2-engine aircraft), and a more detailed classification of aircraft into six categories based on fuel consumption rates. Some of the other differences such as the number of tow vehicles and the base-year of cost calculations are also given in Table C-1.

TABLE C-1

DIFFERENCES IN MITRE AND LOCKHEED
ASSUMPTIONS FOR LAX

	MITRE	LOCKHEED
1.	ARRIVALS TAXI ON REDUCED ENGINES (EXCEPT WIDE BODY AND 2-ENGINE AIRCRAFT).	NOT CONSIDERED.
2.	TWO MINUTE WARM-UP FOR DEPARTURES.	NOT CONSIDERED.
3.	ON ARRIVALS--CYCLE TIME FOR TOW VEHICLES T: 10 MINS. CONSISTING OF 5 MINS. TRAVEL AND 5 MINS. FOR MANEUVER AND HOOK-UP.	10 MINS, CYCLE TIME WITH NO ALLOWANCE FOR MANEUVER AND HOOK-UP, THEREFORE LOW FOR AIRCRAFT FUEL AND CREW COSTS.
4.	NUMBER OF TOW VEHICLES = 34*.	22
5.	BOTH FUEL (22.5¢/GALLON) AND CREW COSTS ($3.64/MINUTE) ARE BASED ON 1974 DOLLARS.	FUEL COSTS ARE 25¢/GALLON CREW COSTS ARE $4.00/MINUTE
6.	TAXI FUEL RATE PER AIRCRAFT BASED ON AIRCRAFT MIX (INCLUDING SUPPORT SYSTEMS).	ASSUMED 40% HEAVIES
	- ARRIVALS 8.7 GALLONS/MIN. - DEPARTURES 10.6 GALLONS/MIN.	- 11.74 GALLONS/MIN. - 11.74 GALLONS/MIN.
7.	FUEL RATE OF SUPPORT SYSTEM DURING TOW	
	- 1.55 GALLONS/MIN.	- 1.0 GALLON/MIN.

*BASED ON PERFECT AVAILABILITY AND BUSY HOUR OPERATIONS.

THE MITRE CORPORATION
METREK Division
1820 Dolley Madison Boulevard
McLean, Virginia 22101
(703) 790-6000

PB274586

17 May 1977

B52-1664

Process as PB - OK'd by FAA TMC

Department of Transportation
Federal Aviation Administration
800 Independence Avenue, S. W.
Washington, D. C. 20590

Attention: Mrs. L. Hoppe, ALG-311
Contract Administrator

Subject: Request for Release of MITRE Technical Papers for Public Dissemination

Gentlemen:

It is requested that The MITRE's Technical Papers, identified below be approved for public release.

1. Reduction of Parallel Runway Requirements
2. An Analysis of Fuel Conservation through Aircraft Towing
3. Requirements for 3500 Foot Spacings for Simultaneous Parallel IFR Approaches
4. Benefits of MLS Guidance for Curved Approaches, Vol. I, Noise Abatement Case Studies
5. Benefits of MLS Guidance for Curved Approaches, Vol. II, Operational Benefits for New York Airports
6. Concepts for Determination of Longitudinal Separation Standards on Final Approach
7. Concepts for Estimating Capacity of Basic Runway Configurations
8. MLS Case Studies at Major Air Carrier Airports
9. MLS Noise Reduction Case Studies at Selected Air Carrier Airports

The documents will be submitted to the National Technical Information Service, Springfield, Va.

To expedite publication, please coordinate with Mr. James G. Cain, AEM-10, Office of Systems Engineering Management. A verbal approval would be appreciated, and a follow up letter can be processed at your convenience.

To our knowledge, no information of a Classified, Proprietary or Government Sensitive nature is included in these documents.

Approval is hereby requested for release of these documents for public dissemination in accordance with the terms and conditions fo Contract DOT-FA70WA-2448.

Very truly yours,

C. Michael Broderick

C. Michael Broderick
Senior Contract
Negotiator/Administrator

JSY:CMB:pap

Enclosures

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20591

DATE: AUG 0 1 1977

IN REPLY REFER TO: ALG-311 (LH)

SUBJECT: DOT-FA70WA-2448; Release of Information

FROM: Contracting Officer, ALG-311

TO: The Mitre Corporation
Metrek Division
1820 Dolley Madison Blvd.
McLean, Va. 22101

You requested approval to release the information contained in nine documents by your letter of 17 May 1977, Serial No. B52-1664. The documents have been reviewed and the seven of them which can be released at this time are listed below:

1. Reduction of Parallel Runway Requirements not yet [illegible]
2. ✓ An analysis of Fuel Conservation through Aircraft Towing
3. ✓ Requirements for 3500 foot Spacings for Simultaneous Parallel IFR Approaches
4. ? Benefits of MLS Guidance for Curved Approaches, Vol I, Noise Abatement Case Studies not [illegible] – too large to reproduce
5. ✓ Benefits of MLS Guidance for Curved Approaches, Vol II, Operational Benefits for New York Airports
6. ✓ Concepts for Determination of Longitudinal Separation Standards on Final Approach
7. ✓ Concepts for Estimating Capacity of Basic Runway Configurations

The remaining two documents can not be approved.

All of the documents are returned as you requested.

M. Stephens

M. STEPHENS

END
DATE
FILMED
1-13-78
NTIS