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Applications of Advanced Transport Aircraft in Developing Countries

F.W. Gobetz, R.J. Assarabowski,
and A.A. LeShane

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16. Abstract

The less developed nations of the world may become an important future market for advanced aircraft. Four representative market scenarios were studied to evaluate the relative performance of air- and surface-based transportation systems in meeting the needs of two developing countries, Brazil and Indonesia, which were selected for detailed case studies. The market scenarios were: remote mining, low-density transport, tropical forestry, and large cargo aircraft serving processing centers in resource-rich, remote areas. The long-term potential of various aircraft types, together with fleet requirements and necessary technology advances, was determined for each application.

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FOREWORD

This study was performed by the United Technologies Research Center (UTRC) under its prime contract with the NASA Langley Research Center. The New York firm of Parsons Brinckerhoff was a subcontractor to UTRC, and the important contributions of Gene Steiker and Sigurd Grava are hereby acknowledged. Acknowledgement is also given to Dal Maddalon, the NASA Technical Representative, for his guidance and support in the conduct of the study, and to Alan Dubin of UTRC, who was responsible for much of the demand forecasting work.

A considerable amount of background work was done to gather data on developing countries and to gain an understanding of transportation requirements. Many of the sources are referred to in the text and are listed in the REFERENCES section of this report. Many additional references were consulted in the course of the study, and these are incorporated in a partially annotated BIBLIOGRAPHY at the end of the report.

APPLICATIONS OF ADVANCED TRANSPORT AIRCRAFT IN DEVELOPING COUNTRIES

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APPLICATIONS OF ADVANCED TRANSPORT AIRCRAFT IN DEVELOPING COUNTRIES

SUMMARY

A study was performed to determine the long-term potential (to the year 2005) for new aircraft applications in structuring the transportation systems of developing countries, to show the resulting benefits and costs of system implementation, and to identify corresponding technology requirements for such aircraft. Detailed transport system evaluations were made for four market scenarios, represented by the following aircraft applications: remote mining, low-density transport, tropical forestry and large cargo aircraft. In these evaluations, various types of aircraft were compared against appropriate surface transport alternatives in order to estimate relative economic performance. Additional considerations relevant to developing country transport needs were evaluated in a sociopolitical analysis.

The developing nation group was found to be an important future market for both used and newly purchased aircraft. However, the technology requirements of many air carrier and general aviation airplanes were not determined to be appreciably different from those of advanced aircraft which will be required in the developed countries. The four market scenarios noted above were selected because they offered unique opportunities for innovative uses with advanced technology requirements. Such opportunities were identified in the remote mining application, where advanced helicopter and STOL uses were found to be promising, and in tropical forestry, where the attributes of a lighter-than-air vehicle could be used effectively as an alternative to a network of logging roads.

Analyses for the four representative airplane applications were specifically tailored to the environments and needs of two study countries, Brazil and Indonesia. These countries are representative of other developing nations with respect to their tropical locations, but perhaps not representative with respect to their diversity of resource wealth. Despite the disparity in their present states of economic development, the air transport and technology requirements in the two countries were determined to be different primarily in scale and not in basic content.

INTRODUCTION

The premise which has prompted this study is that the group of nations commonly referred to as "Less Developed Countries" (LDCs) or the "Third World" may present an important future market for airplane sales. Since the US is the world leader in airplane production, and since high technology content has characterized US aircraft, there is a potential need for NASA-sponsored research and development to stimulate and support US penetration in the LDC market.

Although the existence of a large, future LDC aircraft market is unproven, there is ample justification to believe that such a market could materialize. First, the LDC group comprises a large fraction of the world's land area and population. Second, the high economic growth rates of many LDCs indicate that the LDC group will become an increasingly important factor in the world's economy, even though the LDC contribution to world gross product is presently small. Third, the lack of a well-developed infrastructure of surface transportation in remote interior regions of the LDCs suggests that airplanes might compete on a favorable economic basis by virtue of the minimal facilities investments required to implement an air network. When considerations of distance, terrain, and transport density are accounted for, it is not unreasonable to speculate that expensive investments in surface infrastructure might be postponed or permanently obviated by an air system specifically adapted to LDC needs. Fourth, the lack of a sophisticated industrial base in LDCs necessitates dependence on developed nations for supply of high-technology products such as airplanes and their components. And finally, there is historical precedent for LDC dependence on the air mode, as will be shown subsequently.

Based on these arguments, the study was formulated with the following objectives:

- Determine the long-term potential for new aircraft applications in structuring the transportation systems of LDCs
- Show the social and political impacts of implementing air systems relative to surface systems
- Identify corresponding technology requirements for such aircraft

BACKGROUND ON LDCs

Since the notion of a "developing" country is a subjective concept (all countries are developing although some are further along than others), a useful starting point was to establish a criterion which defined what countries were to be included in the LDC group. There appears to be no consistent definition of an LDC in the literature, but the most frequently used parameter is per-capita gross national product (GNP)* because it represents a measure of the degree to which national output reaches the people. However, any precise cut-off value of per-capita GNP which defines LDCs will necessarily encounter anomalies. In recent years, for example, some of the oil-rich nations of the mid-East have experienced enormous increases in GNP which give them per-capita GNPs well above those of the US and other industrialized nations generally considered to be "developed". Yet these oil-rich nations are still largely undeveloped, particularly with respect to transportation infrastructure. Thus, for the purposes of this study, it was sensible to establish a criterion, but to permit exceptions where good judgment so dictated. The inclusive LDC list in Table 1 was assembled by adopting a $3000 value for per-capita GNP. The countries were categorized geographically, including the Island Groups which were selected by adhering to classical geography delineations rather than politcal boundaries.

ECONOMIC STRUCTURE OF LDCs

The data of Table 1 were generated primarily to facilitate selection of two case-study countries for detailed analysis, as explained further on. By using this format it was possible to reveal similarities and differences among LDCs and also to show the disparities which exist between these countries and the developed nations. However, the table is deceptive in the sense that it reduces the characteristics of each country to simple indices which do not indicate the disparities existing within a country. In any country, regardless of size or present state of development, some geographic diversity of economic conditions will be encountered. The contrast between economic sectors is often very acute. A modern sector will exist, usually small in geographical extent (perhaps no more than one city) which incorporates a large fraction of the national population and produces a large share of national output. In many respects, the modern sector may be almost indistinguishable from that of a developed country. However, the remainder of the country, usually a large percentage of the total area, will be at a

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* Gross national product is the total value of all goods and services in an economy. Gross domestic product (GDP), a term which is also used in this report, differs from GNP only in that GDP excludes income from abroad. Since most developing countries do not make large foreign investments, the two measures are almost interchangeable for the purposes of this report.

very primitive stage of development. It may be populated primarily by native tribes practicing ancient methods of agriculture, or living a nomadic existence in a vast, remote region with little outside contact. These regions have been referred to as the modern and "less-privileged" sectors (Ref. 1) of an LDC economy.

TABLE 1

BACKGROUND DATA FOR LESS-DEVELOPED COUNTRIES

		Population			GNP[2]														
		10^6	Gr. Rate %/Yr[8]	Density Pers./km^2	Total $ 10^9	Per Cap. $	Per Cap. Gr. Rate. %/Yr[9]	Area 10^6 km^2	Max Dimen. km	Terrain[6]	Mineral Resources	Food Prod. kg/Pers./Yr	Cap. Form. % GDP[12]	Trade, % GDP Ex./Im.	Tot. Aid $/Person	Transport % GDP	Surface Index[10]	Aviation Index[11]	Data[7] Avail.
Island Groups	Greater Antilles-5[1]	23.20	2.1	141	18.064	779	3.4	0.7[3]	2040	M+	+	99.5	21	42/54	2.69	6	2.21	0.43	G
	Indian Ocean-5	10.01	2.6	66	2.250	225	1.9	2.2	2800	M	0	222.9	21	25/36	27.80	7	0.64	0.18	G
	Indonesia-2	128.24	2.1	86	21.921	171	4.5	6.0	5275	J+++	++	207.1	18	18/19	4.52	4	0.30	0.10	E
	Lesser Antilles-15	2.81	1.4	212	2.755	981	4.2	0.8	1110	D	0	8.8	21	37/57	96.48	4	6.41	1.28	F
	Malaysia/Singapore-2	14.02	2.7	42	12.928	932	5.9	1.3	2000	J+++	+++	259.2	24	37/35	5.59	7	3.37	2.41	E
	Melanesia-4	3.06	1.9	6	1.935	632	5.3	5.5	3000	J+++	++	37.0	11	53/50	99.31	6	0.69	0	G
	Micronesia-12	1.14	2.5	60	0.960	842	7.6	13.0	7800	J+++	0	58.3	23	45/58	77.97	6	2.21	0	F
	Philippines-1	41.46	3.0	138	13.673	330	2.6	1.0	1550	J+++	+	213.5	21	22/26	4.40	2	0.58	0.30	E
Central America	Belize	0.14	3.2	6	0.090	660	1.9	0.023	300	M	0	90.7	34	38/64	33.92	1	1.83	0	F
	Costa Rica	1.92	2.7	38	1.612	840	3.5	0.051	425	M++	0	246.7	25	33/47	8.46	4	1.58	1.04	E
	El Salvador	3.98	3.0	186	1.594	410	0.8	0.021	250	M++	0	136.2	18	33/41	3.17	5	0.50	0	E
	Guatemala	5.28	2.1[4]	49	3.065	580	3.8	0.109	500	M+++	0	220.5	15	23/26	3.54	4	0.55	0.14	E
	Honduras	2.93	4.0	26	0.954	340	1.1	0.112	650	M+++	0	190.3	21	32/46	5.89	6	0.59	0.46	E
	Mexico	58.12	3.5	29	63.110	1090	2.8	1.973	3250	M+++	++	265.1	21	9/10	0.35	3	2.49	0.51	E
	Nicaragua	2.08	3.3	16	1.396	670	1.6	0.130	500	M++	0	144.4	16	29/44	11.46	5	1.21	0.23	E
	Panama	1.62	3.1	21	1.618	1000	4.3	0.076	650	M++	0	214.9	23	42/52	10.91	6	3.30	0	E
South America	Argentina	25.05	1.3	9	37.462	1520	2.9	2.767	3700	M	0	948.1	20	9/8	0.39	8	4.59	1.05	E
	Bolivia	5.47	2.6	5	1.532	280	2.2	1.099	1575	M++	+++	212.0	11	27/30	7.85	8	0.45	0.22	E
	Brazil	104.24	2.8	12	95.663	920	6.0	8.512	4450	J++	+	409.7	23	8/9	0.93	4	2.19	0.58	E
	Chile	10.08	1.8	14	8.639	830	1.4	0.757	4250	M+++	++	453.1	13	15/16	2.98	5	1.93	0.88	E
	Colombia	23.95	3.2	21	11.563	500	3.1	1.139	1875	M++	0	269.1	19	15/15	4.52	6	0.67	0.78	E
	Ecuador	6.95	3.4	25	3.476	500	2.8	0.284	725	M++	++	279.8	20	33/27	3.77	5	0.89	0.19	E
	French Guiana	0.06	3.5	1	0.070	1360	7.1	0.091	850	J++	0	–	–	–	719.00	–	5.67	0	P
	Guyana	0.77	2.2	4	0.396	500	1.1	0.215	825	J++	+	317.2	24	53/69	14.09	6	3.04	0	F
	Paraguay	2.57	1.9	6	1.267	510	2.2	0.407	1100	0	0	244.8	18	16/17	6.41	4	0.35	0	G
	Peru	15.38	3.2	12	11.065	740	1.8	1.285	2125	M+++	++	440.4	16	16/21	3.99	5	0.99	0.28	E
	Surinam	0.41	2.6	3	0.350	870	2.4	0.163	500	J++	+	336.3	22	53/50	941.75	4	1.68	0	F
	Uruguay	3.03	1.2	17	3.607	1190	0	0.178	575	D	0	562.1	10	12/17	4.78	8	2.45	0.12	E
	Venezuela	11.63	3.1	13	22.911	1970	1.3	0.912	1450	M+	++	193.5	16	52/17	0.63	7	6.79	1.19	E
South Asia	Afghanistan	18.80	2.4	29	1.840	110	0.9	0.648	1460	M++	0	213.4	–	–	2.57	3	1.09	0.11	G
	Bangladesh	74.99	2.4	521	7.620	100	-1.6	0.144	575	M+	0	244.4	–	–	5.09	6	0.07	0	F
	Bhutan	1.15	2.1	24	0.069	60	-0.2	0.047	320	M+++	0	300.6	–	–	0.36	–	–	0	P
	India	586.27	2.1	178	83.382	140	1.5	3.288	2850	J	+	196.4	16	4/5	1.45	5	0.61	0.06	E
	Nepal	12.32	2.3	88	1.232	100	-0.1	0.141	825	M+++	0	335.5	–	–	2.43	3	–	0	F
	Pakistan	68.21	3.3	85	8.738	130	2.5	0.804	1950	M+	0	241.2	11	14/19	4.70	7	0.43	0.20	E
	Sikkim	0.22	2.4	15	0.021	100	0.1	0.015	100	M++	0	–	–	–	–	–	–	0	P
	Sri Lanka	13.68	2.3	208	1.741	130	2.0	0.066	450	J++	0	135.7	16	16/17	4.74	9	0.40	0.10	E
Southeast Asia	Burma	30.31	2.4	45	2.952	100	0.7	0.677	2100	J++	0	300.7	9	6/5	2.03	5	0.11	0.03	E
	Cambodia	7.89	2.8	44	0.552	70	-5.2	0.181	650	J++	0	92.8	16	8/13	22.62	–	0.15	0.03	F
	Laos	3.26	2.4	14	0.195	60	2.5	0.237	1100	J+++	0	266.0	–	–	20.84	–	0.13	0	P
	Thailand	41.02	3.2	80	12.710	310	4.5	0.514	1650	J+	+	397.8	20	22/23	1.52	6	0.51	0.42	E
	Viet Nam	43.63	3.1	3	6.023	140	-0.6	0.330	1400	J+	0	236.6	9	13/30	28.20	–	–	0	P

All figures for 1974 unless otherwise indicated

1) Number of islands or island sub-groups included
2) GNP in market prices
3) Island areas include intervening water; population densities do not
4) 1965-1973
5) World Bank estimate (Ref. 6)

6) M = Mountainous; J = Jungle; D = Desert; 0 = No impediments; index ranges from low of 0 to high of +++
7) E = Excellent; G = Good; F = Fair
8) 1970-1971
9) 1965-1973
10) A composite index based on rail, ship, and highway ton-mi and pass-mi data
11) A composite index based on domestic and international pass-mi and ton-mi data
12) Capital formation is the sum of net changes in the stock of goods within a country

TABLE 1 (CONT'D.

BACKGROUND DATA FOR LESS-DEVELOPED COUNTRIES*

		Population			GNP(2)														
		10^6	Gr. Rate %/Yr(8)	Density Pers./km²	Total $ 10^9	Per Cap. $	Per Cap. Gr. Rate %/Yr(9)	Area 10^6 km²	Max Dimen. km	Terrain(6)	Mineral Resources	Food Prod. kg Pers./Yr	Cap. Form. % GDP(12)	Trade % GPD Ex./Im.	Tot. Aid $/Person	Transport % GDP	Surface Index(10)	Aviation Index(11)	Data Avail.(7)
Europe	Albania	2.42	3.1	84	1.111	460	5.1	0.029	350	M+	++	323.2	–	–	–	–	–	–	P
	Bulgaria	8.68	0.6	78	13.798	1590	3.6	0.111	775	M+	+	902.6	–	–	–	8	6.67	0.26	P
	Czechoslovakia	14.69	0.6	115	42.149	2870	2.6	0.128	750	M+	+++	1237.2	–	–	–	3	14.27	0.50	P
	East Germany	16.93	-0.2	157	50.775	3000	2.9	0.108	500	M	++	1788.3	–	–	–	5	11.62	–	P
	Greece	8.96	0.5	68	18.852	2090	7.6	0.132	775	M+	+	636.1	21	15/25	–	6	2.90	1.99	E
	Hungary	10.48	0.3	114	19.384	1850	2.7	0.093	550	O	+	1392.3	–	–	–	–	6.99	0.32	F
	Iceland	0.22	1.3	2	1.098	5490	2.6	0.103	325	M+	0	4451.5	31	39/41	–	–	2.32	50.40	F
	Ireland	3.09	1.1	44	7.192	2320	3.9	0.070	450	O	0	1962.8	22	38/46	–	–	4.86	4.09	F
	Malta	0.32	-0.2	1024	0.365	1215	7.0	0.0003	50	O	0	84.2	24	84/113	–	3	4.90	0	F
	Poland	33.69	0.9	108	70.414	2090	4.2	0.313	800	O	+++	2156.3	–	–	–	7	10.68	0.17	P
	Portugal	8.74	0.2	95	14.693	1630	8.0	0.092	600	M	0	379.3	20	27/33	–	6	3.80	3.05	G
	Romania	21.03	0.9	89	20.608	980	–	0.238	700	M+	+	997.9	–	–	–	6	8.37	0.14	P
	Spain	35.23	1.1	70	87.421	2490	5.3	0.505	1150	M	++	672.6	22	17/19	–	6	5.27	1.69	G
	Yugoslavia	21.15	0.9	83	27.925	1320	4.5	0.256	950	M	+	966.1	–	–	–	8	4.72	0.33	P
Middle East	Bahrain	0.24	3.1	391	0.199	996	-7.8	0.0006	75	D+++	0	–	–	–	4.00	–	15.54	0	P
	Cyprus	0.64	1.0	69	0.851	1320	6.8	0.009	200	M+	0	687.5	21	39/59	–	8	12.84	4.26	E
	Iran	32.14	2.9	20	41.375	1250	7.4	1.648	2250	D+	+++	266.7	19	19/26	0.10	3	3.11	0.24	E
	Iraq	10.78	3.3	25	12.493	1160	2.9	0.435	1100	D++	++	222.0	13	40/21	0.85	5	1.26	0.20	E
	Israel	3.30	3.2	159	9.930	3010	6.7	0.021	400	M+	0	328.0	28	25/49	40.24	6	4.04	7.96	E
	Jordan	2.62	3.3	27	1.127	430	-2.6	0.098	550	D+	0	93.8	19	19/52	36.86	8	5.49	0.84	E
	Kuwait	0.93	5.6	52	10.219	11000	-2.9	0.018	200	D+++	+++	–	8	74/18	-6.68	–	15.08	1.60	F
	Lebanon	2.78	3.0	268	3.007	1080	3.5	0.010	200	M+	0	99.2	20	20/28	4.94	8	6.85	11.34	E
	Oman	0.74	3.1	4	1.233	1660	19.4	0.212	950	D+++	0	43.6	–	–	0.50	–	6.99	0	P
	Qatar(5)	0.20	8.9	18	1.280	6400	7.9	0.011	175	D+++	+	–	–	–	2.11	–	–	0	P
	Saudi Arabia	8.71	3.0	4	14.017	1610	10.1	2.150	2250	D+++	+++	25.1	8	87/13	0.34	3	8.70	0.93	E
	Syria	7.12	3.3	38	4.019	560	3.6	0.185	775	D	0	371.3	22	29/34	1.67	7	1.76	0.23	E
	Turkey	38.27	2.4	49	29.375	750	4.4	0.781	1650	M++	+	560.1	18	7/11	–	8	0.92	0.18	E
	UA Emirates(5)	0.36	11.0	4	4.794	15980	16.1	0.084	300	D+++	+++	163.8	–	–	0.33	–	–	0	P
	Yemen, AR	6.48	2.9	33	1.166	180	–	0.195	550	D+++	0	58.0	–	–	3.86	2	–	0	P
	Yemen, PDR	1.63	3.3	6	0.170	220	–	0.288	600	D+++	0	82.6	–	–	4.85	5	1.28	0	P
Far East	China, Peoples Rep.	824.96	1.7	86	222.739	270	4.6	9.597	4900	M+	++	302.2	–	–	–	–	–	–	P
	China, Rep. (Taiwan)(5)	15.71	2.8	436	12.725	810	7.3	0.036	425	M+	0	–	–	–	–	–	–	–	P
	Hong Kong	4.25	1.8	4066	6.415	1530	5.8	0.001	100	O	0	27.6	22	–	0.38	–	2.19	0	P
	Macau	0.27	1.8	16625	0.069	230	-4.6	0.00006	5	O	0	–	–	–	4.46	–	2.70	0	P
	Mongolia	1.40	3.0	1	0.772	550	1.6	1.565	2350	D+++	0	389.4	–	–	–	–	5.15	0	P
	North Korea	15.44	2.7	128	5.249	340	2.7	0.121	700	M+	++	461.6	–	–	–	–	–	–	P
	South Korea	33.46	1.7	340	16.060	480	8.7	0.098	650	M	+	298.8	26	30/43	9.11	6	1.13	0.72	E

5) World Bank Estimate

* Footnotes are on first page of table

TABLE 1 (CONT'D)

BACKGROUND DATA FOR LESS-DEVELOPED COUNTRIES*

		Population			GNP(2)														
		10^6	Gr. Rate %/Yr(8)	Density Pers./km^2	Total \$ 10^9	Per Cap. \$	Per Cap. Gr. Rate. %/Yr(9)	Area 10^6 km^2	Max Dim. km	Terrain.(6)	Mineral Resources	Food Prod. kg/Pers./Yr	Cap Form. % GDP(12)	Trade. % GDP Ex./Im.	Tot. Aid \$/Person	Transport % GDP	Surface Index(10)	Aviation Index(11)	Data(7) Avail.
Africa	Algeria	16.28	3.2	7	10.803	710	4.3	2.381	2200	D++	+	106.5	–	–	7.13	–	1.66	0.31	E
	Angola(5)	5.79	1.3	5	2.801	490	3.2	1.247	1850	D	+++	247.2	–	–	4.53	–	3.97	–	G
	Benin	3.03	3.1	27	0.363	120	1.5	0.113	675	C	0	151.5	17	36/40	9.09	–	0.36	0.36	P
	Botswana	0.66	3.4	1	0.190	290	6.4	0.600	1100	D+	+++	123.7	55	40/74	52.78	4	2.38	–	P
	Burundi	3.68	2.0(5)	132	0.329	90	1.4	0.028	300	M	0	173.5	6	10/13	7.88	–	1.04	0	P
	Cameroon	6.28	1.9	13	1.899	300	4.9	0.475	1300	M	0	133.2	14	23/25	10.07	5	0.56	0.22	E
	Cent. African Rep.(5)	1.75	2.2	3	0.367	210	1.0	0.623	1450	C	+	100.3	14	19/26	16.84	3	0.18	0.65	F
	Chad	3.95	2.1	3	0.395	100	-3.3	1.284	1800	D	0	82.6	11	15/25	11.81	–	0.08	0.31	F
	Congo	1.31	2.5	4	0.611	470	1.9	0.342	1150	J+	+	34.3	–	–	22.54	–	1.62	0.90	F
	Egypt	36.42	2.2	36	10.178	280	0.8	1.001	1450	D++	+	236.4	13	14/20	2.54	4	2.13	0.20	E
	Equatorial Guinea	0.31	1.7	11	0.079	290	-3.1	0.028	275	J++	0	68.5	23	52/52	2.20	–	–	0	F
	Ethiopia	27.24	2.6	22	2.724	100	1.6	1.222	1750	O	0	91.6	10	15/12	2.79	5	0.09	0.12	E
	Fr. Terr. of Afars	0.10	2.3	5	0.180	1785	10.3	0.008	250	D++	0	–	–	–	219.30	–	5.46	0	P
	Gabon	0.52	1.0	2	1.035	1960	6.1	0.268	775	J+	+++	13.3	47	73/72	55.12	4	4.34	2.38	F
	Gambia	0.51	2.5	45	0.086	170	2.2	0.011	350	J	0	320.2	–	–	12.80	–	0.36	0	P
	Ghana	9.61	2.7	40	4.132	430	0.8	0.239	750	J	+	128.8	9	23/16	4.76	4	1.34	0.10	E
	Guinea	4.31	2.4	18	0.517	120	0.1	0.246	875	J++	+	170.3	–	–	4.29	–	1.24	0.02	P
	Guinea-Bissau	0.52	1.5	14	0.178	350	5.9	0.036	300	J++	0	119.9	–	–	8.82	–	–	0	P
	Ivory Coast	4.77	2.5	15	2.938	460	3.0	0.322	825	J	0	247.5	20	34/30	13.55	9	1.48	0.24	E
	Kenya	12.91	3.6	22	2.582	200	3.3	0.583	1125	M	0	202.8	20	35/43	7.58	7	1.44	0.35	E
	Lesotho	1.02	2.2	33	0.167	140	2.6	0.030	250	M+	0	134.6	12	5/56	16.13	2	1.10	0	P
	Liberia	1.67	2.3	15	0.585	390	4.7	0.111	575	J++	++	151.6	18	61/42	7.28	7	4.95	0	E
	Libya	2.35	4.2	1	8.281	3530	5.7	1.760	1975	D++	+++	54.0	29	57/38	4.26	6	16.62	0.91	E
	Malawi	4.92	2.6	41	0.694	140	3.7	0.118	875	Q	0	285.3	18	24/33	7.42	5	0.23	0.09	E
	Mali	5.56	2.5	4	0.445	80	0.5	1.240	1925	D+	0	81.9	13	16/22	13.06	–	1.07	0.09	F
	Mauritania	1.27	2.7	1	0.374	290	1.2	1.031	1625	D++	+	20.7	33	49/51	21.12	6	16.16	0.97	E
	Morocco	16.88	2.4(5)	38	7.005	430	2.5	0.447	1450	M+	++	192.9	14	27/26	5.88	–	1.57	0.23	E
	Mozambique	9.03	2.3	12	3.431	380	4.1	0.783	2100	J	0	90.7	–	–	2.08	–	1.82	0	F
	Namibia	0.86	3.0	1	–	–	–	0.824	1600	D+	+++	90.7	–	–	–	–	–	0	P
	Niger	4.48	2.7	4	0.538	120	-4.6	1.267	1850	D+	+	77.3	6	11/18	18.87	3	1.10	0.25	F
	Nigeria	61.27	2.7	66	21.183	290	8.3	0.924	1450	O+	++	57.5	20	26/18	1.28	3	0.60	0.04	E
	Rwanda	4.12	2.9	157	0.325	80	3.2	0.026	250	M	0	40.1	–	–	9.51	–	1.08	0	F
	Senegal	4.32	2.4	22	1.607	330	-2.8	0.196	750	O	0	336.8	10	18/23	17.78	–	0.94	0.27	E
	Sierra Leone	2.71	1.5	38	0.553	190	1.5	0.072	375	J+++	++	227.6	11	28/30	4.09	9	1.76	0	F
	Somalia	3.09	2.6	5	0.279	90	1.6	0.638	1975	D+	0	52.0	–	–	9.98	–	1.21	0.03	F
	So. Rhodesia	6.10	3.5	16	2.623	430	3.5	0.391	775	C	++	322.5	21	–	0.19	5	3.56	–	G
	Spanish Sahara	0.11	10.9	0.4	–	–	–	0.266	1225	D+++	0	–	–	–	–	–	1.25	0	F
	Sudan	17.32	2.5	7	3.502	230	-0.6	2.505	2300	D+	0	168.2	11	19/21	2.66	8	0.52	[illegible]	E
	Swaziland	0.48	3.2	28	0.186	390	6.3	0.017	175	M	+	189.0	18	64/62	24.15	5	1.54	0	E
	Tanzania	14.76	2.7	16	2.296	160	2.6	0.945	1475	O	+	113.9	–	–	7.12	7	1.21	0.06	G
	Togo	2.17	2.6	39	0.544	250	2.5	0.056	600	D	+	61.2	23	25/41	13.31	7	5.31	0.52	F
	Tunisia	5.64	2.4	34	3.549	650	4.9	0.164	800	O	+	171.8	22	35/35	23.48	5	1.94	0.33	E
	Uganda	11.17	3.3	47	2.685	240	1.2	0.236	800	O	0	108.8	14	19/23	1.68	3	1.03	0.10	E
	Upper Volta	5.90	2.3	22	0.518	90	-1.1	0.274	925	O	0	34.3	8	8/7	10.47	5	1.08	0.19	F
	Zaire	24.22	2.8	10	3.370	140	2.9	2.345	2200	J+	+++	59.5	27	37/47	6.24	9	0.50	0.22	E
	Zambia	4.75	3.3	6	2.486	520	-0.2	0.753	1400	C	+++	152.3	31	42/45	8.79	6	1.77	0.61	G

5) World Bank estimate

* Footnotes are on first page of tables

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ROLE OF TRANSPORTATION IN LDCs

It is generally recognized that national economic growth cannot proceed without adequate means of transportation within a developing economy. The feasibility of stimulating economic growth by heavy investment in the transportation sector is supported by some economic planners and disputed by others (Refs. 2-5). Historically, investments in transportation, as percentages of total investments, have been higher in LDCs than in developed nations; e.g., Mason (Ref. 4) estimates that 15-25 percent of LDC investment has been in the transportation sector, and Owen (Ref. 5) says that 12-46 percent of public investment has been in transportation. In general, transportation growth does seem to lead GNP growth in LDCs, but recent trends, as indicated by the distribution of World Bank loans in various investment sectors (Fig. 1) show that increasing emphasis is presently being placed on agriculture, with the result that transportation is somewhat deemphasized. It appears that agricultural development is now perceived as a prerequisite to overall development (Ref. 13). In the past, the reverse was true: industrial growth was stressed in the early developmental phase, with transportation investments required primarily to support new industry, and agriculture was given a low priority. Nevertheless, loans in the transportation sector have been about 20 percent of the World Bank total in recent years (Refs. 6, 7). It must be stressed that the fraction of LDC transportation spending assigned to the air mode is presently very small and consists primarily of major airport construction projects.

The need for adequate transportation to support agriculture is not necessarily less than for industry, although a shift in modal development may be involved; e.g., more investment in feeder roads and highways than in railroads. It may be expected that the trend toward increasing emphasis on agriculture in LDCs will continue because present population growth rates necessitate an expanding need for food (Ref. 4).

An important determinant of the role that transportation plays in a developing economy is the objectives of the national plan (Refs. 8, 9). A problem in evaluating such plans, however, is the uncertainty that they are realistic and that they will be followed. Since planning is often done for relatively short horizons, typically five years, the time required to complete large-scale projects is frequently beyond the immediate planning cycle, leading to uncertainties in funding and to shifting objectives, even though long-range policies are stated or implied. This problem is not unique to LDCs, but these shifting targets may cause particular disruption in an economy in which investment funds are limited and basic needs can be perceived in every sector.

BREAKDOWN OF LDC SPENDING IN 1975

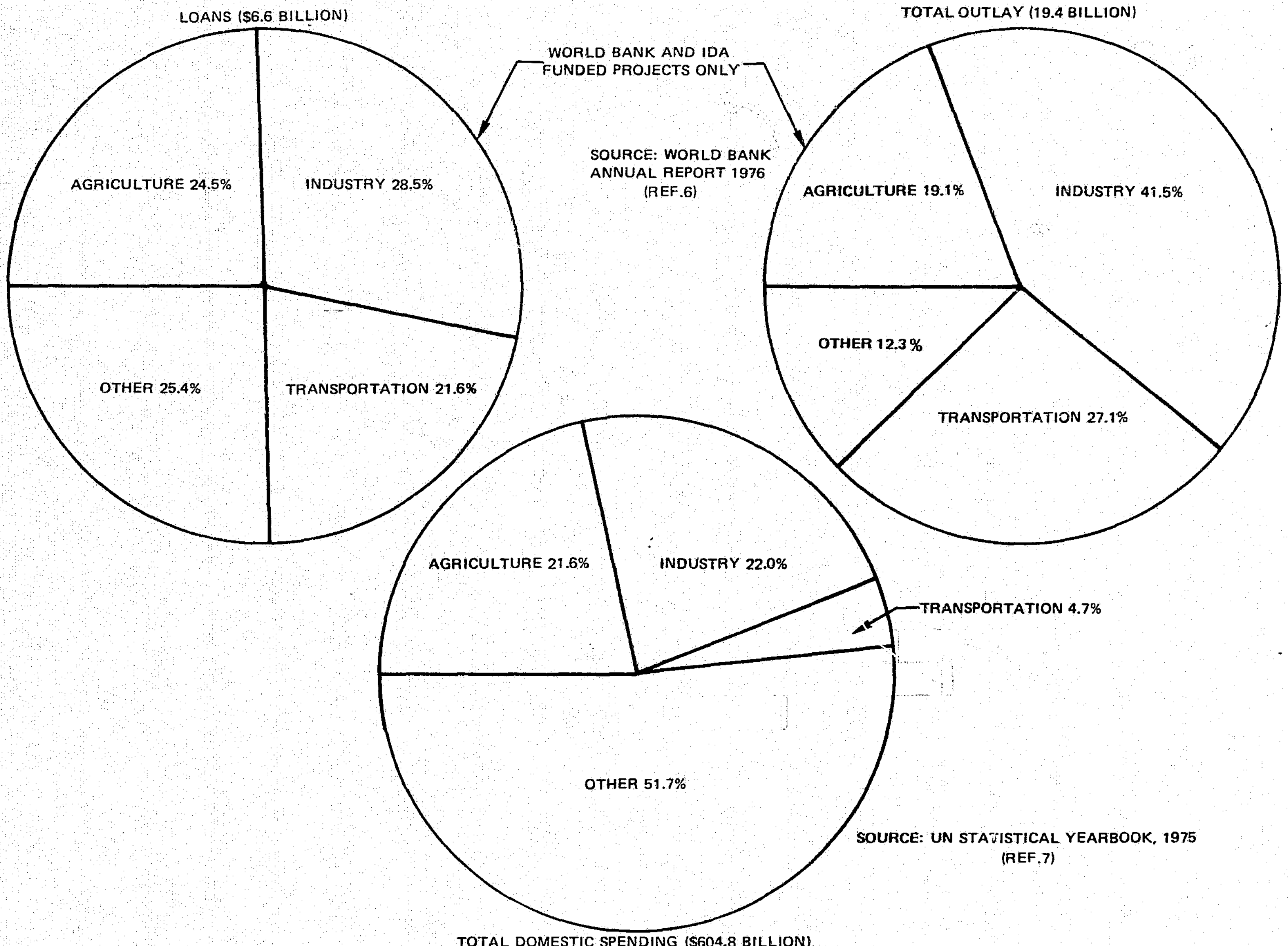

FIG. 1

77–09–127–1

Despite these problems, the existence of a national plan may provide a useful guideline by which to project transportation needs and developments into the future. This is particularly true if the quality of the plan can be judged and if there is some tangible evidence that past plans have been implemented (e.g., regional redistribution of population and investment in Brazil and East Africa).

A number of causal mechanisms have been identified in order to explain the development of transportation in LDCs. Although these reasons can be enumerated, it is important to recognize that the transport needs for each country are different (Ref. 10). Therefore, while examples can be given to support many intended roles of transportation, there appear to be no general rules that apply universally for the LDC group. Past history and future economic plans for each country are the best determinants of the transportation priority in each country.

National defense has also been an important stimulus to transportation development, particularly in the politically unstable regions of the world where many LDCs are situated. The fact that large areas of LDCs are often sparsely populated creates a difficult logistical problem in defending borders from intrusion. These same undeveloped regions are frequently the sources of untapped resources which must be exploited to promote future development (Ref. 11). In general, the opening of underdeveloped territories is an important element of the national planning process, and transportation plays a vital role in that process. Furthermore, the linking of dispersed regions that have been separated culturally as well as economically will also serve to promote national unity.

In agricultural regions, provision of dependable transportation can have a profound effect. Small farmers, whose crops are selected primarily to provide subsistence for their families, can introduce instead cash crops for which the land is often better suited, relying on improved transportation to get the crops to market and to bring their necessities to them. This release from subsistence agriculture is especially significant in LDCs, where the agricultural sector usually constitutes the largest single concentration of labor. Thus, by connecting outlying agricultural regions to commercial centers, a two-way flow of goods is promoted (Ref. 4). If an export market exists for agricultural produce, timber, ores, or manufactured products, the transportation infrastructure is a vital link between developing regions and world markets. It also facilitates expansion of health, education, and other social services. Indeed, provision of these services may be the primary motivation for an expanded transportation network (Refs. 5, 12).

Finally, LDCs have shown a tendency to rely on the international travel sector as a way of projecting a favorable world image (Ref. 13). In many cases, this activity is a preferred utilization of scarce foreign exchange, taking precedence over domestic uses which are more defensible on purely economic grounds (Ref. 14). There appears to be a strong desire in LDC cultures to show a modern image to the world as a means of achieving status.

CHOICE OF MODE IN TRANSPORTATION PLANNING

Two basic determinants of modal choice are physical characteristics -- geography and climate -- over which only limited control can be exercised. Terrain features, such as rivers, islands, mountains, deserts, and jungles alter the relative cost and functional utility of surface modes by imposing circuitous routings, steep grades, and difficult maintenance and logistics problems. Similarly, broad expanses of sparsely populated area can lead to high capital expenditures and underutilized capacity. Certain geographies do lend themselves to efficient use of surface modes; an example is the coastal corridor of cities which is a characteristic of some LDCs. Such corridors create high-density links for which surface capacity can be efficiently used (Ref. 11). The level terrain commonly found in these cases also favors surface mode development.

Climate can be an important factor, particularly when seasonal extremes force a reduction in capacity and even complete shutdown; e.g., long periods of interrupted service during monsoon seasons in tropical areas (Ref. 15). Technology advances may lessen the impacts of climate by permitting improved navigation and control in adverse weather conditions, and by facilitating large-scale irrigation of arid regions, etc. (Ref. 16, 17).

Despite the apparent advantage of the airplane in overcoming terrain impediments, rail and road developments have generally been favored in LDCs, even when spectacular engineering projects have been required to permit construction of surface links in remote areas. Several compensating features of surface transport can be identified to explain its selection in these cases. An important one is the surplus of labor in LDCs (Refs. 3, 4, 18). Rail and road projects employ large numbers of unskilled workers and make use of domestic construction materials. Often this coincides with a vital element of the national plan, which is to create employment. Public works projects of this type have also been used in developed nations in periods of persistent unemployment. By contrast, airplanes are almost always puchased abroad, exacerbating the foreign exchange problem common to LDC economies. Although good arguments can be advanced to show that the productivities of modern airplanes overcome their perceived economic disadvantages, the attitude that air travel is a capital-intensive mode is widely* accepted (Ref. 19).

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* More objective studies, e.g., (Ref.11), describe rail and highway as capital-intensive modes, identifying air with minimal initial investment for a startup service.

Another important advantage of surface systems is to provide an ubiquitous, multi-purpose network. There is a tendency for development to occur along the entire right of way, often extending many miles from the route. In this way, growth is stimulated over a wide area rather than at a few densely populated nodes, where problems of urbanization can ensue unless careful planning is followed (Ref. 20). The concept of the Airport/Industrial City (Refs. 21, 22) is an example of a planned development in conjunction with a transportation system, but it has yet to be adopted in either the developed or developing world.

When a highway cuts through an underdeveloped region, it becomes a part of the local transportation system, where both mechanized and primitive vehicles can utilize it in the course of local commerce. This unique feature of roads provides a strong impetus for selection of the highway mode (Ref. 23). In addition, it has been found that trucking is an activity to which people adapt quickly in underdeveloped areas. A further benefit of the widespread use of trucks is the training it provides for local labor. The need to keep a truck in operating condition can stimulate the beginning of a semi-skilled work force for industry.

Depending on the national plan, the role of transportation can emphasize passenger or cargo applications. Since surface modes are better adapted to routine movement of bulk commodities and other low-value goods characteristic of a developing economy, there is a strong preference for road and rail systems (Ref. 24). In the instances where passenger travel is an important function, as in the case of tourism, airplanes have found a useful application. Also, the mobility requirements of the small class of skilled professionals, including government employees, is a further justification for the time-saving attributes of an air system (Ref. 2, 5).

Another factor in modal choice which favors air development is the lead time required to establish a transport system. Rail, port, and highway projects can be very time-consuming to implement, whereas an air system requires only a few airports and a small fleet of vehicles to begin productive operation. This advantage is even more pronounced when long distances are to be covered, since the capital costs of rail and highway projects increase with distance but air system investments generally do not. Studies which concentrate on the use of air transportation usually identify "long thin" routes as primary applications. Thus an evolutionary development is suggested with initial emphasis on air transport (Ref. 11).

In the case of the national defense role, airplanes are often the preferred mode because of their great flexibility of use and their ability to deliver men, material, and weapons in rapid response to demand. Similarly, interface problems among modes may favor air because of the incompatibility of existing surface facilities; e.g., containers and heavy loads may exceed the weight and width limits of bridges and other structures designed to accommodate the needs of the past. Therefore, the ability of the airplane to overfly transfer points common to surface-mode systems is an important advantage. Typically, a surface system infrastructure has many such transfer points which introduce severe delays. Use of air transport results in greatly reduced transit times and improves the reliability of service, which can reduce expensive warehousing and inventories. Thus, air transport provides an economic advantage by virtue of its less cumbersome logistical support system (Ref. 25).

A final consideration in modal choice is energy, particularly in recent years as the cost and availability of conventional fuels have changed so dramatically. Although this consideration is not stressed in the literature because the development is so recent, it can be expected that energy and, to a lesser extent, ecological factors, will play a role in modal decisions in LDCs.

POTENTIAL AIRPLANE APPLICATIONS IN LDCs

There has been considerable variety in the use of airplanes in developing countries (Ref. 26), but the categories of use are not different from those found elsewhere. What is different about LDC airplane applications, compared to the developed world, is the distribution of fleets by category. As might be expected, personal uses of airplanes do not predominate (particularly in the poorer countries) as they do in developed countries. Instead, air carrier and commercial uses comprise a large fraction of LDC fleets.

A comprehensive tabulation of historical and potential future LDC airplane applications is provided in Table 2. This list was assembled after an extensive literature survey conducted early in the study. It served as a useful starting point in determining which applications would be most promising from the standpoints of R&D possibilities, numbers of aircraft required, and value of deliveries. These points are enlarged upon in the next section.

Documentation of the present and past airplane fleets of LDC air carriers appears in Fig. 2 for the period between 1967 and 1976. Since the sources of these data are the periodic airline censuses which appear in Flight Magazine (Ref. 27), the Table 2 categories incorporated in the data are primarily the scheduled carriers and air taxis. For this reason, many small airplanes, such as the DHC-6 Twin Otter, are not represented. The figure shows the breakdown of airplanes, by type, displaying the recent changeover from prop to jet equipment by LDC carriers. The emphasis on long-range aircraft is indicated by the numbers of four-engine, regular-body and wide-body models. Throughout this period of changeover, the total number of aircraft has been fairly constant as larger, more productive jet aircraft replaced the smaller piston and turboprop models. More than 50% of the LDC fleet now consists of jet airplanes, particularly two- and four-engine models.

TABLE 2

AIRCRAFT APPLICATIONS

General Aircraft Use Category	Possible LDC Applications	Aircraft Types
MILITARY	Instruction	Trainer
	Tactical	Fighter
	Logistics	Cargo Transport
CERTIFICATED CARRIERS		
Passenger	Domestic Pass./Cargo	Short-Medium Range Pass. Transport
	International Pass./Cargo	Medium-Long Range Pass. Transport
All Cargo	Domestic Cargo	Short-Medium Range Cargo Transport
	International Cargo	Medium-Long Range Cargo Transport
GENERAL AVIATION		
Private Flying	Personal & Instructional	Light Aircraft
Business/Gov't.	Executive Transport	Business Aircraft
Commercial:		
Air Taxi	Low Density Routes	Small Commercial Transport
Aerial Applications	Agriculture, Forestry	Ag Aircraft
Logistic Supply	Offshore Oil, Remote Mining, Ship Load/Unload	Helicopter or Fixed Wing Transport
Construction Support	Hydro Project, Pipeline, Power Line	Helicopter
Commodity Transport	Agriculture, Forestry, Mining	Fixed Wing, Helicopter, Airship
Utility	Exploration, Mapping, Emergency, Tourism	Helicopter, Small Comm. Transport

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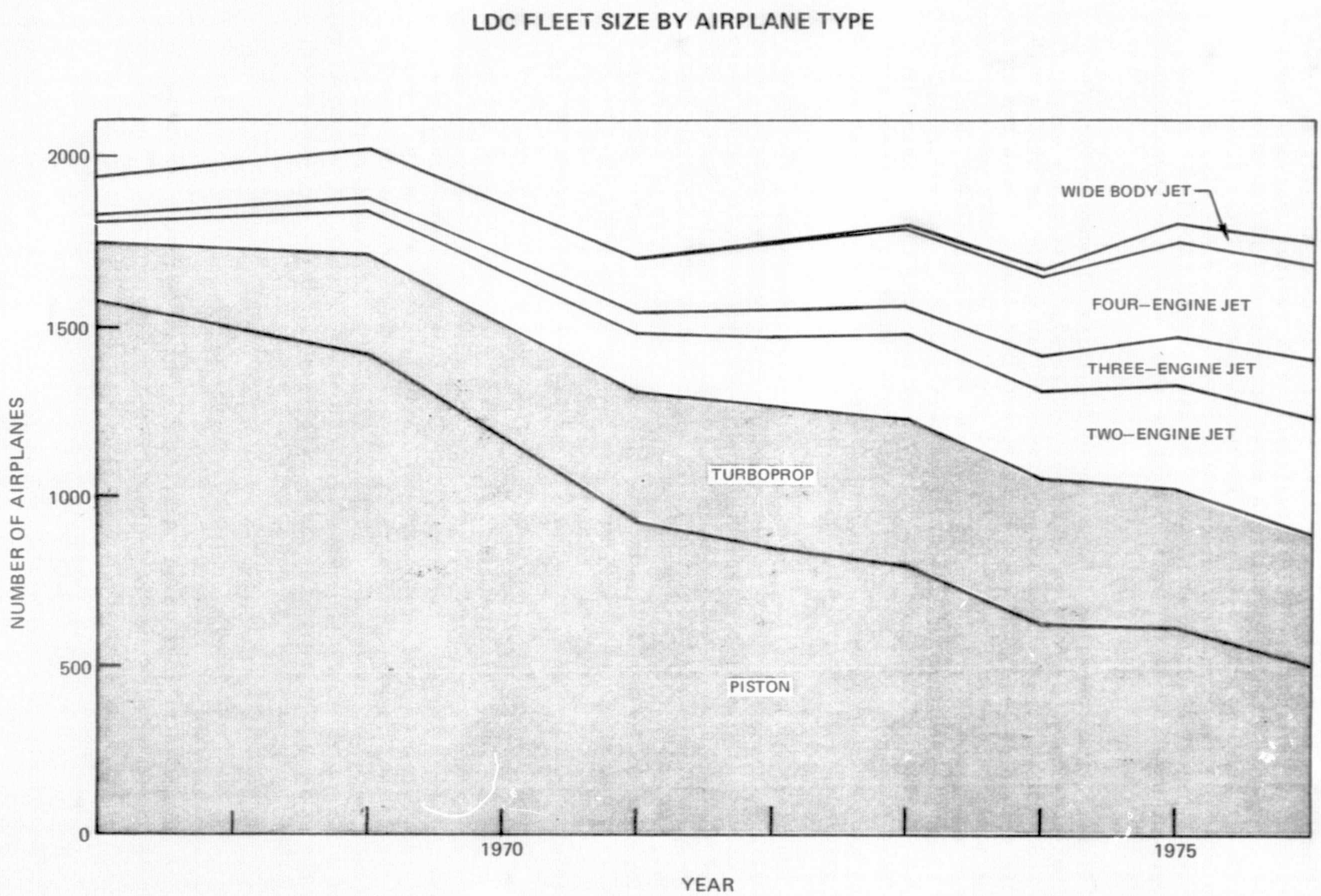

FIG. 2

Since LDCs have in the past relied heavily on used aircraft to fulfill their transport needs, the future availability of various airplane types on the used market is of importance. A world forecast for piston-powered aircraft is given in Fig. 3. Since future purchases of these airplanes would have to come from these diminishing fleets, and since Fig. 2 showed that about 500 of these airplanes were already in the LDC fleet in 1976, it is apparent that LDCs will certainly not be able to rely on these airplanes beyond 1980.

Similarly, turboprop models are also declining in numbers (Fig. 4) although two-engine turboprops in the 19,000-to-25,000 kg gross weight class will continue to be available for at least another decade, as will a much smaller number of large, four-engine aircraft (Hercules). These two categories constitute a major reserve of used aircraft which LDCs may draw upon to meet domestic capacity needs through the 1980s. Beyond 1990, however, even these airplanes can no longer serve that purpose.* An additional reserve consists of the very large numbers of two- and three-engine jet airplanes presently operating in the developed countries. As these airplanes are replaced by newer and larger models, an extremely large pool of used airplanes will become available to the LDC group.

Despite their proclivity toward used aircraft purchases, the LDCs have already demonstrated their readiness to equip with new models. Moreover, they have allocated large expenditures for aircraft in recent years despite shortages of capital. As shown in Fig. 5, there has been a consistent trend of increasing value of fleet additions as GDP increases (Refs. 7, 28, 29). The primary data base is represented by the group of (unidentified) developed nations which forms the shaded region on the chart. Although there is considerable spread in the value of purchases among the smaller nations (low GDP), the trend is toward a narrower band as GDP increases, ultimately focusing on the US, which is by far the highest point on the diagram.

A similar plot for LDCs would show a wide variation because all the points would fall at the lower end of the GDP range, and many would even be beyond the range shown. Therefore, LDCs have been aggregated into the geographical groups used previously, in Table 1. It can be seen in Fig. 5 that five of the nine LDC groups fall above the developed-nation band but none fall below it. Therefore, it is apparent that LDCs have tended to spend a disproportionately larger share of GDP on purchase of airplanes than have the developed nations. In terms of percent increase in fleet investment, the disproportionality would be still greater.

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* It is assumed here that large numbers of military versions of these airplanes will not be converted to commercial use.

WORLD FLEETS OF PISTON–POWERED AIRCRAFT

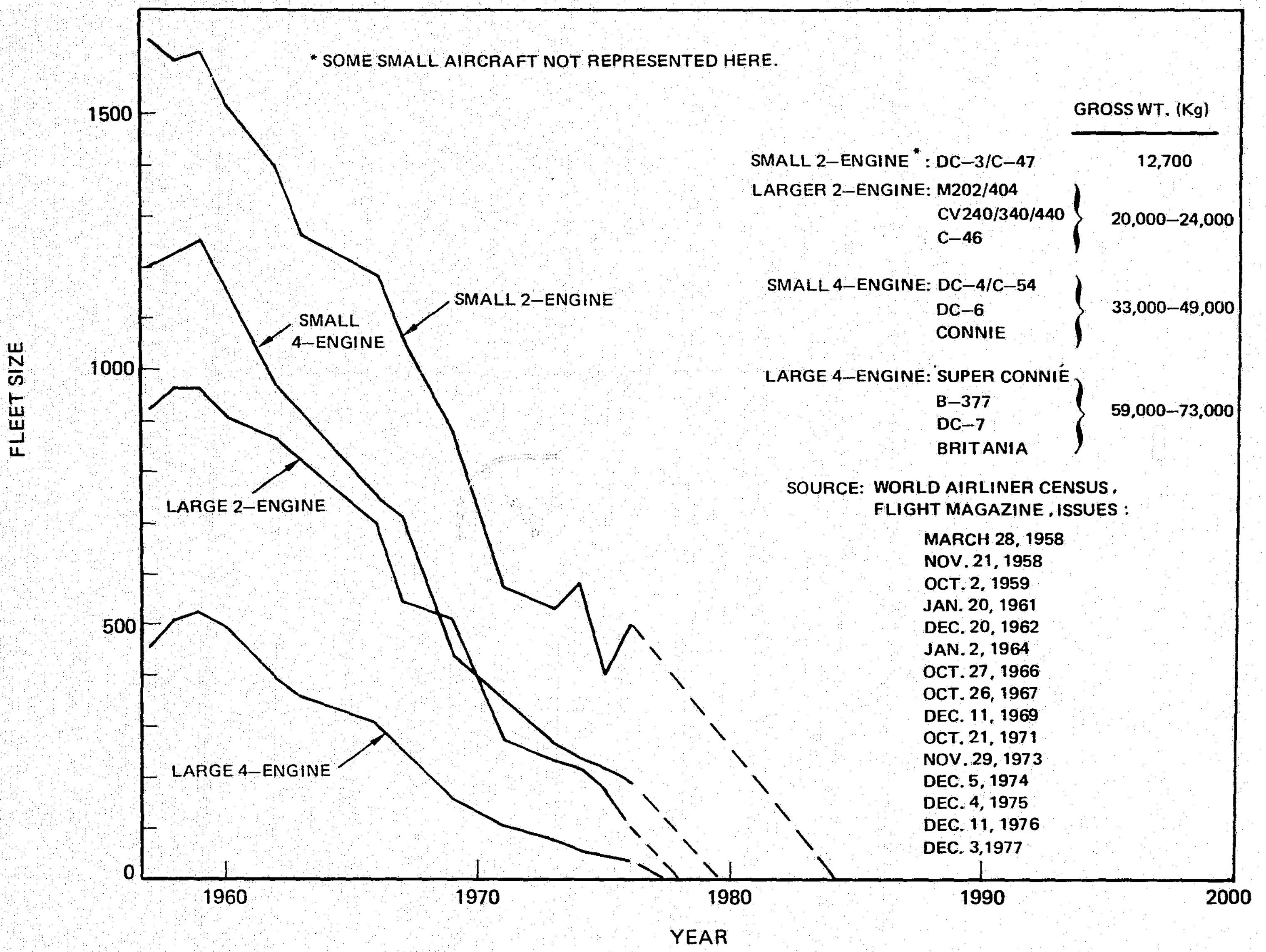
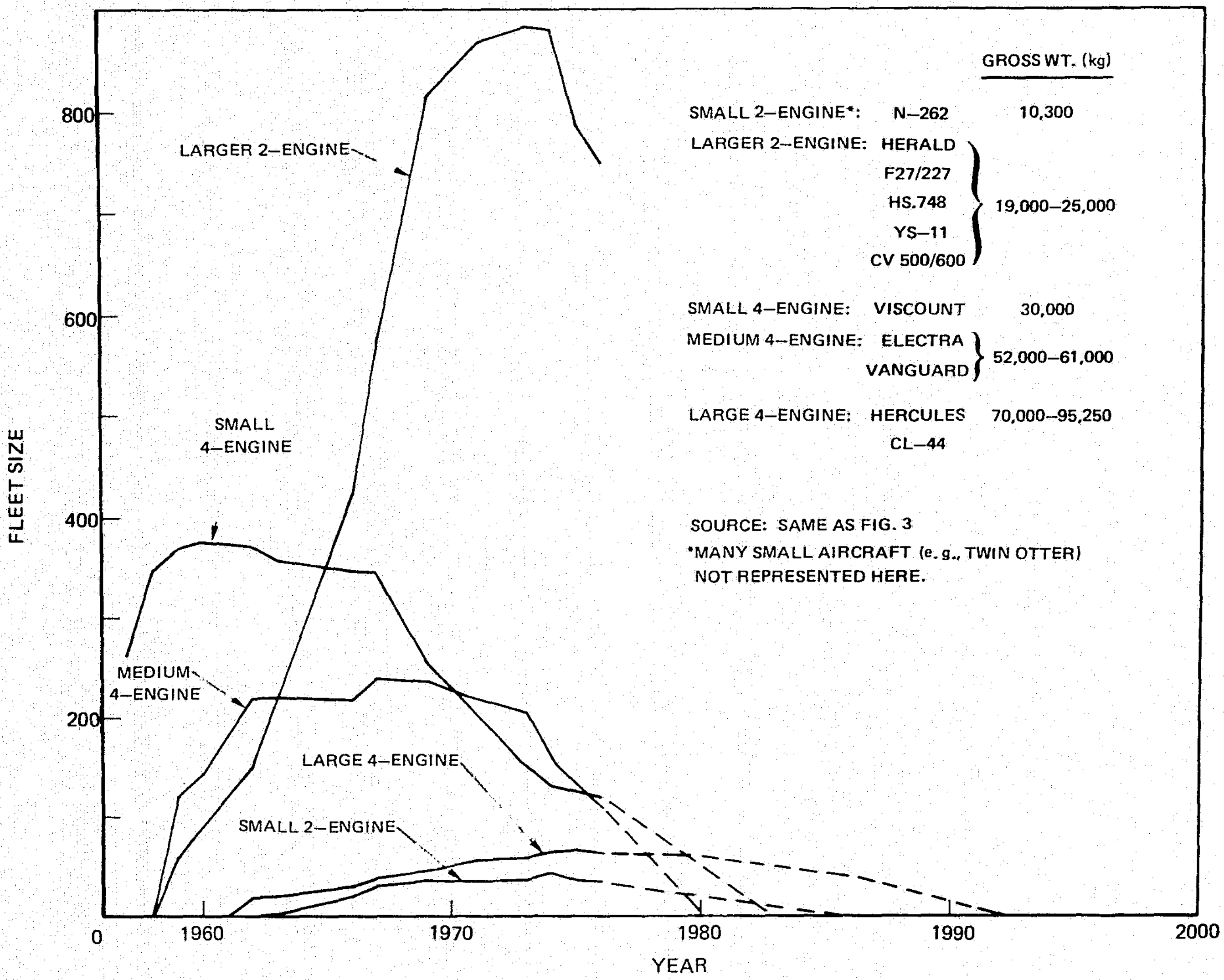


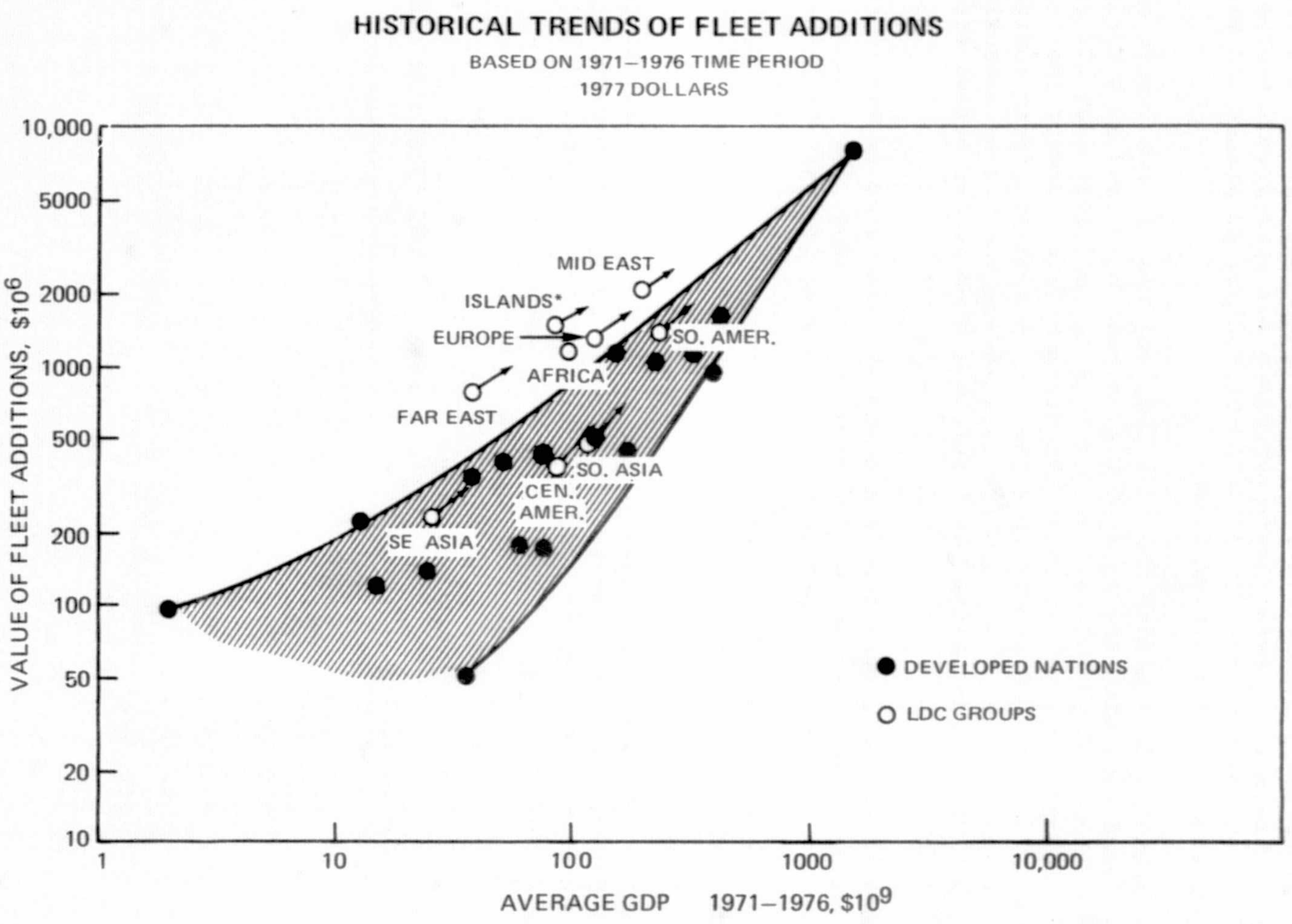
FIG. 3

WORLD FLEETS OF TURBOPROP–POWERED AIRCRAFT



*MANY SMALL AIRCRAFT (E.G., TWIN OTTER) NOT REPRESENTED HERE

FIG. 4



* SEE ISLAND GROUPS IN TABLE I

FIG. 5

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The implication of these fleet data is that future LDC airplane purchases will serve two important functions which impact future technology. First, LDCs will provide a ready market for resale of the first- and second-generation jet airplanes presently operating in the fleets of developed nations. This will facilitate reequipping developed-nation fleets with advanced-technology aircraft. Second, because of rapid growth and their demonstrated history of new-aircraft purchases for prestigious routes, LDCs will broaden the market base for advanced-technology airplanes and provide further impetus for their introduction.

As a means of determining the role LDCs may play in the future marketing of new and used aircraft, the data of Fig. 5 have been used as a basis for projecting future LDC purchases. It has been assumed that each LDC group will shift toward the focal point of the diagram (i.e., toward the US) with GDP growth. Thus, if GDP growth is estimated in each five-year period to 2005, the value of fleet additions for each LDC region can be approximated from Fig. 5 by proceeding along the lines indicated by the arrows attached to each point.

Forecasts of GDP growth for each group are presented in Fig. 6 together with the historical trends in the 1958-1976 period (Ref. 7). Future growth rates shown on the chart are predicted to be higher or lower than the historical period. These predictions of future growth were based on judgments from the background data phase of the contract. As indicated, a slight increase in GDP growth rate is forecast for the total of all LDC groups.

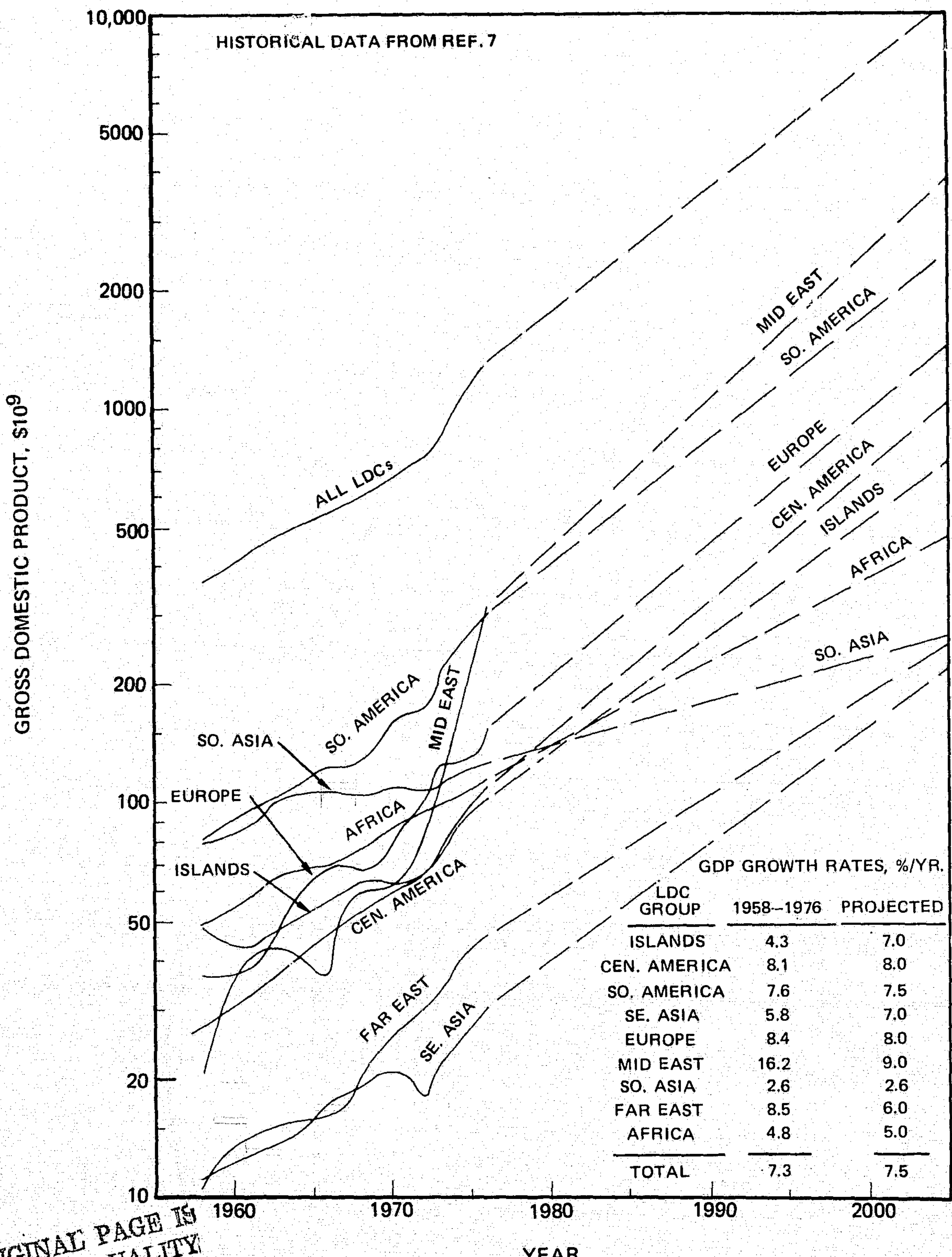
Using Fig. 6 to estimate average GDP in each five-year period from 1975 to 2005, and Fig. 5 to convert this growth to future investments in new aircraft in each respective period, the forecast for the total of all LDC groups is as follows:

Time Period	Value of LDC Fleet Additions $\$10^9$
1975-1980	12.0
1980-1985	16.1
1985-1990	20.9
1990-1995	27.4
1995-2000	36.6
2000-2005	48.2
1975-2005	161.2

FIG. 6

LONG–TERM GDP GROWTH TRENDS FOR LESS DEVELOPED COUNTRIES

1977 DOLLARS



LDC GROUP	1958–1976	PROJECTED
ISLANDS	4.3	7.0
CEN. AMERICA	8.1	8.0
SO. AMERICA	7.6	7.5
SE. ASIA	5.8	7.0
EUROPE	8.4	8.0
MID EAST	16.2	9.0
SO. ASIA	2.6	2.6
FAR EAST	8.5	6.0
AFRICA	4.8	5.0
TOTAL	7.3	7.5

A determination of the number of aircraft which would be purchased requires an assumption as regards the average purchase price. The only basis for estimating the average price was the historical value from the period of the data base. The figures below summarize some basic information relevant to this period for the LDC and developed-nation groups.

	Total LDC Group	Developed-Nation Group
No. of Countries*	114	20
No. of Airplanes Purchased	917	1058
Avg. No. per Country	8.0	52.9
Value of Airplanes Added, $\$10^9$	9.3	17.2
Avg. Value per Country, $\$10^6$	82	858
Avg. Value per Airplane, $\$10^6$	10.2	16.2

* Communist countries excluded

Although the total number of airplanes and the total value of purchases are comparable for the two groups, the LDC averages per country are understandably lower. Furthermore, the average value of airplanes purchased is considerably lower for the LDC group, reflecting the greater percentage of smaller aircraft purchased by LDCs. Even the value shown is somewhat inflated because the average price of new aircraft was used in the computation, whereas many LDCs purchase aircraft on the used market (as do the smaller developed nations). For the same reason, the projected values of LDC fleet additions are also somewhat inflated, although the degree of this inflation is difficult to estimate, and future purchases of the leading LDCs will tend to be of new rather than used airplanes. Therefore, it is reasonable to accept the projected values and apply the average price of $\$10 \times 10^6$ (1977 dollars). The result is a future estimate of about 16,000 airplanes over the 30-year period, for an average of over 500 airplanes per year.

APPROACH TO ACHIEVING STUDY OBJECTIVES

Although a general understanding of the characteristics of LDCs was sought in the first phase of this study, the contract specified a case-study approach in which two LDCs would be selected for detailed evaluations of air transport opportunities. One of these LDCs was to be a Latin American nation and one was to be from another continent. Therefore, a data-gathering task was conducted in which basic information was sought for the 125 countries listed in Table 1.

An important finding of this preliminary data-gathering effort was the wide variation in quality of available information among LDCs. For the established countries, particularly those in the higher GNP range, the data are accurate and available in time series dating back many years. (The primary data source was Ref. 7.) For many LDCs, however, the data are less credible and often not available for other than a few recent years. This data problem necessarily became a factor in the country selection process because it was not desirable to retain nations for which a good data base could not be assembled. Absence of important data in the UN sources (Ref. 7) served as an indication that a country should be dropped unless there were overriding reasons for its retention.

A wide variety of data appears in Table 1, representing demographic, economic, physical, resource, agricultural, trade, and transportation parameters. In veiw of the large number of countries, data for only a recent year (usually 1974) are presented, although growth rates for population and GNP are shown. The purpose of the table was to provide a country-by-country comparison in a reasonably concise format. Therefore, certain criteria were expressed as simple indices (terrain, surface transport, aviation, data availability) by combining various parameters of each type in a nondimensional form. In every instance, more comprehensive data were assembled so that the scope and depth of the comparisons could advance as the number of countries was reduced in the selection phase. These data are presented in Appendix A which describes the selection process. Certain data (e.g., employment) were either unavailable or unreliable for so many LDCs that their inclusion would have served no useful purpose (Ref. 30).

CASE-STUDY COUNTRIES

A number of LDCs would have served as good case-study countries, but Brazil and Indonesia were considered to be the best choices. These two large countries, the relative sizes of which are indicated in Figs. 7 and 8 (Ref. 31) are disparate in many respects, their primary similarities being bright prospects for future growth and for aircraft applications in the rapid

RELATIVE SIZE OF BRAZIL

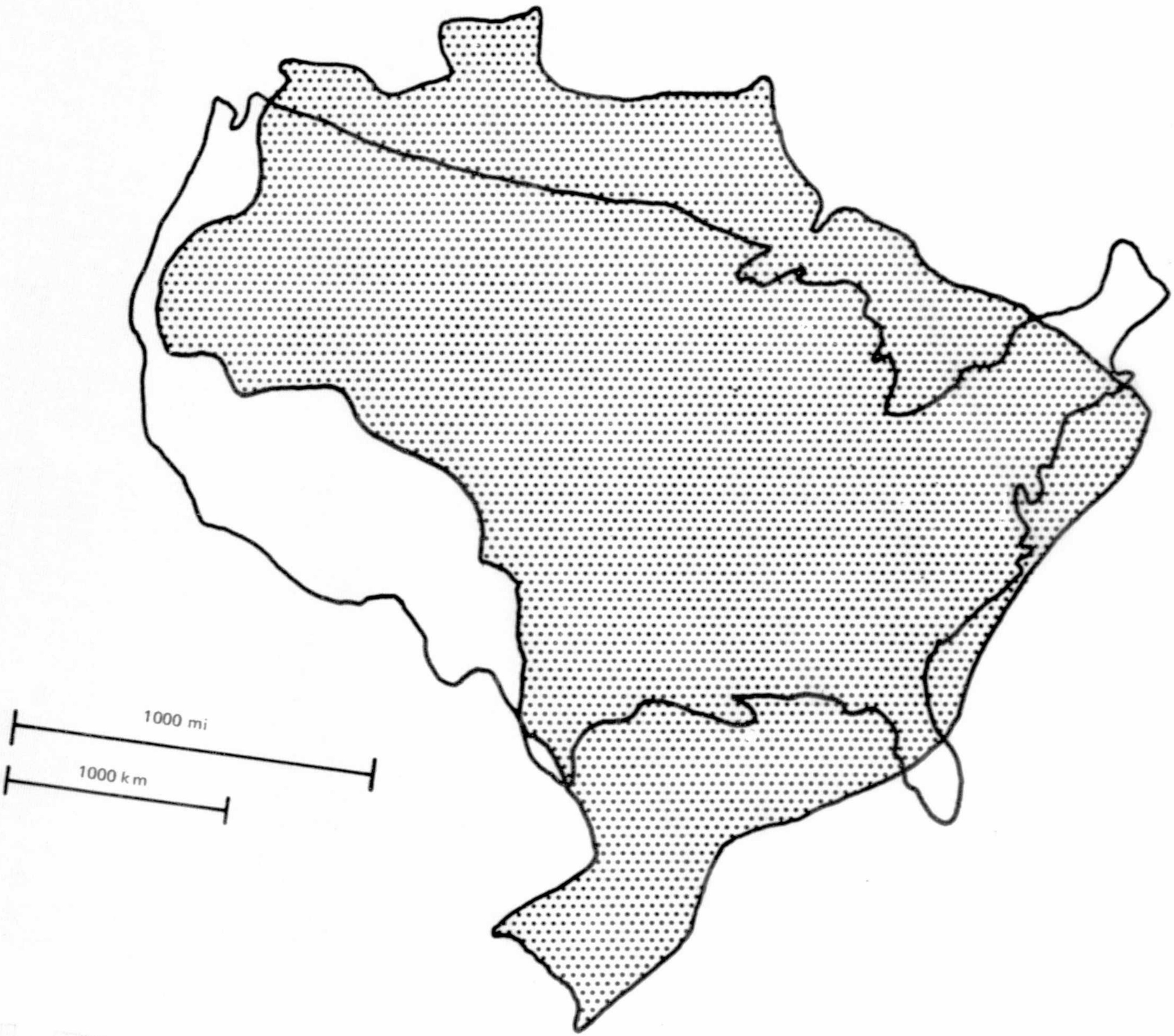


FIG. 7

RELATIVE SIZE OF INDONESIA

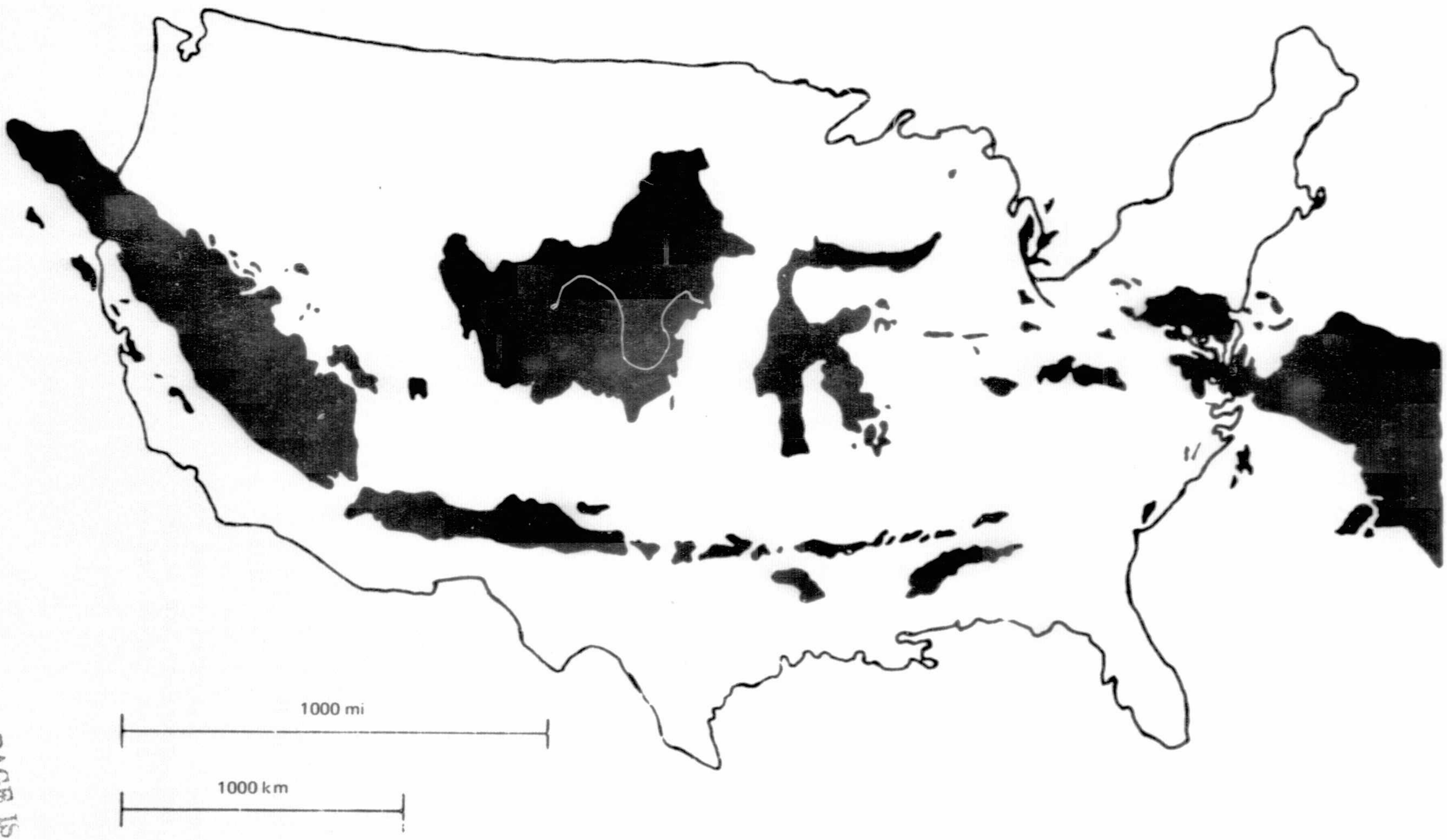


FIG.8

development they will experience during the next several decades. A wealth of information has been published on Brazil. The transport planning agency of the Brazilian Government (GEIPOT - pronounced jay-pot) is very active and produces documents comparable in quality to US agencies, although only a handful are available in English translations. By contrast, sources of information on Indonesia are more limited, and only estimates are available for basic transportation, market, resource, and demographic data. In this respect, Indonesia is more typical of LDCs than Brazil, and it is important to recognize the formative nature of available quantitative data.

The most useful sources of data employed in conducting the case studies (besides the open-literature sources in the Reference List) have been: international institutions, such as the agencies of the United Nations, the World Bank, and the International Civil Aviation Organization, and domestic sources, including the Washington consulates of Brazil and Indonesia, private firms, and the agencies of the US Government. Obtaining information directly from the Brazilian and Indonesian Governments would have been difficult because of the language problem and also because of the short duration of the study. Instead, the local area representatives of United Technologies Corporation (Rio de Janeiro and Singapore) made the necessary contacts and secured essential information.

Appendix B provides various kinds of data descriptive of the case-study countries. The results of the baseline economic scenario projections are summarized below, since these projections will be used throughout the economic evaluations in the next section. The data listed here include GNP (constant 1976 dollars) and population figures for Brazil and Indonesia, and also for the US for purposes of comparison

Projected Economic Growth

	Brazil	Indonesia	US
Real GNP Growth, %/yr	6.6	7.5	3.0
1974 GNP, $\$10^9$	96	22	1400
2005 GNP, $\$10^9$	694	206	3500
Population Growth, %/yr	2.6	2.5	0.7
1974 Population, 10^6	104	128	212
2005 Population, 10^6	231	276	263
1974 Per-capita GNP, $	920	170	6600
2005 Per-capita GNP, $	3000	750	13,300
Years to catch US	126	145	---

These comparisons point out several important facts. As indicated, Brazil and Indonesia are at very different stages of economic growth, and both countries are at formative stages of national development relative to the US. Although their economic growth rates (GNP) are high, population growth rates are also high. Therefore, progress toward reaching "developed" status, as measured by the $3000 GNP per-capita criterion adopted in this study, is rather slow. Meanwhile, the US and other developed nations have experienced very slow population growth in recent years, causing the per-capita GNP gap between developed nations and LDCs to widen, in many cases. Brazil and Indonesia are exceptions. Assuming the above growth rates were to continue indefinitely into the future, both countries would eventually overtake the US. However, this assumption is quite academic since high rates of economic growth characteristic of the early development period would be expected to diminish as development proceeds.

The fact that Brazil and Indonesia are at different stages of development was an important factor in their selection as case-study countries. It is to be expected that potential airplane markets in Brazil will be greater than those in Indonesia because of this disparity, but the types of aircraft needed and their technology requirements might also be different. As a final point, it can be observed in the above comparison that Brazil will have reached the $3000 GNP per-capita criterion by the year 2005, whereas Indonesia will not quite have reached Brazil's present stage of economic development by that date.

NATIONAL DEVELOPMENT PLANS

The approach formulated to address transport needs in Brazil and Indonesia was greatly influenced by their stated long-range goals, as revealed in the national plans of the two countries (Refs. 32, 33). Although these plans are directed to the achievement of specific short-range objectives (five years), longer periods are implied, and even stated, to achieve continuity in development. Therefore, the national goals of Brazil and Indonesia, especially those which are strongly related to transport alternatives, were of direct relevance to this study.

A summary of public expenditures in major economic sectors appears in Table 3 which was abstracted from the published development plans. There has been some consolidation of categories in order to make direct comparisons between the two countries. The expenditures shown in the table are public expenditures and, therefore, do not include private domestic or foreign investments in the economies of Brazil and Indonesia. These private-sector investments would be expected to dominate in both economies, but Government intervention would reflect the national goals implicit in the plans. Thus, foreign investments in industry, for example, would incorporate social factors such as employment of the local work force and upgrading of skills,

TABLE 3

SECOND NATIONAL DEVELOPMENT PLANS
Sources: Refs. 32, 33

<table>
<tr><th rowspan="2">Sector</th><th colspan="2">% of Public Expenditure</th></tr>
<tr><th>Brazil</th><th>Indonesia</th></tr>
<tr><td>Agriculture & Livestock</td><td>5.9</td><td>19.3</td></tr>
<tr><td>Industry & Mining</td><td>20.3</td><td>3.5</td></tr>
<tr><td>Electric Power</td><td>11.2</td><td>7.4</td></tr>
<tr><td>Transportation</td><td>7.6</td><td rowspan="2">16.6</td></tr>
<tr><td>Communications</td><td>2.8</td></tr>
<tr><td>Regional Development</td><td>9.3</td><td>17.7</td></tr>
<tr><td>Employment</td><td>1.2</td><td>1.3</td></tr>
<tr><td>Education</td><td>7.6</td><td>10.1</td></tr>
<tr><td>Housing</td><td>4.7</td><td>1.9</td></tr>
<tr><td>Health & Nutrition</td><td>6.2</td><td>3.7</td></tr>
<tr><td>Other</td><td>23.2</td><td>18.5</td></tr>
<tr><td>TOTAL</td><td>100.0</td><td>100.0</td></tr>
</table>

and might even provide for housing, power, and education. In some remote-area projects, facilities for entire towns are included as conditions for proposed industrial projects (see Ref. 34).

The differing stages of economic development between the two countries are clearly represented in the emphasis of public expenditures in Table 3. Because Indonesia is still in an agrarian stage, she devotes a large percentage to agriculture, whereas industry and mining dominate in Brazil's plan. Transportation is a significant factor in both plans. However, almost all of these allocations are earmarked for upgrading and extensions to the surface transport infrastructure. Airport development is the primary item in the air transport allocation, although Indonesia has specified provision of small airplanes to serve outlying islands as part of its regional development and national integration plan.

Development of "frontier" areas, a significant element in both plans, was of special importance in this study because it is in the remote regions that transport infrastructure remains largely undeveloped. If air-oriented alternatives to surface transport are to exist in these countries, they are surely most likely to occur where a large investment in surface transport has not yet been made. In Indonesia, the frontier program is termed "transmigration," which refers to the Government's policy of promoting a net migration from the densely populated islands (Java, Bali, Lombok) to the outer islands of the Indonesian archipelago where population density is much lower. The program seeks a more even level of development among regions in order to promote national unity through a policy of economic and social integration. Portions of the allocations to various sectors in Table 3 are implicit in this program.

Brazil's frontier development program takes on a similar, but more specific, form. To continue the past period of rapid economic growth and to promote stability at the same time, Brazil's plan includes the following elements as specific goals: 1) substitute domestic manufactures for foreign imports, 2) develop overseas markets for manufactures, 3) achieve a wider geographic dissemination of industry, 4) emphasize agriculture and livestock raising in virgin areas, and 5) begin a massive program to develop new sources of energy, including oil, agriculturally derived alcohol (e.g., manioc), and hydro power. The Brazilian frontier consists largely of the Amazon region, the enormous area in the North which is drained by the Amazon river and its numerous tributaries. A specific, long-range plan, entitled Polamazonia (Ref. 35) has been conceived to implement development in this vast tropical forest region.

The Polamazonia program includes development of a large number of population centers (poles) distributed throughout the Amazon. Each pole is designated by the most appropriate economic activity in its area. Thus, agricultural, mineral, and cattle poles are specified, as well as combinations of these. Forestry is recognized as an important adjunct to development throughout the region. The delicate ecology of the Amazon forests has received much attention, and the national plan calls for both "preservation of the environment" and "avoiding the devastation of the country's natural resources" (Ref. 32). As an essential part of this Amazon development plan, the Government has conducted a comprehensive exploration and mapping program called Project RADAM, some results of which are documented in a series of recently published volumes (Ref. 36). The purpose of this extensive project has been to obtain and disseminate detailed knowledge of the geography, geology and ecology of the entire area, and to determine both the potential uses of the land and limitations which should be imposed to prevent its despoilation. The data base provided by the RADAM results served as a valuable source in the Brazilian case study, as demonstrated in the next section. A similar project is planned for Indonesia by the World Bank, but it is still in its formative stages.

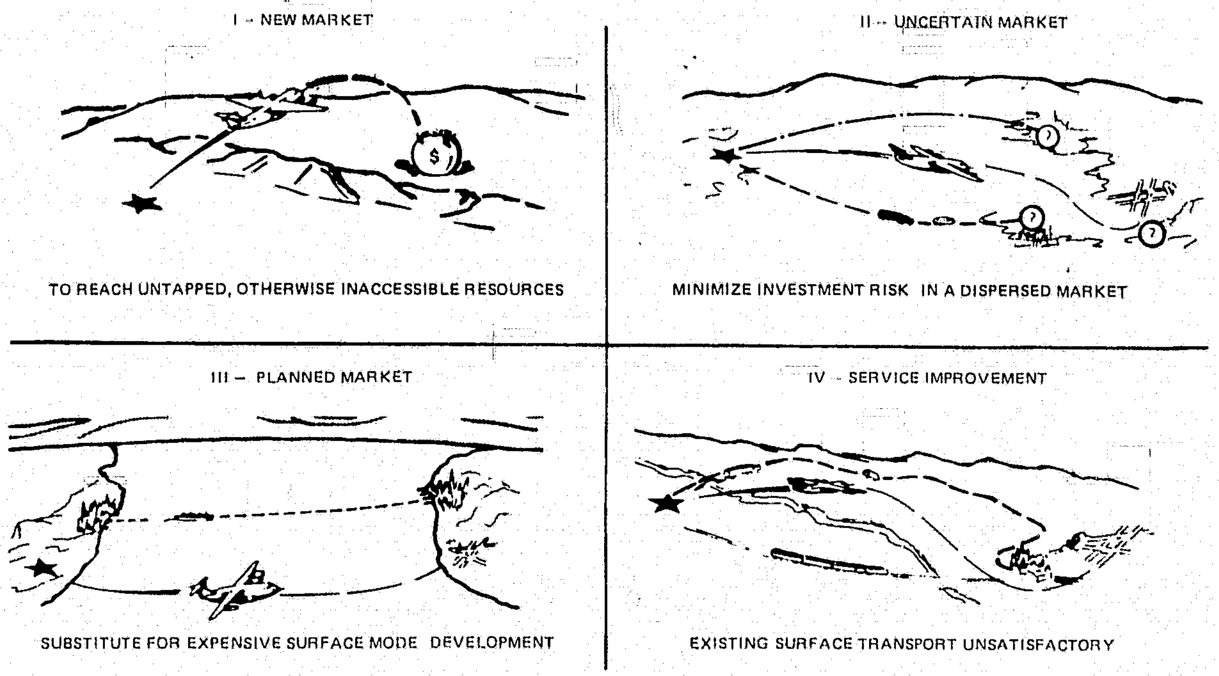
SELECTION OF PROMISING APPLICATIONS

Although a large number of air applications was identified in this study, some of the categories listed in Table 2 were judged to be of limited potential in pursuing study objectives, and were either eliminated or treated in lesser detail than the primary applications. Those which were eliminated were the nontransport applications (tactical, instructional, and personal uses) which were beyond the intended scope of the study, and the agricultural applications, which are to be treated separately in a follow-on study.

The remaining categories may be divided into two parts: "conventional" (i.e., identical uses are found in developed countries), and "unconventional" (i.e., developed-country uses are uncommon or are a relatively minor factor in the air transport system). In the conventional category are: military logistics, certificated carrier, executive transport, and some commercial applications such as offshore oil logistics and supply. There is no intention to minimize the importance of these applications by using the term "conventional." In the past, they have accounted for most of the LDC air transport investment (see Fig. 5), and they have comprised the base of advanced aeronautical technology transferred to the LDC group. However, their commonality with developed-country uses suggests that future aircraft introduced to fulfill these applications can be based on developed-country requirements, as they have in the past, and will still correspond closely with LDC needs. Therefore, with respect to technology content and potential impact on the NASA's research and technology programs, the conventional applications were not the primary focus of activity in this study. Opportunities for new research are more likely to emerge from the unconventional uses. It is also important to point out that most of the conventional uses will be concentrated in the more-developed regions of LDCs rather than in the remote areas where future progress is more transport-dependent, and which the national plans have specified as deserving special emphasis. By contrast, the unconventional uses are most relevant to remote-area transport.

Unconventional uses benefiting from the unique characteristics of air transport may be divided into four generic categories, as depicted in the following sketch. In Category I, heretofore inaccessible resources are tapped. In Category II, an interim air transport system is implemented in a region of uncertain potential, thereby opening the region at minimum risk and with a limited investment. In Category III, a known market exists but the large capital expense of a planned surface system is reduced by reliance on the air mode. And in Category IV, an existing system, not well matched to the market environment, is replaced or supplemented by an appropriate air system.

AIR MARKET SCENARIOS



The strategy followed to achieve the study objectives has been to select four applications, each an example of one of the market scenarios in the above sketch and to perform detailed economic evaluations comparing candidate air vehicles with the most likely surface modes. The four applications are:

- Remote Mining (Category I)
- Low-Density Transport (Category II)
- Tropical Forestry (Category III)
- Large-Cargo Aircraft (Category IV)

The first three of these are clearly of the "unconventional" type. The last is included because the need for a large cargo airplane (LCA) in the developed world has not been definitely established, thereby making future LDC requirements potentially critical to the feasibility of such an aircraft.

Each of the four applications chosen for detailed analysis falls into one of the broad categories of unconventional use. Mineral discoveries in remote areas may require extensive use of airplanes in the exploration and development phases in cases where development could not be accomplished by any other means (Category I). Airplanes might also be economical for routine transport of minerals and personnel as a surrogate for surface development, although this is less likely. Low-density transport is an example of Category II, where air serves as a primary means of communication for large areas of uncertain growth. Implementing an air system may be less expensive than road construction, particularly at low volumes. The rail mode was not evaluated as a surface transport alternative because the high capital costs of a rail mode make it a poor choice unless large transport volumes are assured. In tropical forestry, use of aircraft is contemplated primarily as a substitute for an expensive network of logging roads in certain situations (Category III). Furthermore, ecological considerations may prohibit road construction, thereby isolating these areas from development except by means of air transport. Finally, the LCA application is essentially a substitute for existing slow and unreliable surface transport (Category IV). Although smaller airplanes than a LCA would also serve this purpose, the improved economic performance that comes with increasing airplane size can improve air penetration.

The four primary applications were chosen for their potential market sizes (numbers of aircraft) and their possibilities for high technology content. Also, although the evaluations performed were specific to Brazil and Indonesia in most cases, the selected applications are common to other LDCs as well. Low-density transportation in particular, is a basic LDC transport problem. But the prevalence of tropical environments in LDCs, as shown in Fig. 9, and incomplete knowledge as to the resource potential of remote areas, make tropical forestry and remote mining equally important uses. Only the LCA application is unique, its potential being restricted to the most economically advanced members of the LDC group.

Detailed evaluations of the four aircraft applications are described in the next section. However, it is important to note that these evaluations are basically economic in nature, and that they serve only to indicate whether air transport competes favorably with surface modes on economic grounds alone. While economic criteria usually (but not always) dominate in the developed world, mode choice decisions in LDCs are strongly affected by noneconomic factors. Therefore, each economic comparison was supplemented by a sociopolitical analysis to account for specific factors which are relevant in LDC policy-making decisions.

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LESS DEVELOPED COUNTRY LOCATIONS

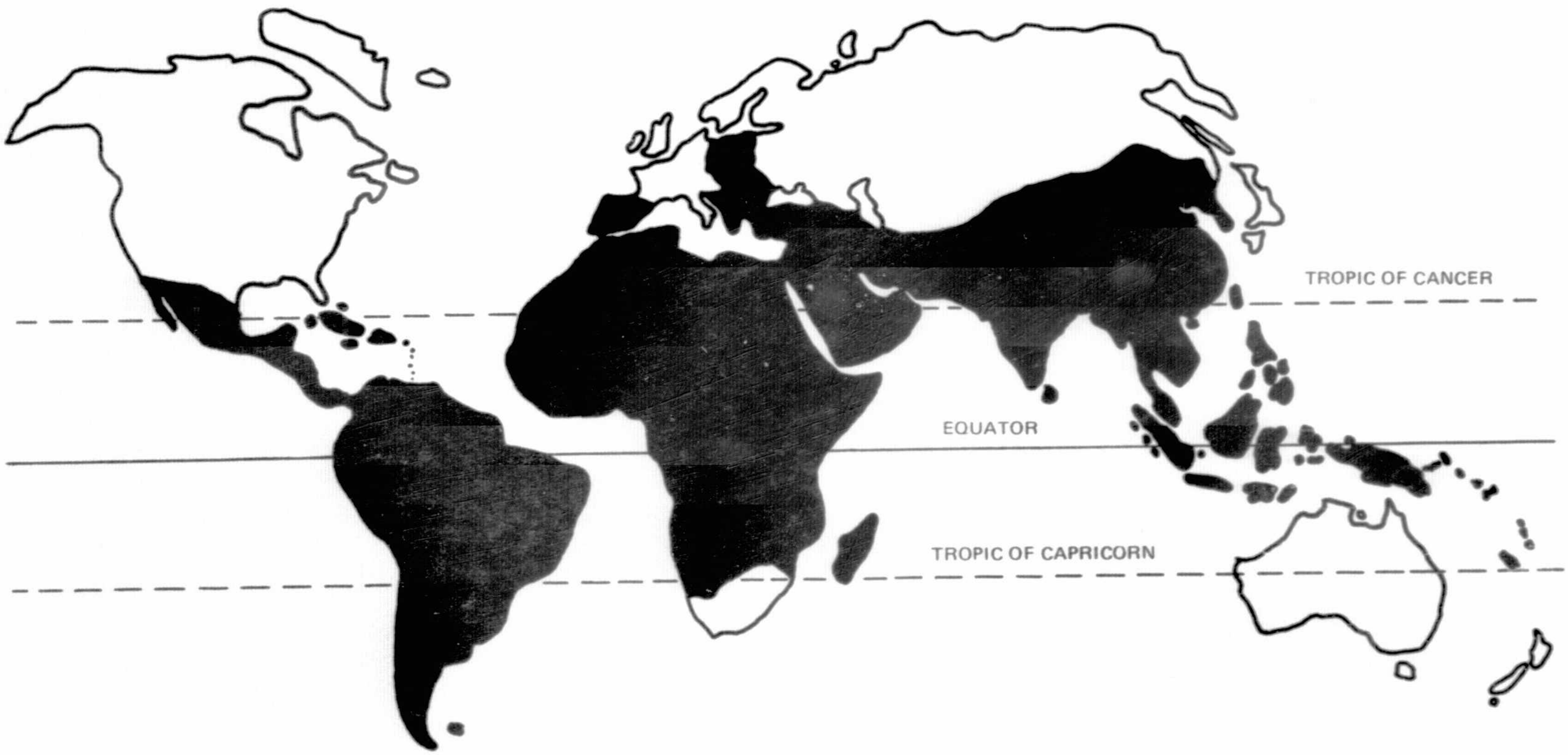

FIG. 9

PRIMARY AIRCRAFT APPLICATIONS

The four primary aircraft applications are taken up consecutively in this section. Each application is analyzed independently in its proper context, including an economic evaluation relative to applicable surface-mode competition, estimates of aircraft types and numbers required, and sociopolitical considerations associated with implementing air and surface systems. In the economic comparisons, operating costs were calculated by standardized methods adopted for this study. A complete exposition of these methods, and representative costs for various airplanes and road alternatives, are presented in Appendix C.

REMOTE MINING

As used here, the term "remote mining" refers to mining projects in virgin territory where even the most rudimentary support facilities, including transport, are virtually nonexistent. Since remote areas are common in LDCs, it is not unlikely that such extreme conditions would be encountered in the course of exploring for and, ultimately, developing mineral deposits.

The approach consisted of several analytical stages. First, an estimate was made of the scope of future mining investments in the two case-study countries. Then, a recently completed mining venture was carefully analyzed in order to construct a model by which hypothetical future ventures could be studied. Next, various aircraft and surface transport alternatives were examined parametrically to evaluate the economics of heavy reliance on airplanes. Numbers of aircraft needed to support remote mining projects in Brazil and Indonesia were then estimated, based on the investment projections made in the first part of the analysis. And finally, some additional considerations which affect modal choice were considered in a sociopolitical comparison of air and surface systems.

Future Mining Investments in Brazil and Indonesia

Total investments in mining and drilling operations in Brazil and Indonesia are projected to increase rather dramatically in the next decade. Many literature sources document the growing interest in mineral development in these resource-rich nations. (See Refs. 37 to 52.) Capital outlays to finance projects will come from both domestic and foreign sources, as shown in Table 4. Foreign participation is already high in Indonesia, and can be expected to remain high because of Indonesia's great resource potential and her

TABLE 4

INVESTMENTS IN MINING AND DRILLING IN INDONESIA

	Sources of Investment, %			
	1965-1975		1975-2005	
	Domestic	Foreign	Domestic	Foreign
Mineral Mining	13	87	10	90
Oil Drilling	7	93	10	90

	Domestic Investment as Percent of GDP			
	1965-1975	1975-1985	1985-1995	1995-2005
Mineral Mining	0.10	0.20	0.15	0.10
Oil Drilling	0.15	0.30	0.20	0.10

INVESTMENTS IN MINING AND DRILLING IN BRAZIL

	Sources of Investment, %			
	1965-1975		1975-2005	
	Domestic	Foreign	Domestic	Foreign
Mineral Mining	50	50	60	40
Oil Drilling	100	0	75	25

	Domestic Investments as Percent of GDP			
	1965-1975	1975-1985	1985-1995	1995-2005
Mineral Mining	0.2	0.3	0.2	0.15
Oil Drilling	0.8	1.1	0.7	0.5

inability to finance the large sums required for development of these resources. Brazil has historically relied less on foreign capital, particularly in oil development, but some change is anticipated. There has been intense foreign interest in high-grade mineral reserves, and there has recently been a policy change by the Brazilian government which will permit foreign participation in oil drilling. In the long term, it is projected that Brazil will continue to maintain a high percentage of investments in both sectors.

Also indicated in Table 4 are the domestic investments as percentages of GDP. Existing and planned projects in both countries show that higher percentages can be expected in the next decade compared to the 1965-to-1975 period. In the remainder of the forecast period, the percentages of GDP invested in mining and drilling are projected to diminish. However, as shown in Fig. 10, investments will continue to increase due to rapid GDP growth during the forecast period. Total investments in the 1975-2005 time period were therefore projected to be $62 billion for Indonesia and $113 billion for Brazil. These levels of investment imply numerous projects of the types described in the literature. Each will have its own air transport requirement.

Ertsberg Project

A recent Indonesian mining project, "Ertsberg", was an excellent choice by which to model future mining ventures. Research into this project revealed some significant possibilities for aircraft technology developments. This research included discussions with representatives of the firms involved in the Ertsberg project (Freeport Minerals and Bechtel*), review of the extensive literature on the subject (Refs. 53 to 58), and viewing of a 45-minute film which documents the entire venture. What follows are some highlights gleaned from these sources.

Ertsberg means, literally, "ore mountain" in Dutch. The deposit is a large outcropping (500 ft high) containing some 33 million tons of high-grade copper ore. It is located on Irian Jaya, the easternmost island of Indonesia, 120 km inland through swamp, dense jungle, and steep mountain ridges. The base of the Ertsberg is at 11,500 ft altitude. Therefore, it is remote, both in geographic location and its extreme elevation.

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* The transport logistics of the Ertsbeg project, including quantitative information concerning the helicopter and truck fleet utilizations, were described in a memo, dated December 19, 1977, from E. W. Craven of Bechtel (San Francisco office) to F. W. Gobetz of UTRC.

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PROJECTED INVESTMENT IN OIL DRILLING AND MINING

BRAZIL AND INDONESIA

$1977

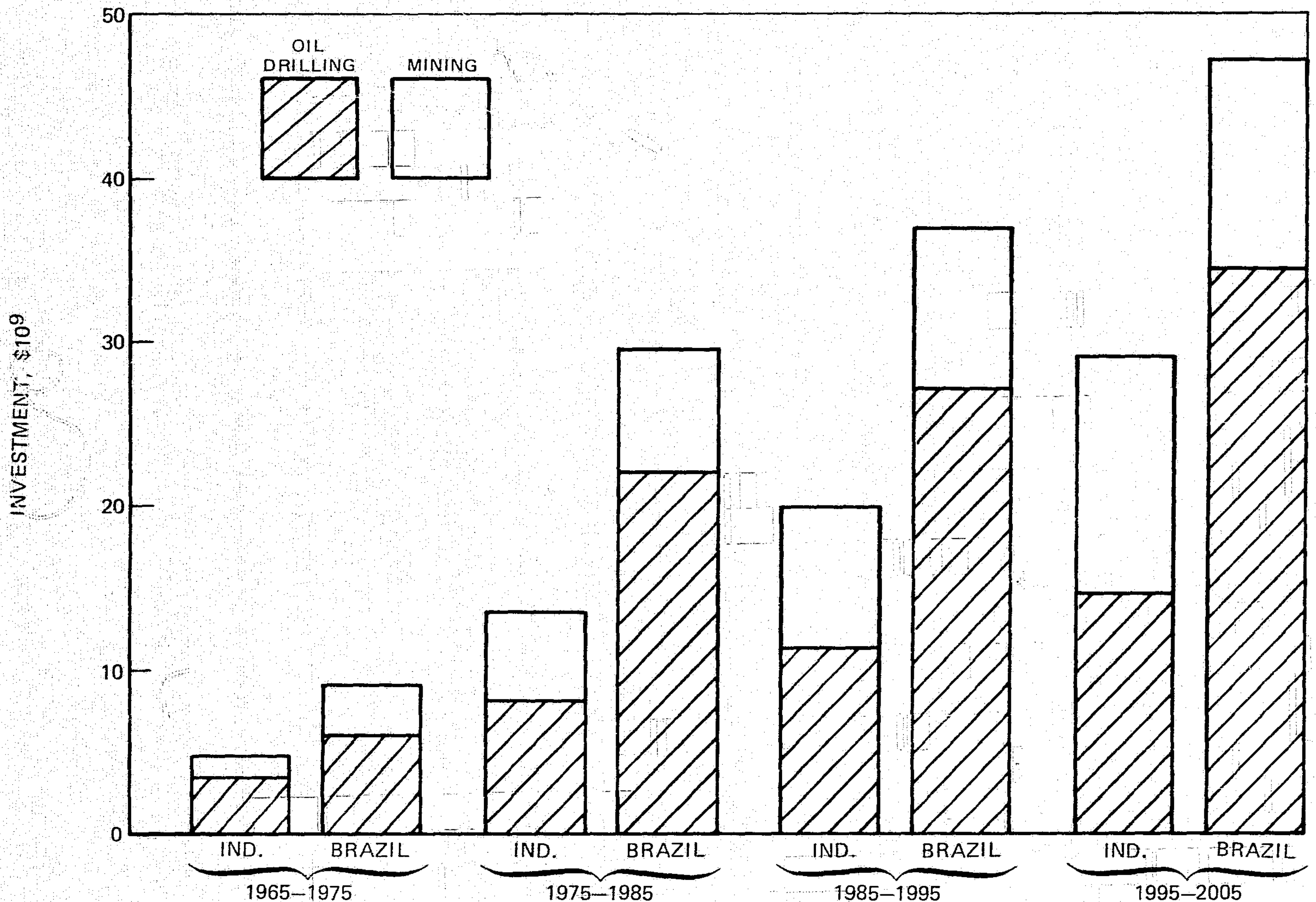

FIG. 10

77–12–43–1

The logistics plan to develop the mine involved construction of a mill at 2750 m, a small town at 1850 m, and a port at sea level. In addition, a 110 km road was constructed from the port to the mill, including over 1800 meters of tunnels, and several segments with grades as steep as 20%. A mining town, or base, began as one of 19 mountain camps and ultimately housed 1,500 workers and their families.

Ore is blasted off the mountain and scooped up by front loaders feeding 45,000-kg trucks which deliver their loads to a crusher. From the crusher, a conveyer delivers the ore to an aerial tram, by which the ore is delivered to the mill site in 10-ton loads. Although the mine is only 2000 m from the mill, there is a precipitous 750 m drop which necessitates delivery of the ore by the cable system. The mill consists of crushers, a concentrator, and storage buildings. At the concentrator, the ore is slurried and pumped via a 110 km pipeline all the way to the port.

In the early phase of the project, up to completion of the road which required two years to construct, all logistics support was provided by air. A fleet of six Bell 204B helicopters was used, transporting a total of some 10,000 tons of equipment, supplies, and personnel during this period. Choice of a small helicopter (typical payload 800 kg) was, in part, dictated by the requirement to establish and supply numerous camps along the road route. Construction of crude helipads, utilizing logs from the trees felled to clear landing zones, was done mostly by hand. The choice of the small helicopter made camp resupply less expensive than if a smaller number of larger machines had been selected. Later on, when heavy equipment was to be transported to the advance bases, this choice resulted in severe constraints. Bulldozers had to be flown in disassembled, and the largest assembly (the frame) had to be cut in half and welded back together on site. Furthermore, the inability of the helicopters to hover with these very heavy loads at high altitude made it necessary to drop them rather than setting the pieces down in adjacent positions.

Conversations with representatives of the minerals industry suggest that the difficult conditions experienced in the Ertsberg project may be representative of future mining operations in developing countries. The "easy" finds having already been developed, future mineral finds are likely to be in remote regions, so that access and logistics will present difficult problems. Furthermore, since geologically active areas are common exploration grounds for minerals, rich finds are also likely to be at increasingly higher altitudes, as in the Ertberg case. The technological implications of such environments are that airplanes might play a wider role if they can be shown to operate reliably and economically in delivering heavy loads to high mine sites. Problems encountered at Ertsberg included cross currents, clouds, and heavy rainfall (average annual rainfall of 450 cm; 140 cm/month in the rainy season). Although the Ertsberg site did not permit construction of even a short airstrip at the high elevations, STOL aircraft should not be ruled out; however, fields will be crude as well as short.

Existence of airplanes better adapted to these conditions could alter project planning and result in considerably more reliance on aircraft than has been the case in the past. Surface transport is not likely to be displaced by aircraft for bulk movement of heavy, high-volume loads such as ores. However, aircraft may be used more effectively to condense the period of road and/or rail construction and to facilitate earlier start of advance-base construction. These ideas will be developed further to estimate the extent to which advanced aircraft might be utilized in future mining projects.

A careful review and analysis of the anatomy of the Ertsberg project led to division of the development period into five phases.

- Phase I - Early exploration
  September 1967 to March 1969
  Establishment of a permanent camp at the mine site; transporting men and equipment into the camp for exploratory drilling.

- Phase II - Gathering of ore samples
  March 1969 to August 1969
  Transport of bulk ore samples from the mine site (elevation 11,800 ft) to the coast for laboratory analysis.

- Phase III - Preliminary road construction
  August 1969 to January 1971
  Establishment of jungle and mountain camps for road construction and transport of personnel, supplies and equipment into camps.

- Phase IV - Major road and port construction
  January 1971 to December 1971
  Continuous logistical support of road construction crews at six points along the route.

- Phase V - Pipeline and mill construction
  December 1971 to November 1972
  Major construction of facilities at the mine and mill sites, and laying of slurry pipeline from mill to port.

Most of the information regarding the transport aspects of the project was made available by the companies involved, but financial data were not provided because of proprietary considerations. Therefore it was necessary to piece together the economics of the project from general information available in the open literature. Nevertheless, it was possible to construct a good representation of the cash flow during the various phases and thereby facilitate discounted cash flow analyses of the base case (actual history of the project) and revised project schedules in which increased utilization of aircraft was hypothesized.

As explained earlier, extensive use was made of helicopters (Bell 204B) in the exploration and road construction phases. Altogether, some 20,000 tons of cargo (including personnel) were transported by air. The major share of total tonnage was carried by trucks after completion of the road at the conclusion of Phase IV. Thus, as depicted in Fig. 11, most of the material was transported in Phase V, and the bulk of that requirement was met by the truck fleet.

An understanding of the types of cargo carried in each phase is provided in the first part of Table 5. The categories include: personnel, supplies (to support crews), equipment (to support construction), facilities (only those erected in the mountains), fuel, transport (helicopters and trucks)*, and other (includes coastal facilities, ore samples, etc.). The totals and percentages by project phase are the basis for Fig. 11. The breakdown of tonnage by category shows that facilities and fuel were the major items. However, it should be noted that personnel transport was a significant logistical consideration, even though the tonnage in this category was not large. A large percentage of flights included passengers being transported to and from the coast, the mine and mill sites, and various camps. For this reason, airplanes designated in the hypothetical ventures considered subsequently in this analysis must be capable of mixed passenger/cargo loads, or, alternatively, a mix of passenger and cargo airplanes must be assumed.

A very important factor in the air transport logistics of the Ertsberg project was the limited payload of the B-204B helicopter, particularly in its high-altitude operations. There are definite indications (e.g., Ref. 57) that payload restrictions caused significant delays (and thereby escalated costs):

1. Removal of ore samples was restricted to one 450-kg drum per flight, necessitating 557 flights in all and extending the length of Phase II by four months.

2. In Phase III lumber was often flown into jungle and mountain camps to construct helipads. Prefabricated pads might have been carried by a larger machine, reducing both time and cost. (More than 40 helipads were constructed in all.)

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* This item included for purposes of investment breakdown only.

HISTORY OF TRANSPORT DURING ERTSBERG DEVELOPMENT PHASES

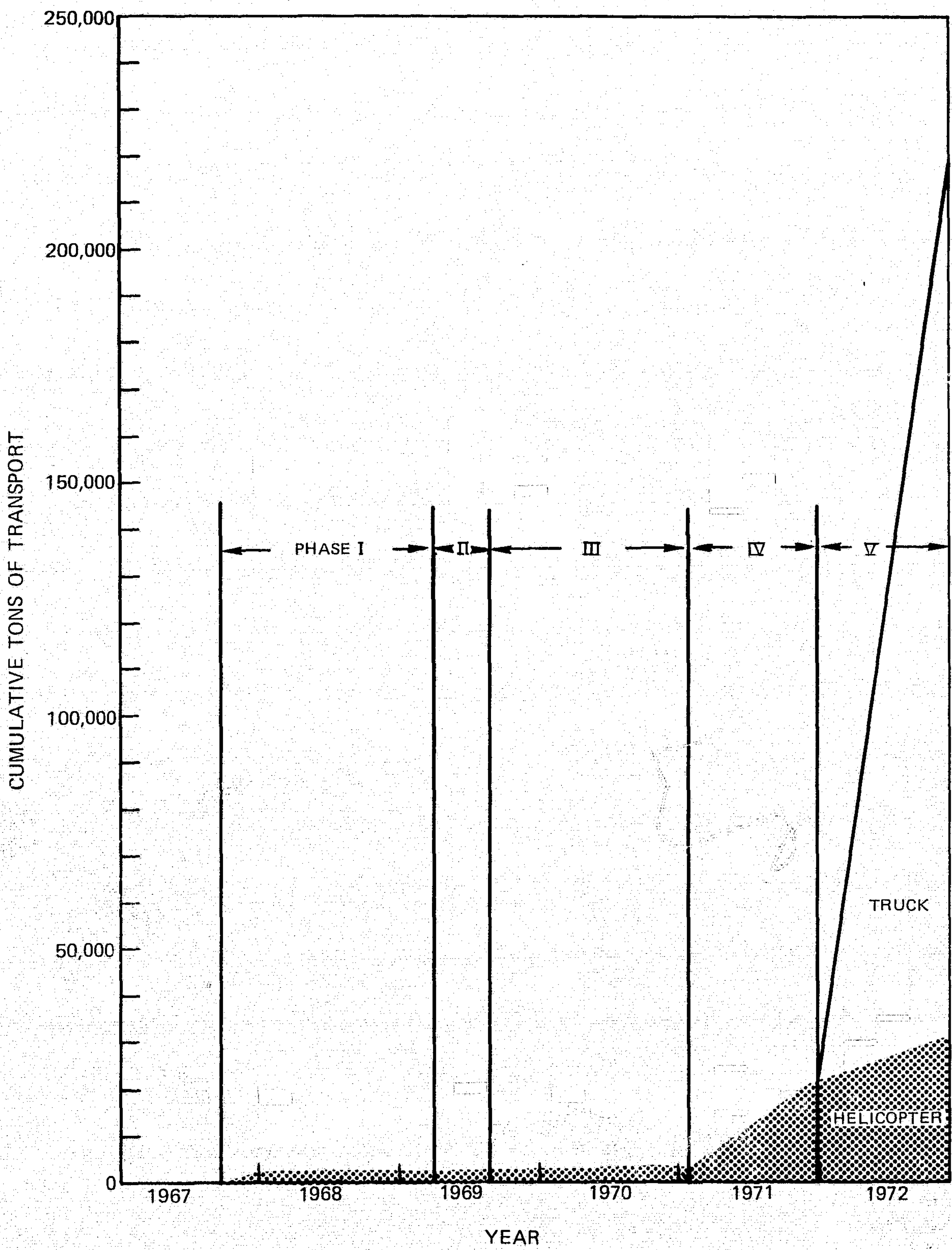

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TABLE 5

TRANSPORT AND INVESTMENT BREAKDOWNS OF ERTSBERG PROJECT

	Tons Transported							Investment[3], $10^6						
Phase:	I	II	III	IV	V	TOTAL	(%)	I	II	III	IV	V	TOTAL	(%)
Personnel	10	1	550	7139	1100	8800	(4.2)	0.15	0.02	2.06	2.63	3.67	8.53	(5.8)
Supplies	50	7	170	1285	1700	3162	(1.5)	0.20	0.03	0.68	5.14	6.86	12.91	(8.8)
Equipment	200	0	180	2427	2427	5234	(2.5)	0.40	0	0.36	4.86	4.86	10.47[2]	(7.2)
Facilities	90	0	191	2506	131,924	134,711	(63.9)	0.18	0	0.38	5.01	74.16	79.73	(54.6)
Fuel	211	113	540	8567	49,000	58,451	(27.7)	0.01	0.01	0.02	0.34	1.96	2.34	(1.6)
Transport	-	-	-	-	-	-	-	1.70	0	0.80	2.50	1.00	6.00	(4.1)
Other	0	300[1]	0	0	0	300	(0.1)	0	0	18.00	4.00	4.00	26.00	(17.8)
TOTAL	561	421	1631	21,924	186,151	210,658	(100)	2.64	0.05[2]	22.31[2]	24.48	96.50[2]	145.98	(100)
(%)	(0.3)	(0.2)	(0.8)	(10.4)	(88.4)	(100)		(1.8)	∿ 0	(15.3)	(16.8)	(66.1)	(100)	

(1) Ore Samples
(2) Does not add due to round-off
(3) Debt service not included
All figures in current dollars during the period 1969 to 1972.

3. Road construction was hampered by unavailability of large bulldozers. Even the D6 machines used in mountain road construction had to be broken down for delivery to mountain sites, 18 separate flights being required to deliver a D6 to the camp at milepost 60 (8500-ft elevation) and 26 trips for a delivery to the mine site at 11,800 ft.* Furthermore, once the time-consuming process of reassembly was completed in the field, these machines could not be airlifted to other sites to speed construction or to facilitate centralized maintenance.

4. Difficulty in transporting prefabricated living units necessitated recourse to flying in lumber and building living quarters.

Although most of these problems could have been overcome, at least in part, if a larger payload capacity had been available, it should be stressed that other performance improvements, such as better all-weather capability, easier handling in mountain air currents, and better high-altitude performance would have been equally desirable. Therefore, the potential for improving the transport logistics of a project of this type is great.

Remote Mining Project Model

Based on the Ertsberg example, the generalized remote mining project layout depicted in Fig. 12 was adopted. Although it was recognized that each project will be unique, the general features of a physical model patterned after Ertsberg appeared to be a good starting point in analyzing future ventures in LDCs. The same five phases enumerated earlier were assumed to apply in the general model.

Physical Model

Near the port, and at sea level, is a CTOL airfield used for routine air transport connections with the outside world. Along the road route is a series of temporary fields which are used to fly in road construction machinery, fuel, supplies, and personnel. These temporary strips (or helipads) are spaced every 30 km along the route near main depots and camps, and road construction proceeds in both directions from each site. If the inland distance is long, most of these strips are at sea level. At the mine end, the last 25 percent of the route was assumed to include a rise in elevation to the mill and mine sites. At the mill, which was assumed to be at 10,000 ft elevation**, a high-altitude airfield (short airstrip or helipad) is

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* For the high-altitude delivery it was also necessary to cut the D6 main case in two and reweld it in the field.

** In the case studies, the 10,000 ft altitude assumption applied only to Indonesia. Ventures in Brazil were assumed to be at sea level.

REMOTE MINING PROJECT MODEL

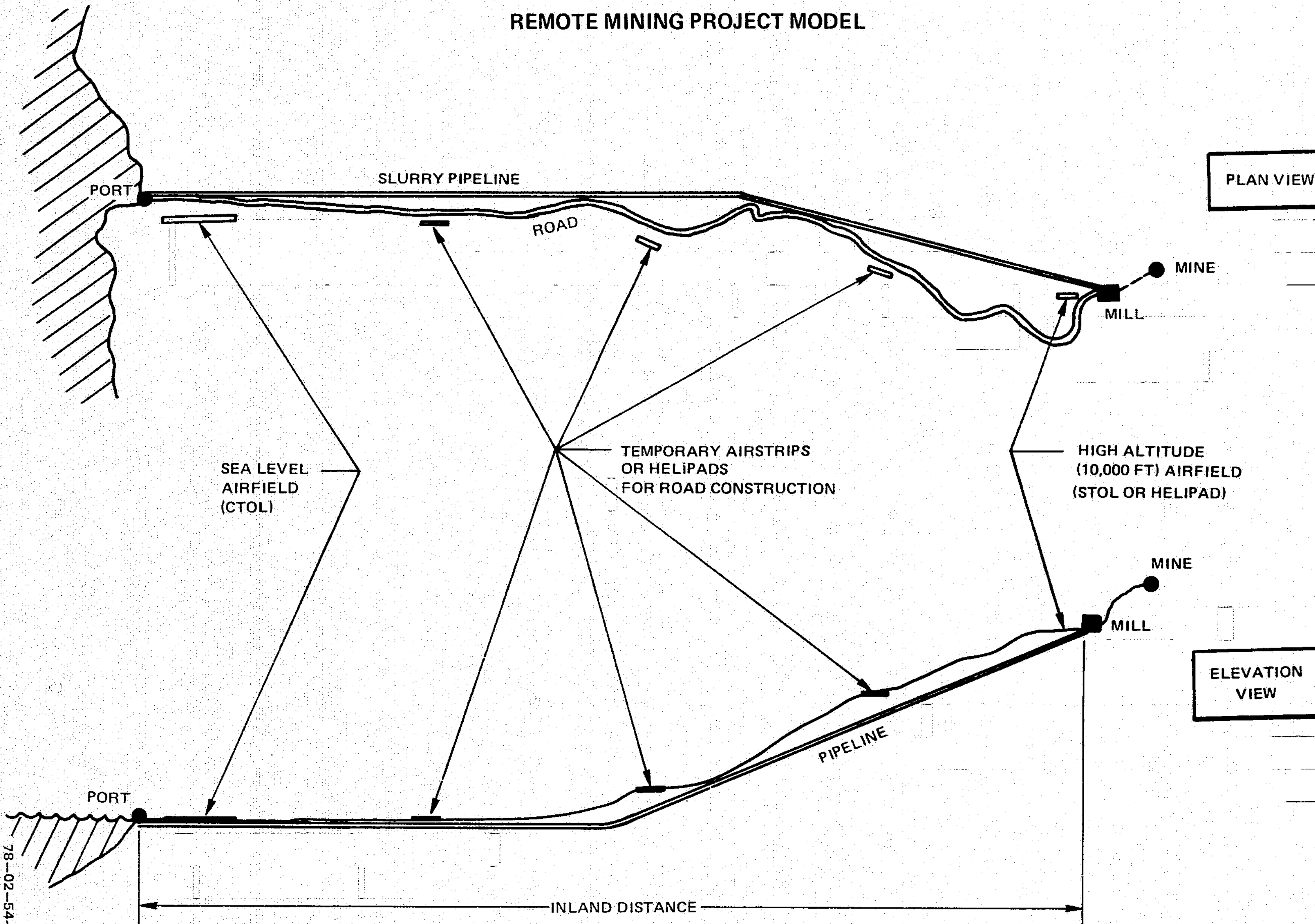

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FIG. 12

situated to facilitate both road construction from the top of the route and transport of facilities for construction of the mill. In the Ertsberg project, this last function was fulfilled by trucks which could not begin transporting mill facilities until the road was completed. In the analytical model employed for this study, aircraft were often used, in which case this phase coincided with major road construction, thereby shortening the project significantly*.

It was presumed that the length of the high-altitude airfield would be restricted by a scarcity of suitable sites, although the exact field length could not be specified. Also, only aircraft capable of transporting whole units of outsize equipment, such as bulldozers, were considered. This limitation restricted the available aircraft considerably.

It may be argued that construction of the road might be dispensed with by complete reliance on air trnsport in both the preproduction and production phases. However, in the Ertsberg case, if there had been no road, construction and maintenance of the pipeline would have been difficult, and all ore would have had to be airlifted to the port without comparable backhaul. The routine transport of large volumes of ore, even in the form of a concentrate, is a task almost always better suited to a surface mode. Although airplanes specifically designed as resource carriers have been proposed, the limited field length likely to be available at high altitude, and payload limitations caused by high-altitude operation, probably preclude such an approach in this instance.

Another assumption implicit in the analysis was that airplanes could operate out of very crude airstrips without sacrificing performance. The temporary strips used in the road construction phase might only be clearings bulldozed in dense jungle. These clearings might be uneven, perhaps on somewhat of an incline and, in the rainy season, the surface could be sodden. Conventional landing gear would not be adequate. However, no cost or performance penalty was imposed to account for rough-field conditions.

Cash Flow Model

The primary benefit of using airplanes extensively in a remote mining project lies in the shortening of the preproduction period. During the period from early exploration through completion of the facilities required to begin ore production, invested capital is at risk. Only when ore production begins can the negative cash flow situation of the preproduction period be changed to a positive, income-producing state. In a venture where a

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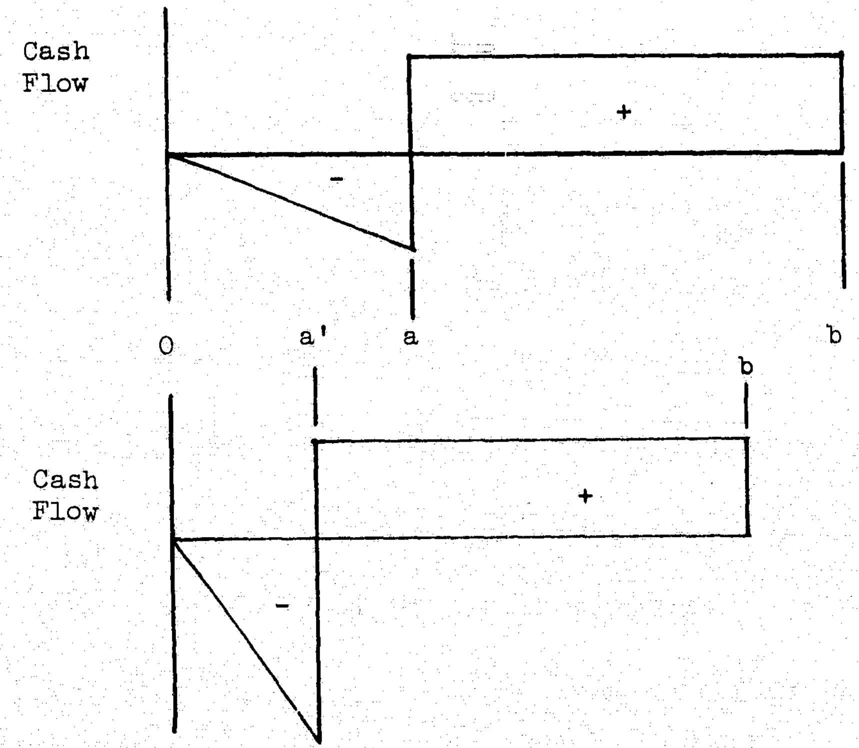
* Although a rail system is an alternative to a road when grades are not steep, a rail system is clearly infeasible in the case described here. For mineral deposits in remote locations at lower elevations (e.g., the Carajas Project in Brazil) rail is more competitive. In view of rail's high capital costs, however, the road/pipeline model is a better basis for the economic comparison.

significant element of risk is present, the benefit of condensing the development period must be analyzed by a discounted cash flow process in order to properly account for the expected return on invested capital. As an example, consider the two cases illustrated below. Both projects are to be evaluated at a future point in time (b) long after project inception 0. In the second case, a larger negative cash flow is incurred in the development phase (0 to a') but more rapid completion results in earlier generation of positive cash flow, which compensates for the increased investment.



The first step in analyzing the cash flow situation was to calculate the net present value of the investment in each of the five project phases, as follows:

$$PV_I = \sum_{i=1}^{5} \frac{I_i}{(1 + r_i)^{T_i}} \qquad (1)$$

In Eq. (1) the index i corresponds to the phase of this five-phase project, and each phase investment I_i is made at time T_i from the initiation date. Individual capital investments were discounted at rates r_i.

A capital recovery factor of the form

$$\frac{ROI}{1-(1+ROI)^{-T}}$$

was employed to compute the return on investment (ROI) at a time, T, after production has begun and revenues generated. Although values for ROI were not available for the Ertsberg project, it is known that mining ventures are characteristically risky and that a good return on invested capital would be expected. For the same reason, investment in a foreign venture probably demands a shorter period in which the return is achieved than would be the case with a more secure domestic mining project. In the model, the preproduction period (o to a in the diagram) was related to the payload capacity and block speed of the aircraft, and the total production period (a to b) was fixed at ten years.

The ROI equation is:

$$PV_I = \sum_{i=1}^{5} \frac{I_i}{(1+r_i)^{T_i}} = \frac{OP \times ROI}{(1+ROI)^{10-b} - (1+ROI)^b} \quad (2)$$

where OP is the operating profit after production begins. The equation was solved iteratively to calculate ROI. Operating profit was estimated according to Ertsberg experience, and scaled to decrease with distance to reflect increasing road transport costs with distance during the ten-year production period of the mine.

Return on investment is a measure of overall project feasibility. Since the preproduction phases of mining ventures on the scale of the Ertsberg project (total investment $146 million*) are largely financed by borrowed capital, project ROI must at least exceed the interest rate on the borrowed portion of the investment. In the Ertsberg case, $21 million was advanced by Freeport Minerals as equity capital; the borrowed portion was financed at a 9.5 percent effective interest rate (Ref. 55). Therefore, even if the ROI of the project had turned out to be only 10 percent, barely above the interest rate, the return on equity (ROE) would have been much higher. Thus, ROE is a significant economic criterion in evaluating projects of this type because it reflects the attractiveness of the venture to the company which makes the transport decisions.

Calculation of a discounted cash flow ROE was carried out in a way analogous to ROI, with some simple changes in the above iterative equation.

$$PV_E = \frac{E}{(1+ROE)^{T_E}} = \frac{OP - 0.15\,(I-E)}{(1+ROE)^{10-b} - (1+ROE)^b} , \quad (3)$$

where the equity, E, was assumed to be 15 percent of the investment, I, and the financing of borrowed capital (I-E) was subtracted from the operating profit based on an annuity calculation over ten years at 10 percent interest.

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* Subsequent investments brought the total to $175 million (Ref. 56).

Operations Model

A basic assumption of the operations model was that the volumes of equipment, facilities, and personnel to be transported in each phase were the same as those in the Ertsberg case (see Table 5). This assumption implies that the scale of production (amount of ore generated per year) does not vary. However, since certain of the facilities (e.g., the road) are independent of production scale, the assumption was not as limiting as it might apppear. Other transport volumes (personnel, supplies, fuel) are functions of the duration of each project phase, so that shortening a phase directly reduces both the volumes of cargo in these categories and the investment costs (Table 5).

The phase durations were affected by the productivities of the aircraft employed, as determined by inland distance, block speed, and payload capability. For cases where airplanes were utilized to transport the large volumes (Phase V in Table 5) required for final construction of facilities, Phases IV and V were condensed to a single operation of one-year duration. This time saving was assumed to be possible because air transport of facilities would not rely on completion of the road. Therefore, the two operations could be carried out simultaneously, albeit with a larger fleet requirement than if they were consecutive.

Magnitudes of the dollar investments in each phase were based on Table 5, but with variations caused by phase duration (as noted above) and transportation cost. Air transport costs were computed by the method described in Appendix C, with assumptions of 2000 hrs annual utilization and an airplane depreciation period of 12 yrs. The utilization figure is in keeping with what was achieved by the B-204B helicopters in the Ertsberg project. Since larger airplanes were evaluated, the utilization penalty associated with a requirement for less than a single airplane in the early phase was accounted for in calculating operating costs. Truck operating costs were estimated to be about double the earth road costs in Table C-2, Appendix C because of the extremely difficult conditions encountered in this application.*

Economic Evaluation of Air Transport Options

Six candidate vehicles were evaluated for the remote mining application, including three helicopters, an advanced STOL, a CTOL operated in an RTOL mode, and the Heavy Lift Airship (HLA) which is a hybrid consisting of a non-rigid airship with propulsive lift from four helicopters (Ref. 70). The helicopters covered a wide range of size and technology levels. At the low end was the B-204B, the aircraft used in the Ertsberg project. In view of its limited payload, the B-204B was used only to support road construction and not for the transport of major facilities. The S-64 Skycrane and a hypothetical Heavy Lift Helicopter (HLH) were evaluated for the entire transport job, including the transport of all facilities payloads to high altitude. An advanced STOL airplane similar in its characteristics to the

* Memo from E. W. Craven to F. W. Gobetz.

Advanced Medium STOL aircraft developed for the US Air Force was synthesized for this application, with performance applicable to a 600-m field length limitation. The CTOL airplane selected for evaluation was the C-130H; its performance was based on a 1220-m field length limit. Personnel transport was assumed to be accommodated by these airplanes, supplemented by one B-204B in the fixed-wing transport options and two B-204Bs to supplement the large helicopters and the HLA. Some basic characteristics of these air vehicles are presented in Appendix C.

Since the transport distances in the remote mining application were frequently short*, the quoted cruise speeds were not always relevant. With external payloads carried in preloaded slings, helicopters make rapid turnarounds. Fixed-wing aircraft must be loaded internally, and suffer taxi and circuity penalties in landing and takeoff. Therefore, block times were computed according to the following assumptions:

Airplane	Round-Trip Terminal and Maneuver Time (hrs)	Cruise Speed (km/hr)
B-204B	0.3	220
S-64	0.4	175
HLH	0.4	260
Advanced STOL	0.7	725
C-130H	0.8	755
HLA	0.6	111

Achieving a reduced-field capability at high altitude introduces special problems, as indicated in Fig. 13, where payload/field restrictions are shown for the aircraft. Both propulsion (takeoff) and aerodynamic (landing) limitations apply. The scenario employed to compute the fixed-wing airplane limits involves a sea level takeoff with sufficient fuel to go 400 km, deliver maximum payload to a high-altitude (arbitrarily set at 3050 m) field, and return empty. Considering the STOL airplane, which features an externally blown flap, it can be seen that, for the selected conditions, the limiting requirement is landing at 3050 m to achieve a 600-meter field length, but that if this limit were eased by moving the diagonal line to the left, the sea level takeoff limit would dominate. Priorities for improving payload/field length performance would change for different altitude assumptions. However, the fact that aerodynamic and propulsive augmentation may be called for, suggests that an internally blown flap STOL might offer an important advantage. By installing an auxiliary engine in the fuselage to augment the flap, an airplane could be adapted to special conditions without changing the basic design. For example, using compressor bleed air from

* Total inland distance of the mine site turned out to be less than 400 km for economically viable projects. In Phase III, when road construction was being supported, transport depots were stationed every 30 km along the route, thereby requiring some very short hops at sea level, and occasional longer flights to the high-altitude fields.

CANDIDATE AIRCRAFT FOR REMOTE MINING APPLICATION

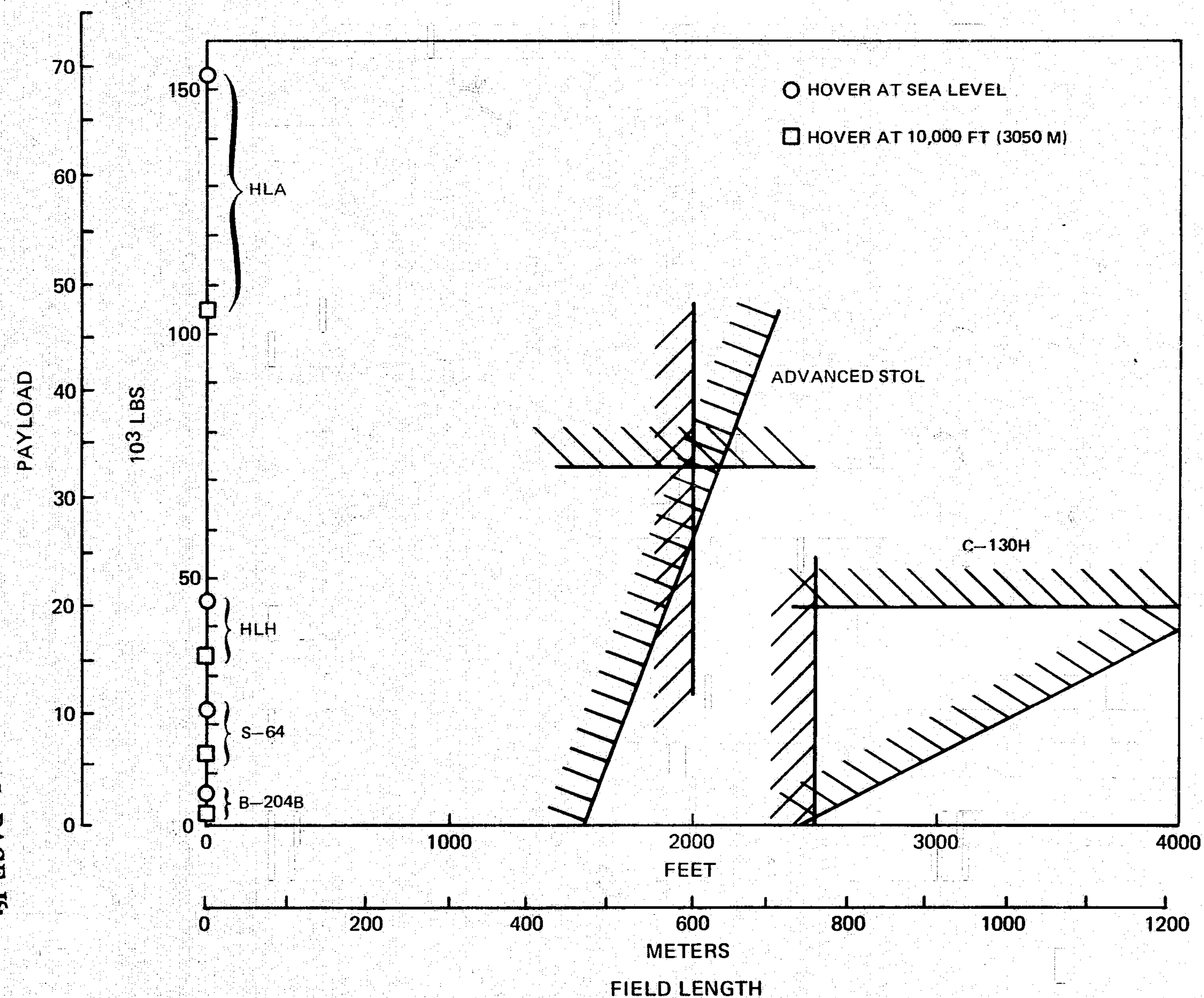

FIG. 13

the internal engine would unburden the external engines to provide more thrust during take-off. A basic problem with any such scheme would be to maintain sufficient control and stability at take-off conditions which involve low dynamic pressure (lower speed or density than design field condition).

Using the payloads in Fig. 13 and the cruise speed and operating costs quoted in Table C-1 of Appendix C, a simple cost/performance index, DOC/V·PL, was calculated to obtain a rough comparison of the airplanes prior to the economic evaluation. The comparison, depicted graphically in Fig. 14, shows that the fixed-wing airplanes enjoy a great advantage over the helicopters and the HLA by virtue of their higher speed and payload capabilities. The advanced STOL shows up particularly well, and the VTOLs rank according to payload.

Obviously, the VTOLs would not be expected to compare favorably on the basis of an index which does not account for field length. However, there is no adequate way of estimating, at this point, what the maximum available field length might be, and therefore the premium that should be associated with short-field performance cannot be defined. There will undoubtedly be cases where even a short strip cannot be situated close enough to the desired high-altitude site to permit fixed-wing operations. In these cases, the HLA or the helicopters are the only solutions, other VTOL configurations probably being ruled out because of their inability to carry external loads, as well as performance, cost, and complexity problems (See Appendix C). But, even if sufficient space for a strip were available, short-field performance would make an airplane eligible for applications not open to a CTOL. Therefore, short-field performance was regarded as an important advantage, though it cannot be quantified further. To enforce this presumption, even the C-130H was evaluated only for 1220-m operations.

With inland distance as the primary variable, the required total project investments for various transport options are presented in Fig. 15. The Base Case involved use of the B-204B helicopter for exploration and to support road construction (Phases I to IV), and trucks to carry the major transport load in Phase V of the project. At an inland distance of 120 km, the Base Case corresponds exactly to the Ertsberg project. A similar transport option is one in which the S-64 was substituted for the B-204B in Phases I to IV, and trucks were again used in Phase V. The required investment for this option was identical to the Base Case. The remaining transport options in Fig. 15 assumed complete air transport of preproduction cargo, including personnel, supplies, equipment, fuel and facilities. Transport in the 10-year production period of the mine would be performed by trucks in all cases.

The results in Fig. 15 show that use of large VTOLs (S-64, HLA, or HLH) to replace truck transport escalates project investment over the Base Case. However, as inland distance increases beyond about 120 km, the fixed-wing airplanes effect an economy in investment because their costs do not increase as rapidly as trucks and VTOLs. An important element

PERFORMANCE/COST COMPARISON OF CANDIDATE AIRCRAFT FOR REMOTE MINING APPLICATION

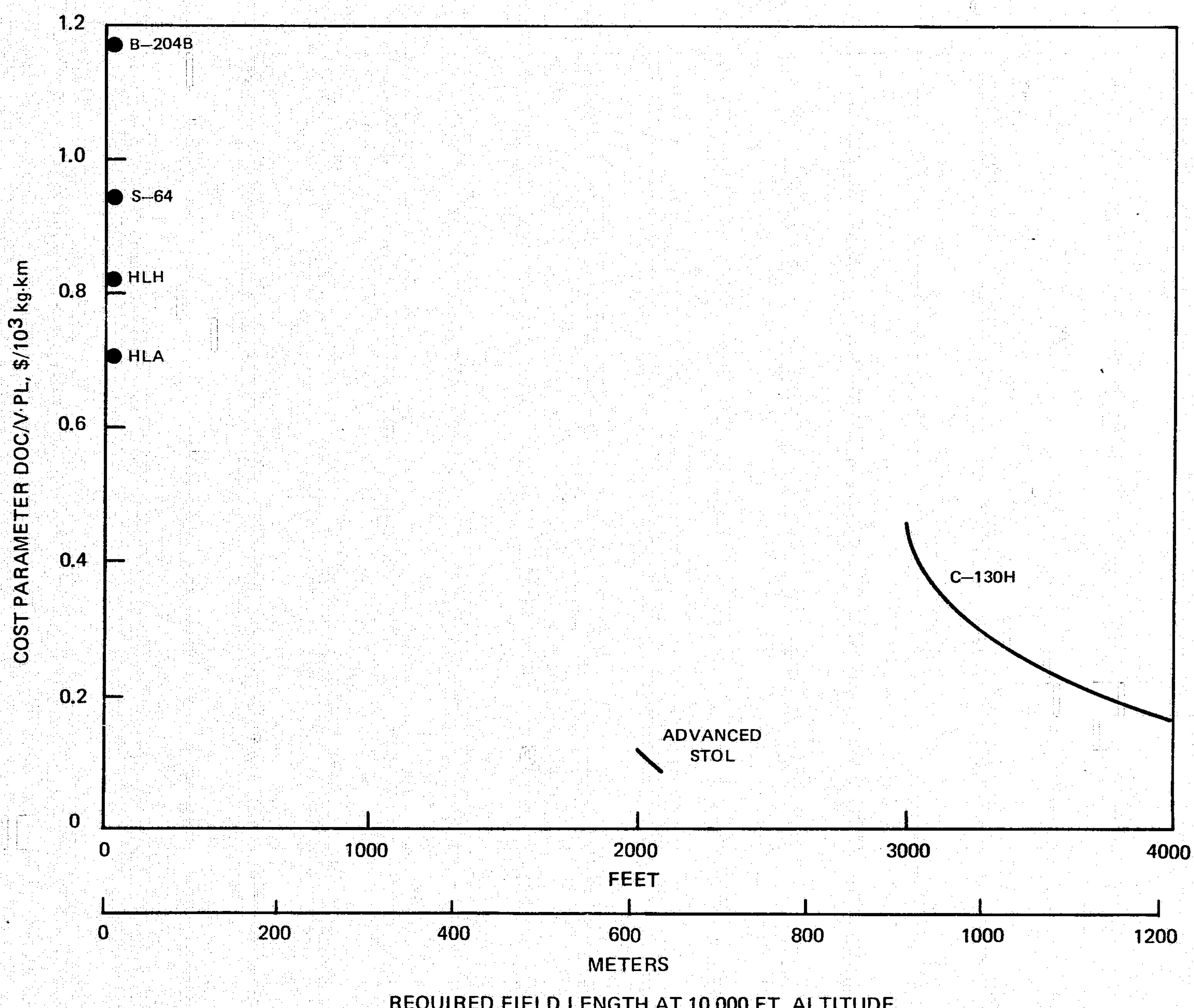

FIG. 14

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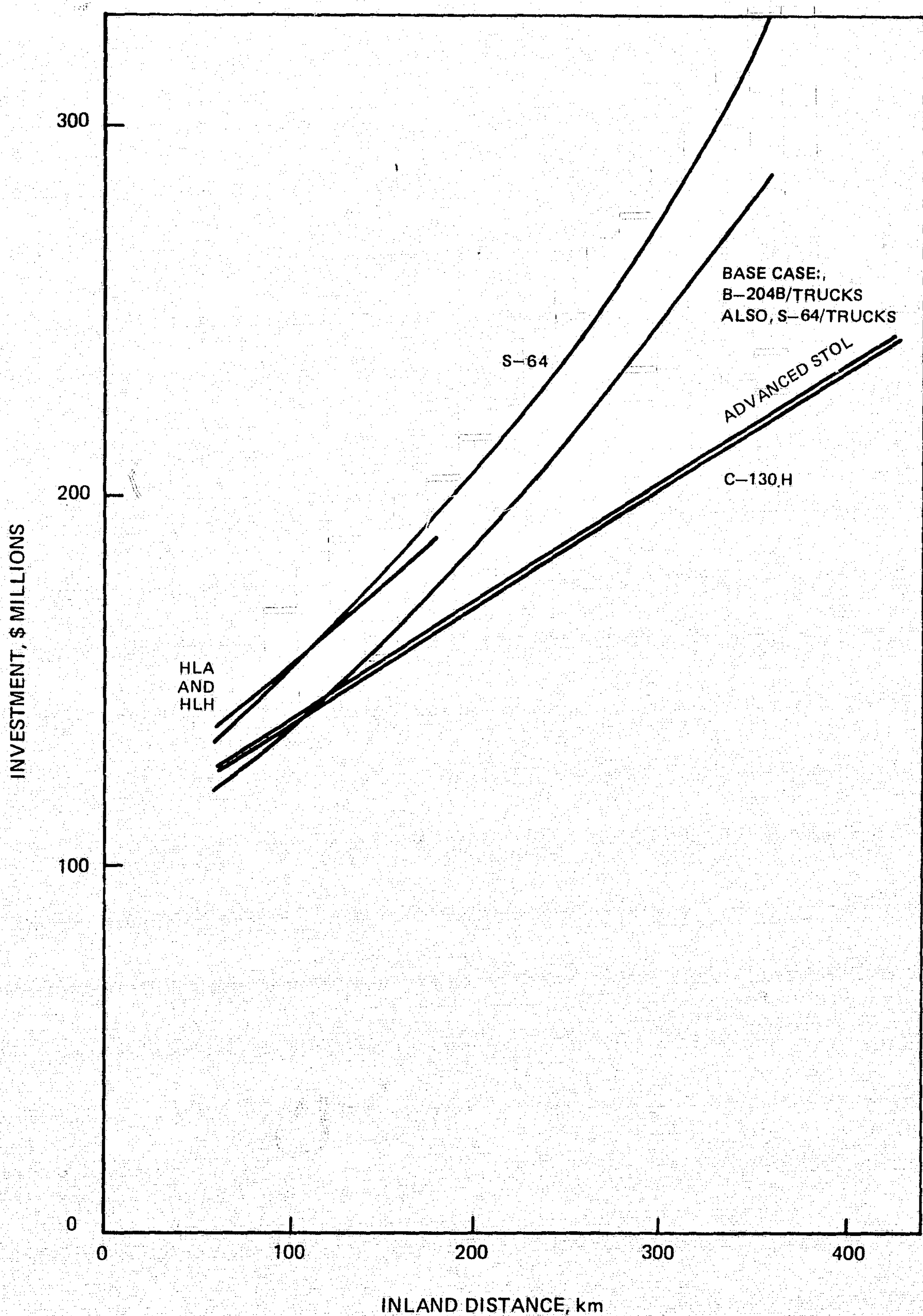
FIG. 15

REMOTE MINING PROJECT INVESTMENT



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TRANSPORT PERCENT OF TOTAL INVESTMENT

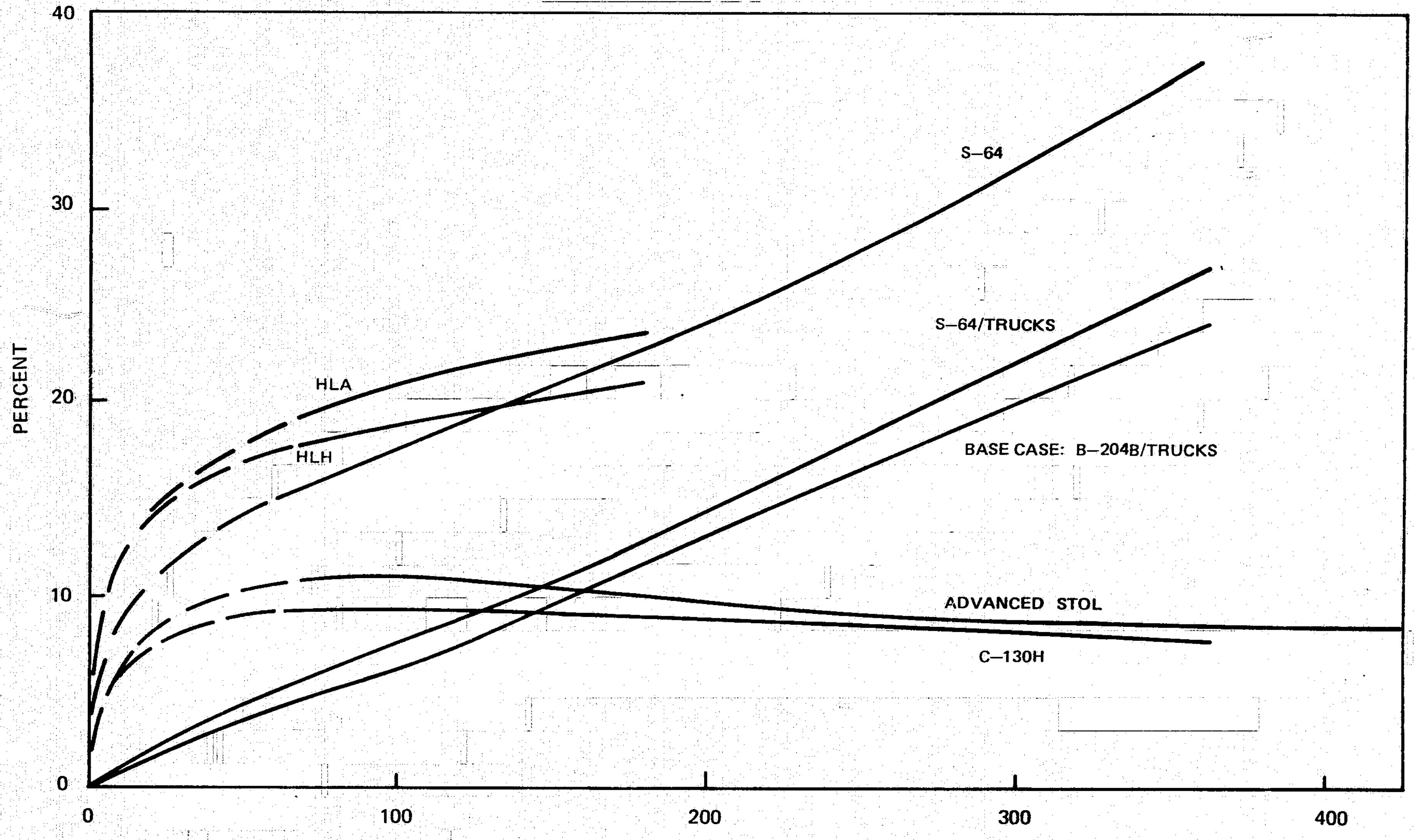

FIG. 16

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in Fig. 15 is the reduced investments made possible by shorter project durations in the air transport options, which compensate for high airplane operating costs. Also, the large fixed investment in facilities was a dominant factor in all cases, as illustrated in Fig. 16 which shows the percentages of total investment allocated to transport costs. For the truck and VTOL options, transport costs were a major factor in the escalation of total investment cost in Fig. 15. Transport costs in the fixed-wing options increase slightly with distance, but Fig. 16 shows that they decrease as a percentage of total investment because investments associated with equipment and supplies to construct a longer road increase even faster than the air transport costs.

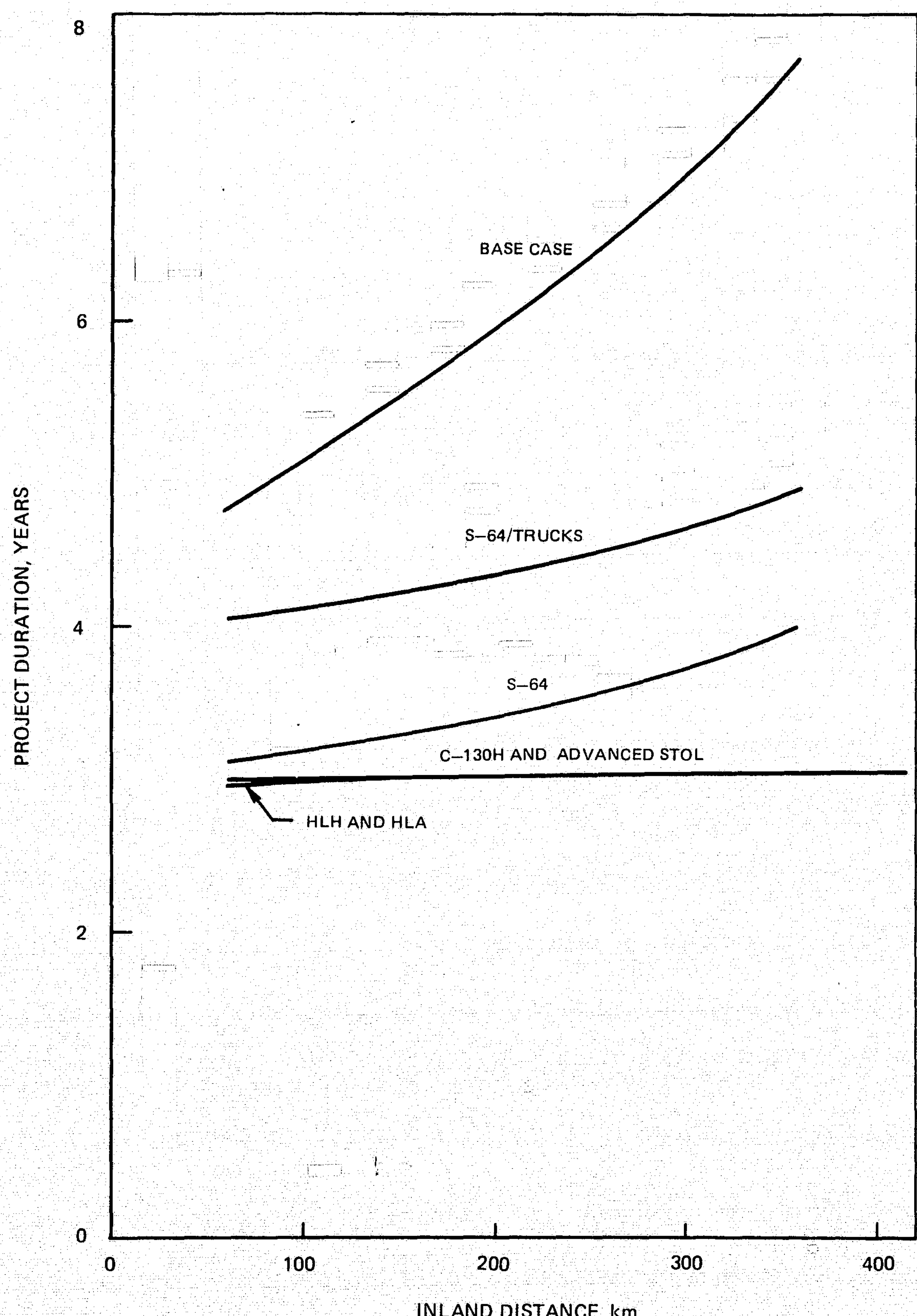
Since reduced project duration has been identified as a factor which makes wider use of airplanes (relative to Ertsberg) potentially desirable, Fig. 17 shows the total time advantages predicted for each air transport option over the Base Case. A portion of the project period reductions depicted in Fig. 17 relates directly to the delays experienced in the Ertsberg project due to lack of sufficient payload capacity in delivering heavy loads. The difference between the S-64/trucks option and the Base Case consists entirely of time savings of this type. In the remaining options, additional time savings (about one year) were achieved by conducting Phases IV and V simultaneously. As inland distance increases, project duration increases rapidly in the Base Case, but only moderately in all other cases. Even at the low end of the inland distance range investigated, significant time advantages are indicated in Fig. 17, thereby compensating for somewhat higher total investments in Fig. 15.

Employing the cash flow model described earlier, the estimated ROI was computed for each transport option over an inland distance range from 60 km to 500 km. The results presented in Fig. 18 demonstrate that all air transport options produced improvements over the Base Case for distances up to about 250 km. Beyond 270 km, the Base Case would clearly be an unacceptable venture because its ROI would be less than the expected interest rate on borrowed capital; i.e., project financing could not be arranged. An important advantage of the fixed-wing aircraft options is the much-extended range of inland distances they facilitate. The VTOL options are less effective in this respect because of range/payload limitations. Although the range of the HLA could be extended considerably by installing fuel tanks, at some sacrifice in payload, its economic performance would suffer and the slope of the HLA curve would turn downward.

As explained earlier, the economic criterion of interest to the mining company is return on equity (ROE), for which results are given in Fig. 19. These results are similar to those in Fig. 18, as far as relative standings of the transport options are concerned. However, whereas only small improvements in project ROI were estimated, particularly for the large VTOLs, considerably larger improvements in ROE are indicated in Fig. 19. For example, the 35 percent ROE estimated for Ertsberg (120 km) increases to 54 percent with the fixed-wing options. Even at the maximum inland distance of 375 km, the fixed-wing options permit an ROE of 24 percent.

FIG. 17

DURATION OF REMOTE MINING PROJECT CONSTRUCTION



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RETURN ON INVESTMENT

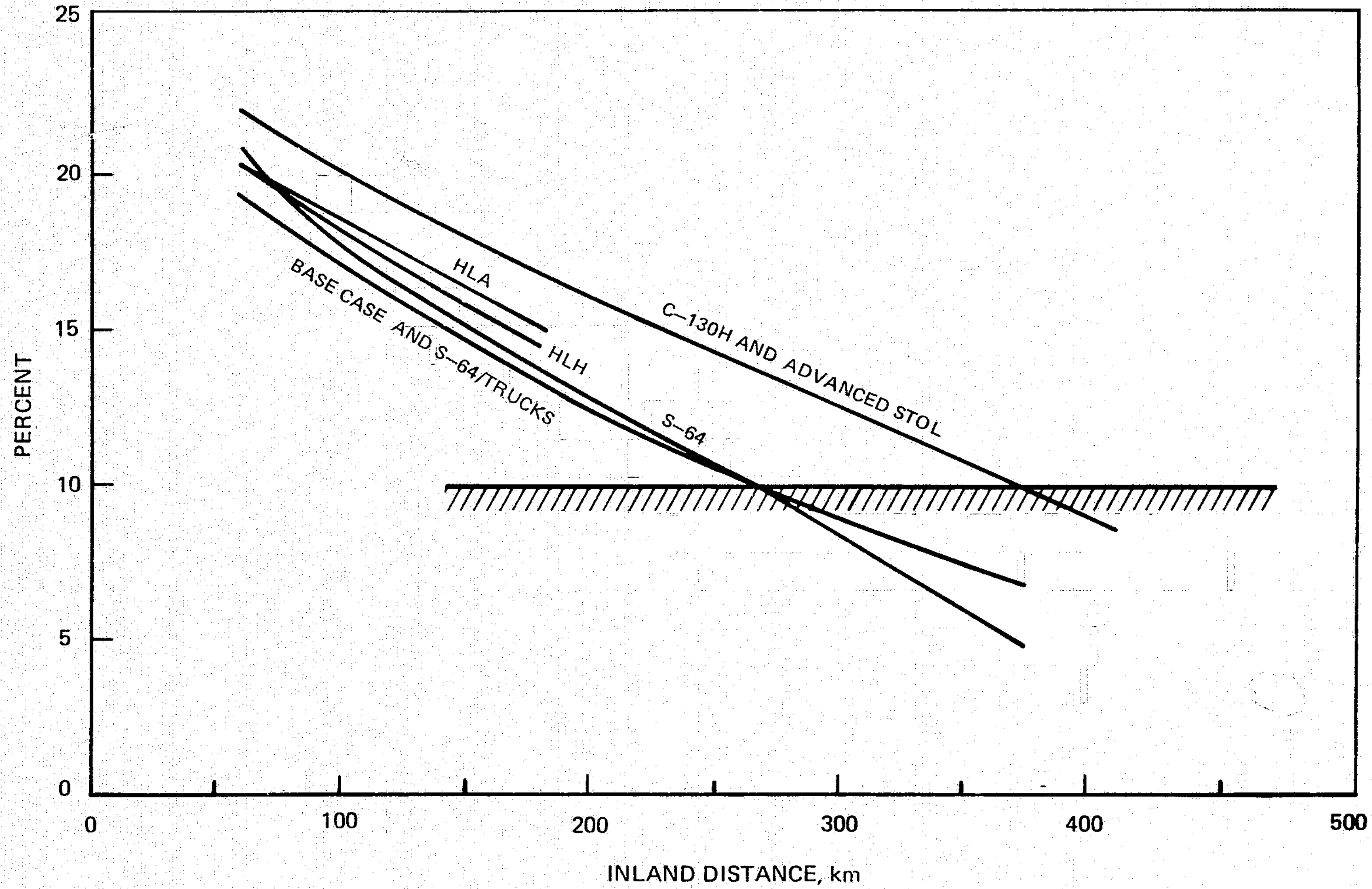

FIG. 18

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RETURN ON EQUITY

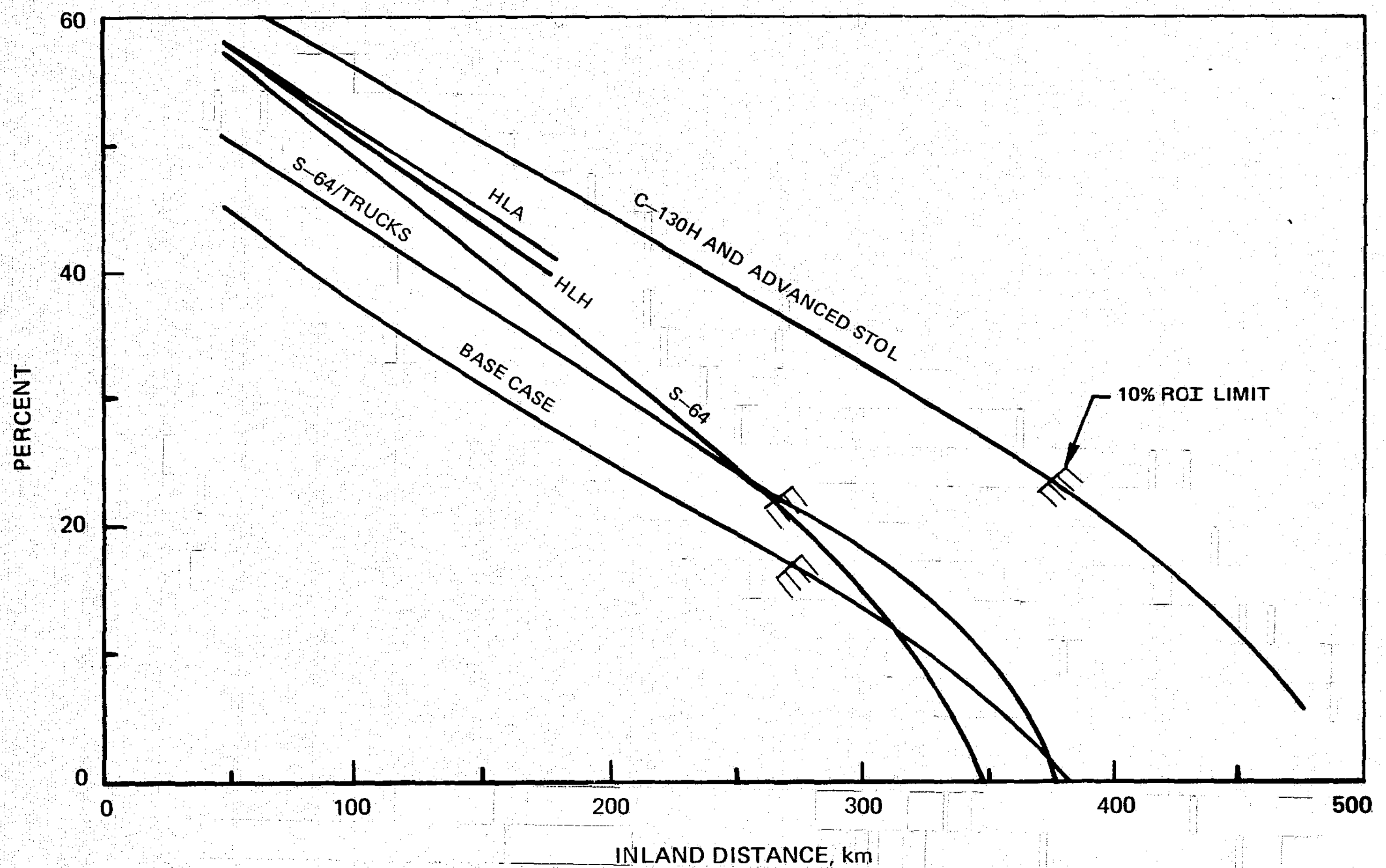


FIG. 19

The implications of these ROE results are that, if the mining company can demonstrate an ROI greater than the minimum acceptable value of 10 percent, there would be an incentive to choose the airplane solutions to leverage the return on its own invested capital. Although this equity capital would generally be only 15 percent of the total investment, it would be advanced close to project inception; therefore, the advantage of shortening the construction period would enhance the return on this portion of the investment.

Estimated Aircraft Requirements

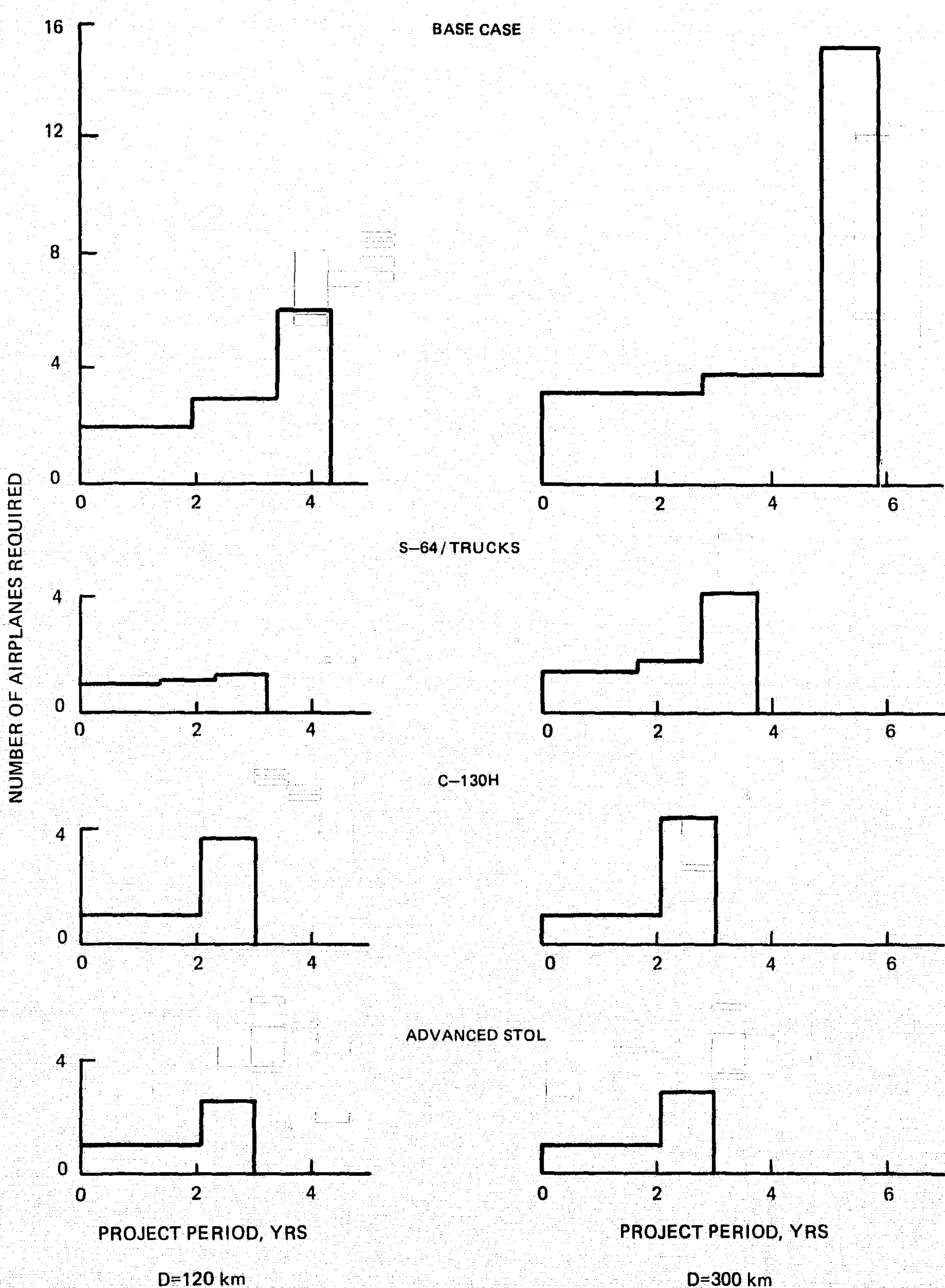
To estimate aircraft requirements in future remote mining projects, it was necessary to first determine the scale of future mining investments in Brazil and Indonesia in order to determine how many projects can be financed. Projected oil drilling and mining investments in Brazil and Indonesia were shown in Fig. 10. Over the period of interest (1975 to 2005), the investments in mining alone total $30 billion for Brazil and $28.5 billion for Indonesia. Knowing the magnitude of required investment for a project, as shown in Fig. 15, it was possible to estimate the number of projects which could be expected to be financed in this period. By determining the number of aircraft required per project, and making some assumptions regarding the timing of projects, it was possible to make at least a first-order estimate of the numbers of aircraft necessary to serve remote mining ventures in the two study countries.

Since the inland distance, like field length and destination altitude, was not a known quantity, this parameter was treated as an independent variable. Also, since the highest altitudes in Brazil are considerably less than in Indonesia, where high elevations are common throughout the outer islands, it was assumed that mineral finds would all be at sea level in Brazil (i.e., no loss in payload due to altitude was suffered for Brazilian projects), while Indonesian finds were all assumed to be at 10,000 ft altitude. With these simplifying assumptions, the numbers of projects which will be possible in the two countries were calculated as functions of inland distance for each airplane option. Because investment per project increased with distance (Fig. 15), and since total investment was assumed fixed, the numbers of projects decreased with distance. The numbers of Brazilian projects were slightly greater, and longer inland distances were possible because of the absence of an altitude effect on payload. With total investments of about $30 billion in each country, and project investments ranging from $120 million to $250 million, the potential numbers of projects which could be initiated during the forecast period would be between 100 and 250 in each country.

In the analysis of each project phase, the numbers of airplanes of each type were calculated to determine transport investments. In general, the number of airplanes required was low in the early phases, then jumped to a higher number to meet the heavy transport requirements of delivering mill and mine facilities in the final phase. Typical airplane requirements are depicted in Fig. 20 for each airplane option and for an appropriate range of inland distances. As indicated, aircraft requirements per project increase with inland distance, and decrease with increasing payload capability.

FIG. 20

TYPICAL AIRPLANE REQUIREMENTS



Translating these results into total numbers of aircraft required for the full 30-year period involved an assumption regarding scheduling of projects (i.e., the number of projects going on simultaneously). Two cases were calculated, as depicted in Fig. 21. The top sketch shows the assumed model for airplanes required in each project. In keeping with Fig. 20, these rquirements are low in the initial phase and then jump to a higher requirement in the final phase, thereby complicating simultaneous scheduling of projects. In the ideal case shown in the second sketch, projects would be "packed" together to reduce the total number of airplanes required to the absolute minimum over a 30-year period consisting of many multiples of the project duration, T_D. Since the ratio $30/T_D$ would always be less than the total number of projects, a second tier would be "stacked" on this first tier, and a third, etc., until all projects were accounted for. The resulting equation gives the total number of airplanes required to serve all projects, where T_{LIFE} is the life of an airplane, which was assumed to be 15 years. In the example, the project duration was divided arbitrarily (3/4 initial phases, 1/4 final phase), but the number of periods was actually different for each case indicated in Fig. 20. The function $f(T_D)$ also depended on the distributions in Fig. 20.

The last sketch on Fig. 21 depicts a less advantageous scheduling algorithm in which the overlapping of projects was arbitrarily reduced to 50 percent. The worst case would, of course, be no overlap at all, but this assumption was considered to be unnecessarily extreme.

The resulting estimates of total aircraft requirements are shown in Fig. 22 for both scheduling algorithms.* It is important to remember that total mining investment was held constant, so that the number of projects in each country decreased with increasing inland distance. Thus, if the number of airplanes required per project increased only slightly with distance, as for the fixed-wing cases in Fig. 20, the total number of required airplanes also decreased with distance. In the helicopter cases, airplanes per project increased rapidly with distance, offsetting the decreasing number of projects and causing the curves in Fig. 22 to increase with distance.

It is clear from Fig. 22 that vastly different airplane requirements would occur for the alternative transport options. However, it must be remembered that restrictions on field length in mountainous terrain, where rich mineral finds are likely to be made, will provide more opportunities for the short-field airplanes. The VTOL vehicles, which can be used regardless of field restrictions, can satisfy the requirements of all projects in both countries. As field length increases, opportunities diminish.

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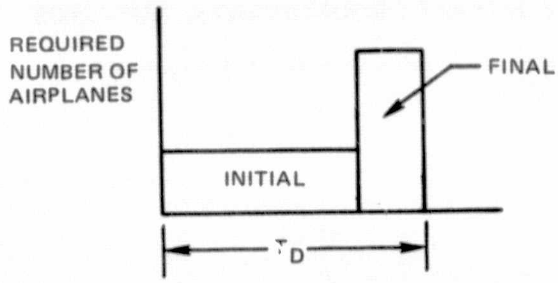
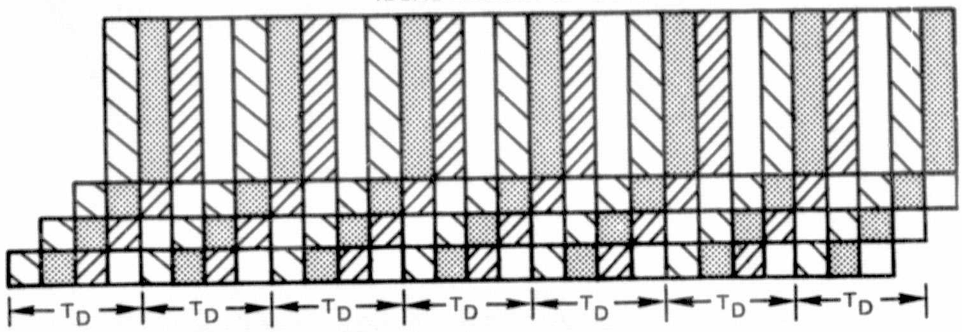
* The HLA curve represents the number of HLA vehicles. If four helicopters comprise each HLA, then the results would be multiplied by four to obtain the total number of helicopters (S-64s) required. Since the HLA first cost of $14 M was based on a production run of 50 vehicles (Ref. 70), that assumption appears to be consistent with these results.

PROJECT SCHEDULING ALGORITHMS

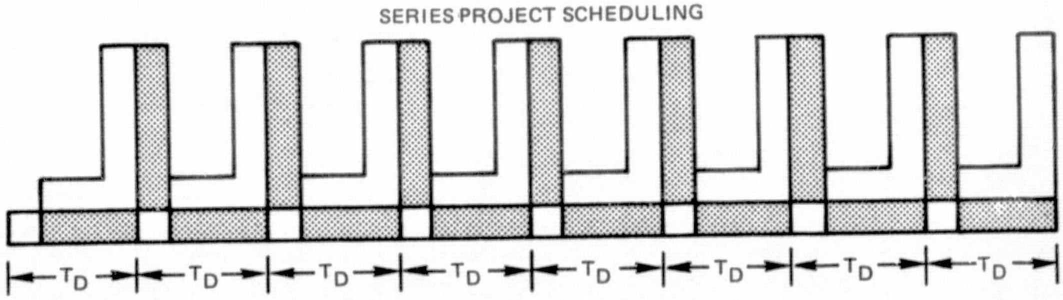


IDEAL PROJECT SCHEDULING



$$N_{A/C} = \frac{N_{PROJECTS}}{N_{PERIODS}} \left(\frac{30}{T_{LIFE}}\right) \left[(f(T_D)-1) \; N_{INITIAL} + N_{FINAL} \right]$$

SERIES PROJECT SCHEDULING



$$N_{A/C} = \frac{N_{PROJECTS}}{N_{PERIODS}} \left(\frac{30}{T_{LIFE}}\right) \left[N_{INITIAL} + N_{FINAL} \right]$$

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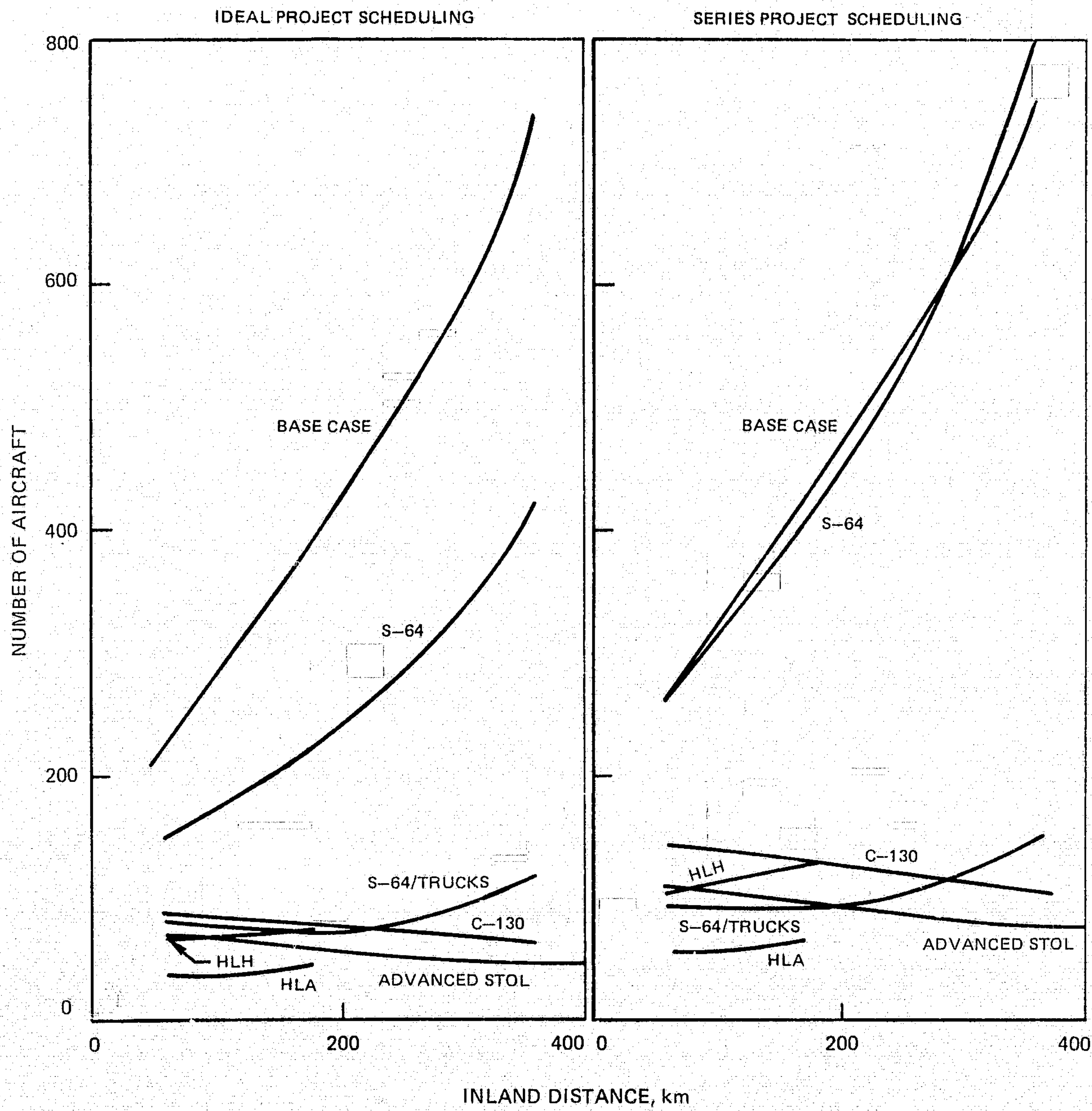
FIG. 22

ESTIMATED AIRCRAFT REQUIREMENTS: 1975–2005

$52.5 B MINING INVESTMENT IN BRAZIL AND INDONESIA
MINIMUM ROI=10%/YR
AIRPLANE LIFE=15 YRS



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Good estimates of field length and mine elevation require a more complete analysis of future remote mining projects in LDCs than could be carried out in this study. It can be said with some confidence, however, that airplane requirements could number in the hundreds for Brazil and Indonesia. When other countries' needs are included, this airplane market might be substantially larger.

Sociopolitical Considerations

The method employed to account for factors other than the economic and technical considerations, on which the foregoing analysis was based, is described in Appendix D. This method consists of a "planning balance sheet" tabulation of the important objectives by which mode choice decisions might be judged by LDC Government planners. It is a necessarily subjective approach incorporating a wide variety of qualitative and semi-qualitative factors affecting modal choice, and the results should be interpreted as indicative rather than definitive. Nevertheless, since decisions may be strongly influenced by noneconomic factors, the benefits and costs associated with these considerations must be incorporated as part of this study.

A summary of the objectives included in the analysis, the weights assigned to each objective, and the ranks and scores attributed to the air* and road alternatives, appear in Table 6. In this comparison, the five general categories of objectives were subdivided into a number of specific objectives upon which the ranking was done. In the context of the remote mining application, it is important to recognize that all air options included construction of a road. Therefore, the ranking was based on considerations associated with road and facilities construction, rather than the end production installation which was essentially the same in all cases.

In general, Table 6 shows that reliance on roads for major cargo transport is more successful than reliance on airplanes in terms of meeting implementation and socio-economic development objectives. Creation of employment opportunities and upgrading of skills are especially important factors for which road ranks higher than air, primarily because air transport has the effect of shortening a project and thereby diminishing manpower requirements. Operational and resource factors tend to favor air, and political factors are not particularly relevant. The overall result favors road but not by a convincing margin. Therefore, it may be concluded that the economic advantage of air transport to a mining company would be the dominant factor in mode choice.

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* No attempt was made to account for differences among the air transport options. The scores in Table 6 apply regardless of airplane type.

TABLE 6

SOCIOPOLITICAL COMPARISON

Remote Mining

OBJECTIVES	UNITS OF MEASUREMENT	WEIGHTS	Air Rank	Air Score	Roads Rank	Roads Score
IMPLEMENTATION						
Open Service Expeditiously	Months	4	5	20	1	4
Minimize Foreign Exchang Req'mts.	$	6	1	6	5	30
Min. Need for Expatriate Labor (Constr)	Person-Years	3	2	6	5	15
Avoid Instit. Delays at Inter'l Level	Prob. of Months	1	3	3	5	5
Secure High Salvage Value	$ or Equiv.	1	5	5	3	3
Subtotal		15		40		57
OPERATION						
Provide for Maximum Reliability	Prob. Days of Service Interr./yr	7	5	35	1	7
Provide for Maximum Safety	Anticip. Level of Damage Claims/yr	5	5	25	4	20
Min. Need for Expatriate Labor (Oper.)	Person - Years	3	1	3	5	15
Subtotal		15		63		42
SOCIO-ECONOMIC DEVELOPMENT						
Create Jobs for Available Work Force						
- In Construction	Person - Years	4	2	8	5	20
- In Operation/Maint.	No. of permanent jobs	7	1	7	5	35
Foster Upgrading of Tech. Skills	No. of skilled work trained/yr	5	3	15	5	25
Provide Reliable & Affordable Means of Mobility for General Pop.	No.Person-Km	5	1	5	5	25
Provide Fast & Comfortable Means of Mobility for General Population	Time Distance	5	5	25	1	5
Provide for Emergency Services	Time Distance	4	5	20	3	12
Encourage Establ. of Secondary Industries	Probability	3	1	3	5	15
Build-up of a Multipurpose Long-Range Infrastructure Network	Policy Judgment	2	2	4	5	10
Subtotal		35		87		147
RESOURCE UTILIZATION						
Conserve Energy, Part. Imported Fuel	Barrel Equiv/yr	7	3	21	5	35
Protect Physical Environment	Tons of Emiss./yr	5	5	25	2	10
Maximize Access to Primary Materials	Policy Judgment	8	5	40	1	8
Subtotal		20		86		53
POLITICAL						
Upgrade National Defense Capability	Policy Judgment	6	3	18	5	30
Promote Political Stability and National Unity	Policy Judgment	6	--		--	
Generate National Pride	Policy Judgment	3	--		--	
Subtotal		15		18		30
GRAND TOTAL		100		294		329

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LOW-DENSITY TRANSPORT

It was observed in the INTRODUCTION that transport requirements in developing countries can be broadly categorized into two geographical sectors, one which is rather well developed, and another which is at a very early stage in its development. This second LDC transport sector is the remote region which usually consists of most of the geographic area of the country, has only a small fraction of the national population, and contributes very little to national output. However, the growth rates of the remote region are often high and usually unpredictable. The nation's untapped natural resource wealth is usually present in this sector. Because the remote region is virtually undeveloped, its transport infrastructure is frequently primitive, and often nonexistent. Airplanes are already used for most long-distance passenger and cargo carriage, although not necessarily on a scheduled basis. A primary characteristic of the transportation requirement in the remote region is low-density passenger and cargo transport among dispersed and relatively small population centers. Distances may be anywhere from 50 to 1000 km and terrain often presents great impediments to surface transport. Therefore, opportunities for air transport as the primary mode are obvious.

As development of these hinterlands takes place, not only will traffic grow on existing routes, but new connections will be made among future population centers. The extent to which air can continue to be a primary means of transport, and its feasibility on these new routes, was examined in order to determine whether air can be considered a viable alternative in future development of the transportation infrastructure. Water-based means of transport (river, inter-island, and coastal shipping), when available, are universally accepted as the lowest-cost solutions for meeting transport needs, without regard to any value of time (Ref. 59). The comparison between road and air is not as clear, particularly when considering development of the hinterland, with its difficulties of access and lack of infrastructure, and its characteristic jungle and/or rugged terrain, as in the case of Brazil and Indonesia. A generalized analysis of the type described here could serve to establish guidelines for future transportation planning and could show the types of aircraft best suited for this application. Also described here is a brief case study in which the generalized results were utilized to evaluate possible future routes in Brazil and Indonesia. Finally, various opportunities for integrating air transport with road construction will be discussed.

Generalized Analysis

The economic evaluation of surface and air modes was made using the methodology described in Appendix D; costs for the road and air modes given in Appendix C are inputs to the model. In Appendix D, an analytical expression was used to develop the "project cost," or present value of the time stream of capital and operating expenditures. The minimization of project costs was used as a criterion for choosing the more desirable transport alternative, considering various combinations of initial transport volume, opportunity cost of capital, and expected growth rate of traffic.

Several assumptions and simplifications were made. For roads, annual maintenance costs were included in the construction cost of the road, and were therefore independent of traffic volume. Two project periods were chosen: 15 years and 30 years. For a project life of 30 years, it was assumed that earth roads (with an average economic life of four years) would have to be "reconstructed" about seven times during that period. For a 15-year project period, only four such fixed-capital investments would be necessary. In practice, these expenditures could be in the form of reconstruction or rerouting of the earth roads, a problem which does not occur as severely with gravel or paved roads with much longer project lives (15 years and 30 years, respectively).

Another simplification was that no "staging" of construction was assumed in the generalized analysis. For example, as traffic grew on a particular link or route, it would eventually be uneconomical to rebuild an earth road, and therefore it would be graveled, and, ultimately paved. This would increase construction costs but would significantly reduce vehicle operating costs. Such staging was not incorporated into this initial analysis, and only traffic volumes which could be economically carried for a 15- or 30-year period for a particular road type were considered. In the case studies, this assumption was relaxed and alternative means of transport development were examined.

Direct operating costs (DOC) were calculated for various aircraft types using data reported in Appendix C, with one exception. Block times were estimated using typical taxi times, and maximum cruise speeds were reduced by 10 percent to reflect remote-region operating conditions. This assumption is consistent with manufacturers' data and actual operating experience. The aircraft used, and their block times, are shown in Fig. 23 for the appropriate ranges of various candidate aircraft. A variety of both existing and future aircraft was chosen to obtain broad coverage of payload, range and cost characteristics desirable for this type of service.

The need for communication and transportation in remote areas is usually met, at least initially, by the use of small airplanes (Ref. 60). These aircraft provide a means of transporting necessary goods and people quickly and efficiently. The appropriate aircraft is one which meets the demand at lowest cost by utilizing its capacity most effectively. An important consideration is, therefore, one of maximizing utilization at a reasonable load factor to reduce cost. This consideration justifies small aircraft for very low volumes, even though their actual operating cost per ton may be high. Table 7 shows the capacity offered by each airplane on an annual basis, and the corresponding daily frequencies.

BLOCK TIME FOR VARIOUS AIRCRAFT

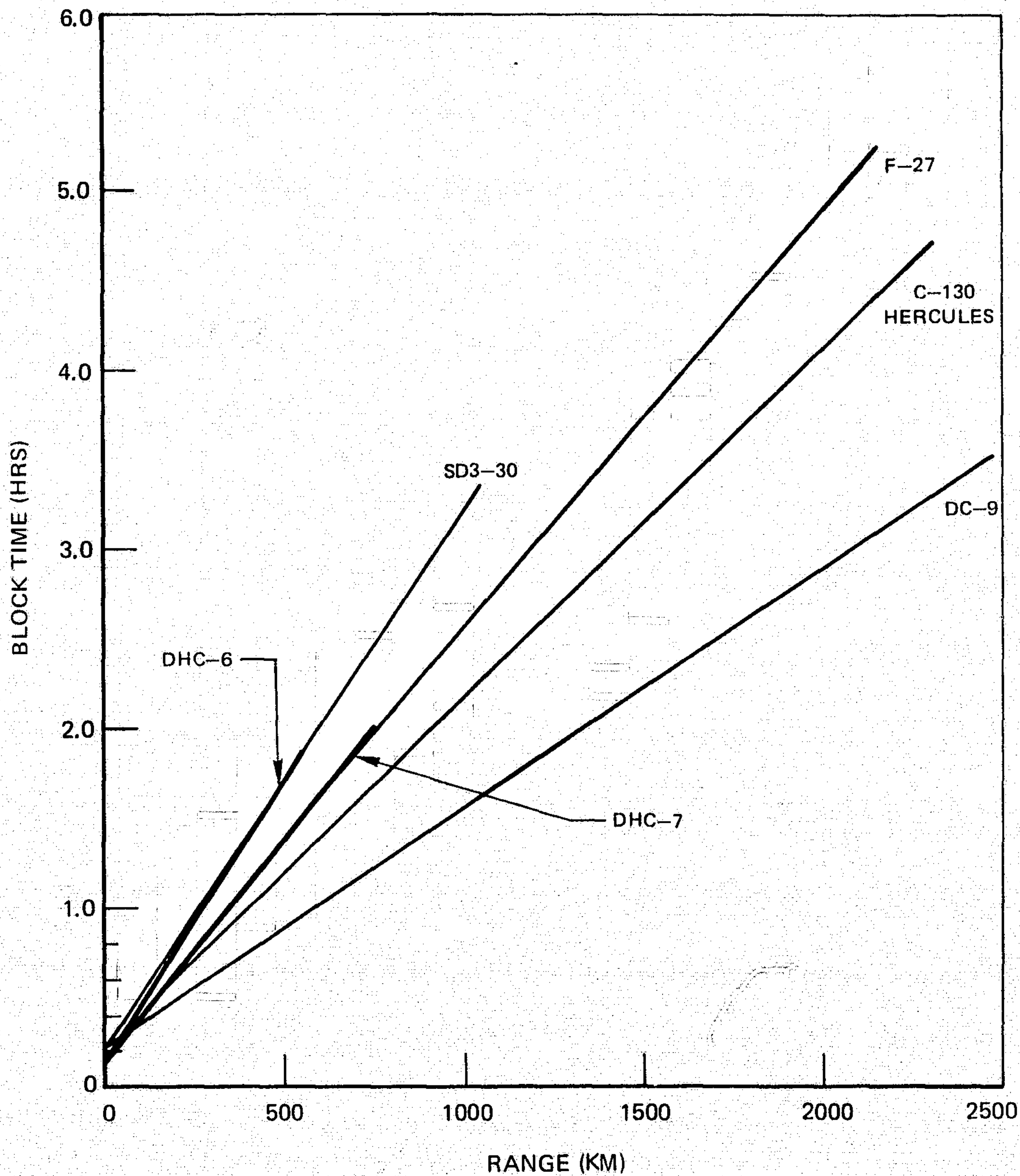


TABLE 7

AIRCRAFT PRODUCTIVITIES

Aircraft Type	Payload (kg)	Block Speed (km/hr) @ 200 km	Annual Capacity[1] (10^6 kg/AC)	Annual Productivity (10^6 kg-km/AC)	Daily One-Way Frequency[2]
C-130	15,000	337	30.4	6.0	13.5
F-27	5,550	300	10.0	2.0	12.0
SD3-30	2,655	248	4.0	0.8	9.9
DHC-6	1,635	255	2.6	0.6	10.2
DHC-7	4,900	308	9.0	1.8	12.3
DC-9	10,900	425	27.8	5.6	17.0

1. Capacity offered by the aircraft at 2000 hrs utilization and 60% load factor, defined as $\frac{\text{PL x Block Speed x U x 0.6}}{D_{\text{one-way}}}$, where D = 200 km
2. For a 200 km distance, at 60% load factor and 250 days/yr

In actual operations, the process of providing service for a growing demand results in incremental additions to the fleet, which may not result in the maximum assumed productivity of 2000 hrs annually. An example is shown in Fig. 24, where the capacity provided by an aircraft is shown relative to a growing demand. If initial demand is smaller than the capacity of one aircraft, under-utilization occurs and higher cost ($/kg) will result.

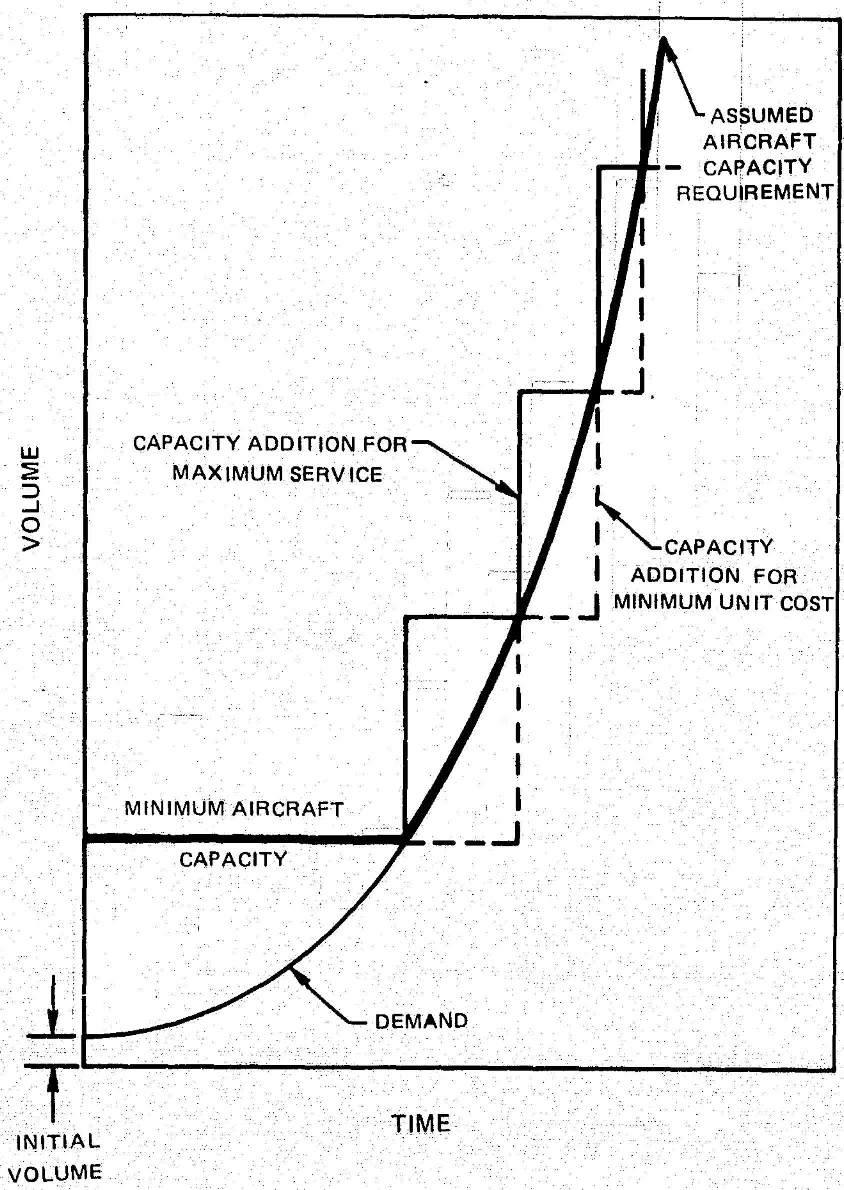
When demand grows beyond the capacity of one aircraft, one of two strategies can be followed. For maximum service, another airplane should be added, which will reduce load factors and increase unit cost. Alternatively, an airplane can be added only when sufficient demand "accumulates," thereby resulting in maximum utilization and minimum unit cost. In reality, a policy somewhere between the two extremes is probably pursued in most cases. An aircraft would be added at some point, perhaps shared with another region until demand grows sufficiently to assure economical service. The result would be that the supply offered would be closely matched to the demand at higher volumes, as illustrated by the heavy line. Initially, however, a minimum of one aircraft would be required, regardless of volume, as represented by the heavy horizontal line in Fig. 24.

Figure 25 shows the resulting annual utilization for the maximum service and assumed fleet-addition strategies. The utilization assumed in further comparisons is that shown by the heavy line, where airplane additions beyond one airplane are made in a "continuous" manner, such that 2000 hours of annual utilization are assured.

Incorporating a minimum requirement of one aircraft results in an absolute minimum project cost at zero volume. At the annual productivity of each aircraft (see Table 7) a "breakpoint" occurs which corresponds to the cost of full 2000-hour utilization at the 60 percent load factor for an initial volume that can be satisfied by one airplane. The resulting cost curves are seen in Figs. 26 and 27. It is interesting to see that for very low volumes (less than about 10^6 kg/yr, or 4000 kg/day), the Twin Otter (DHC-6) is the least expensive of the airplanes evaluated for both high and low growth rates. Although the "envelope" of least-cost aircraft progresses through the order DHC-6, SD3-30, F-27, and DC-9, the aircraft not on this envelope may have other advantages, including landing field capability, range requirements, and other considerations.

In comparing air costs against the surface alternative, which includes road construction, maintenance and operations, costs of fixed facilities were added to each mode. Facilities costs for both road and air were estimated as functions of aircraft parameters and transport volume. These were obtained by "scaling" data from several sources (Ref. 61), and are shown in Table 8. Results show that these costs are minimal relative to the total cost of operation over a 15- or 30-year period, and do not affect the comparison of modes. Nevertheless, these facilities are an initial investment which must be made and they can influence the desirability of a particular alternative.

AN EXAMPLE OF ALTERNATIVE AIRCRAFT ADDITION STRATEGIES



AN EXAMPLE OF AVERAGE ANNUAL UTILIZATION FOR AIRCRAFT

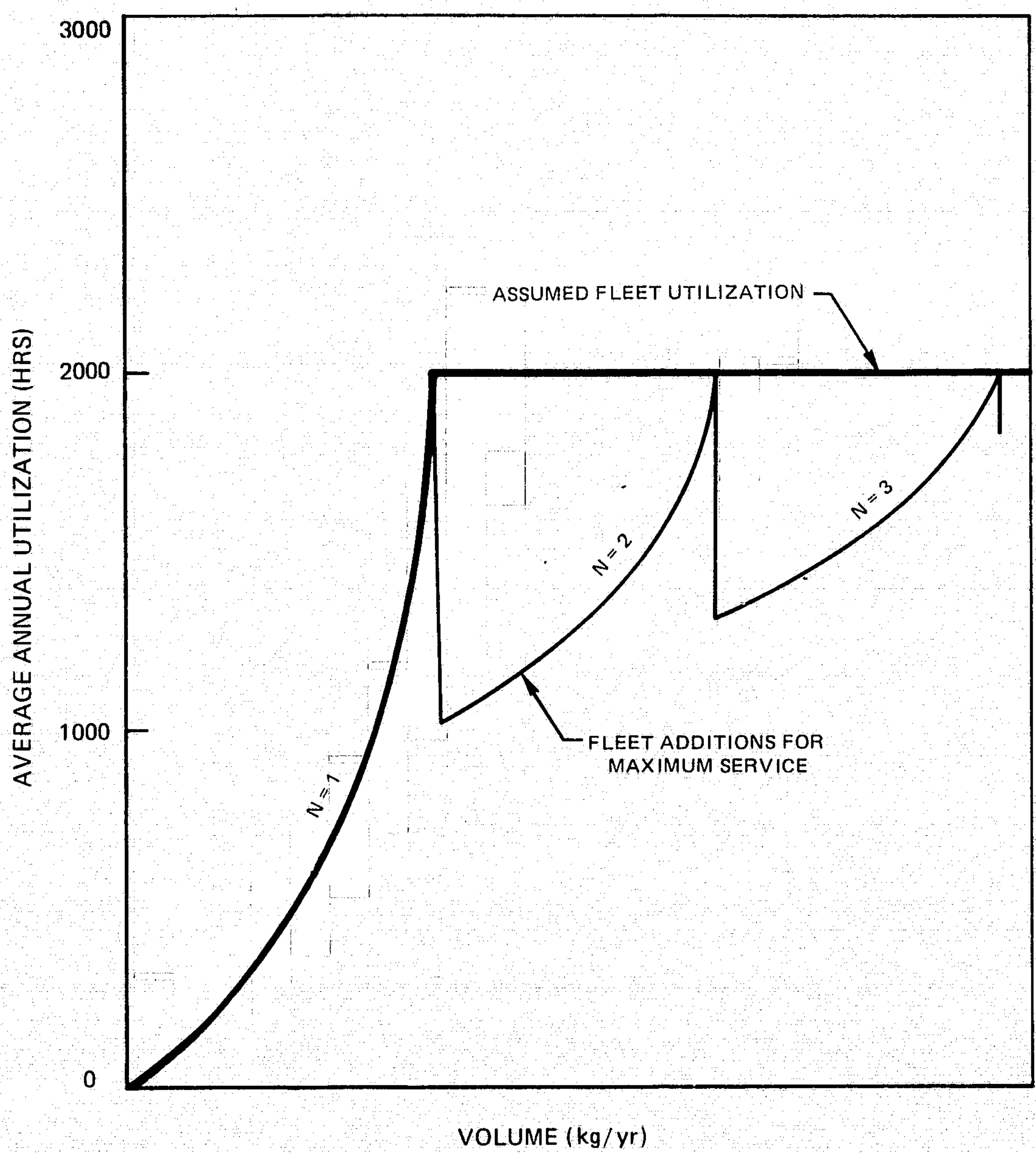
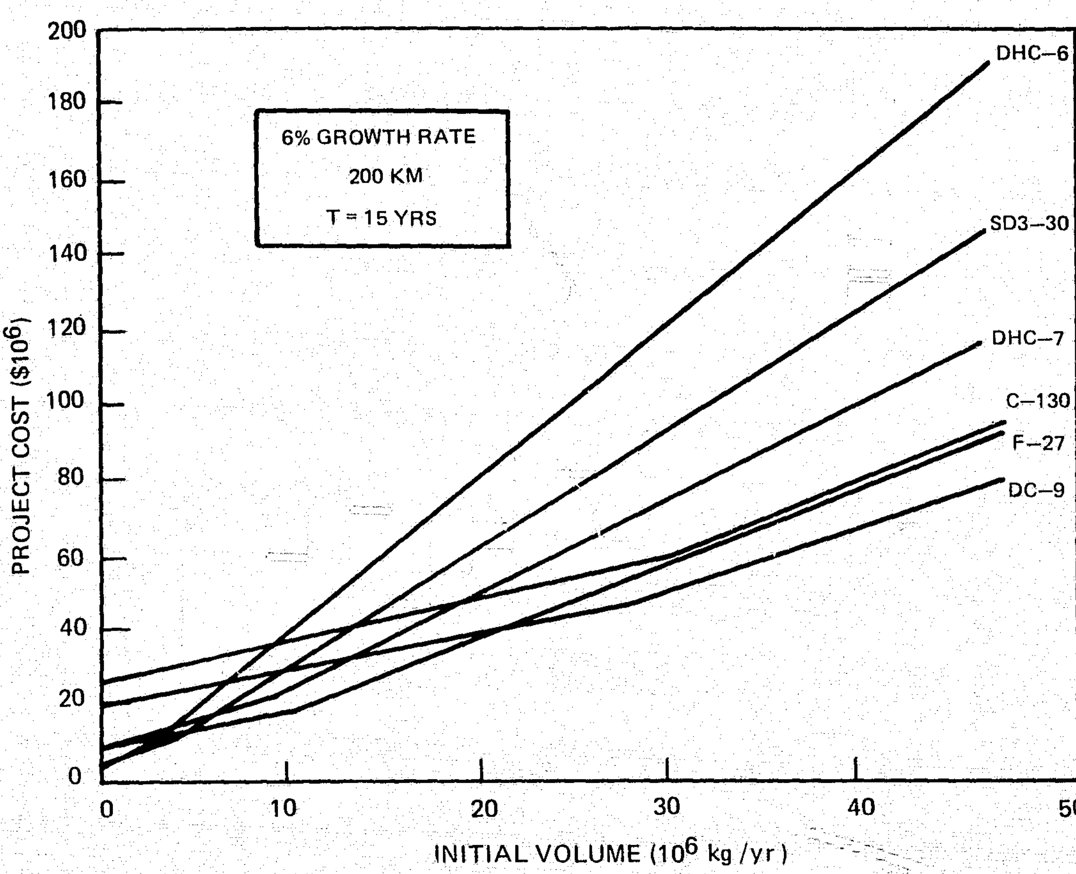


FIG. 26

COMPARISON OF COSTS FOR AIRPLANES AT LOW VOLUMES



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COMPARISON OF COSTS FOR AIRPLANES AT LOW VOLUMES

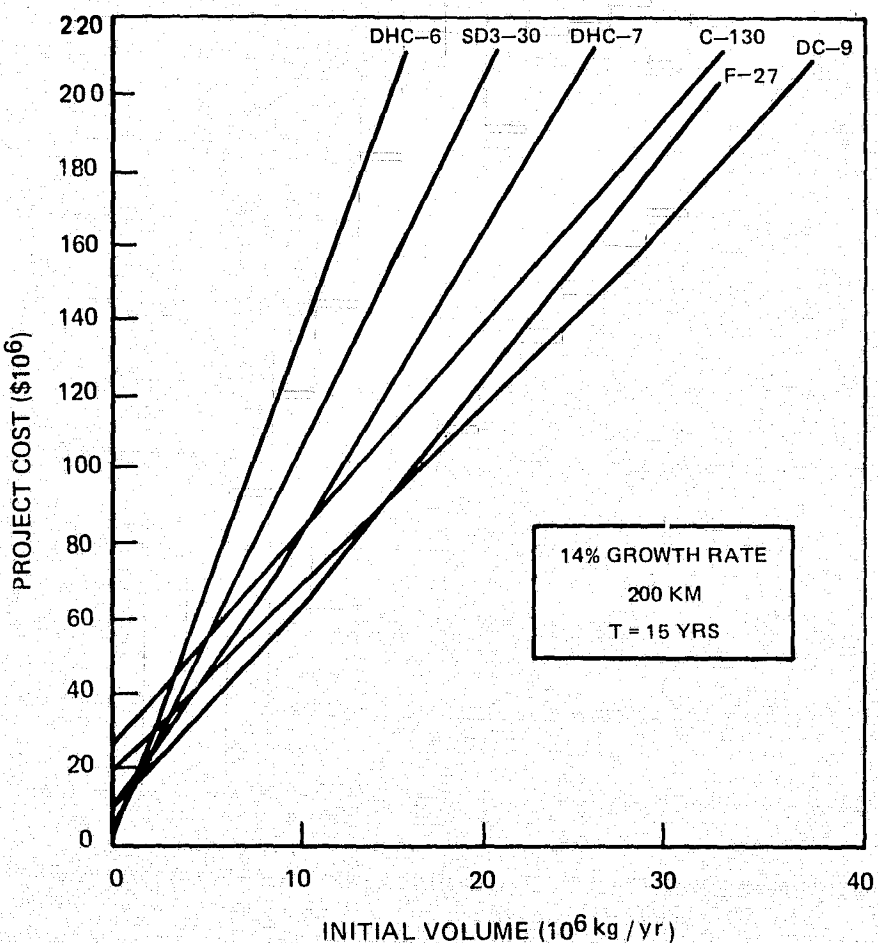

TABLE 8

FACILITIES COSTS
(All Costs in Dollars)

AIR COSTS

$$\text{Pavement} = 0.0025\ GW \cdot FL \cdot N_T$$

$$\text{Navaids} = 10{,}000 \cdot N_T$$

$$\text{Terminal} = 2000\ V \cdot N_T$$

$$\text{Hangar} = \frac{10^6 \sqrt{GW} \cdot V}{PL}$$

$$\text{Fuel Depot} = 0.05\ N_T \cdot V \cdot \dot{W}_f$$

TRUCK COSTS

$$\text{Fuel Depot} = 17\ N_T \cdot V$$

$$\text{Garage} = 1800\ V$$

$$\text{Terminal} = 2000\ V \cdot N_T$$

where

V = Cargo volume (1000 tonnes/year)

N_T = Number of terminals on route

GW = Gross weight of aircraft (kg)

FL = Field length (m)

PL = Aircraft payload (kg)

$\dot{W}_f$ = Fuel rate (kg/hr)

For the comparative analysis, the following ranges of parameters were used:

- Initial volume of traffic = 0 to 200 x 10^6 kg/year
- Growth rate of traffic = 6 percent, 10 percent, 14 percent per year
- Project period (T) = 15 years, 30 years
- Distance = { 200 km with 2 terminals; 700 km with 3 terminals; 2000 km with 5 terminals }

Results are illustrated in Figs. 28 and 29 for 6 percent and 14 percent growth rates at 200 km, and for T=30 and T=15 years. For simplicity, only three aircraft types are shown, disregarding their increased costs at very low volumes. The ranges of road costs reflect the large uncertainty of these costs (see Appendix C) as well as the consequences of differing terrain found in developing countries, as they affect construction costs. Also, the break points in the road cost curves represent a transition from earth to gravel to paved roads, for a least-cost solution. The large intercept at zero volume indicates the construction cost of earth roads. Fixed costs for aircraft were shown in the previous diagrams and are considerably smaller, though the high operating costs of air result in a much steeper cost rise, with volume, than for road.

Comparing results for the two project periods (T=15 vs T=30), road transport becomes more advantageous for longer project lives due to its low variable, or operating, cost. The question of an appropriate project period for analysis is difficult to resolve. A shorter period is more justifiable in that staging of road construction would most certainly occur for longer project periods, a factor which has not been accounted for. Projecting growth for a 30-year period is very speculative, particularly for the rapid changes occurring in developing countries. Finally, air would most likely not be a unique mode used over a 30-year period, since the growth during that period would result in settlement between the population centers linked, thereby justifying a road for access. Thus, a 15-year period seems more appropriate as a basis for comparison. In any case, air is almost certainly superior for initial volumes of less than 5 x 10^6 kg/yr, regardless of anticipated growth, within the 6 percent to 14 percent growth range investigated. This value is equivalent to about 2 daily DC-9 flights per 5-day week, at 100 percent load factor.

The improvement of block speed with distance was found to be only slightly cost-advantageous at longer stage lengths. In practice, shorter distances and multiple stops increase chances for delay. For road traffic, longer distances might affect reliability, but this factor was not considered. Consequently, although results are presented for only one distance, it should be kept in mind that there would be somewhat lower relative costs for air at longer stage lengths.

ROAD VS AIR COSTS

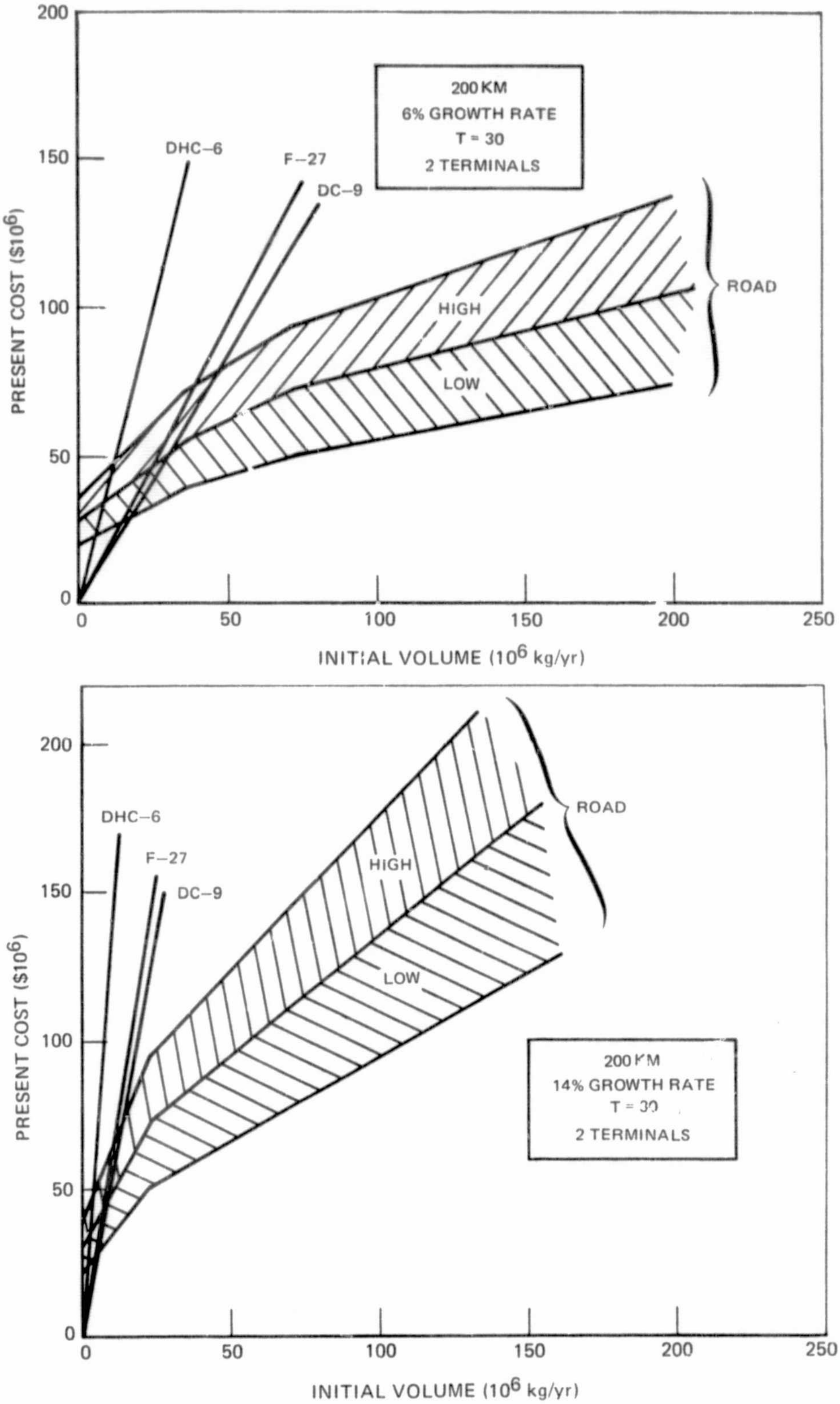

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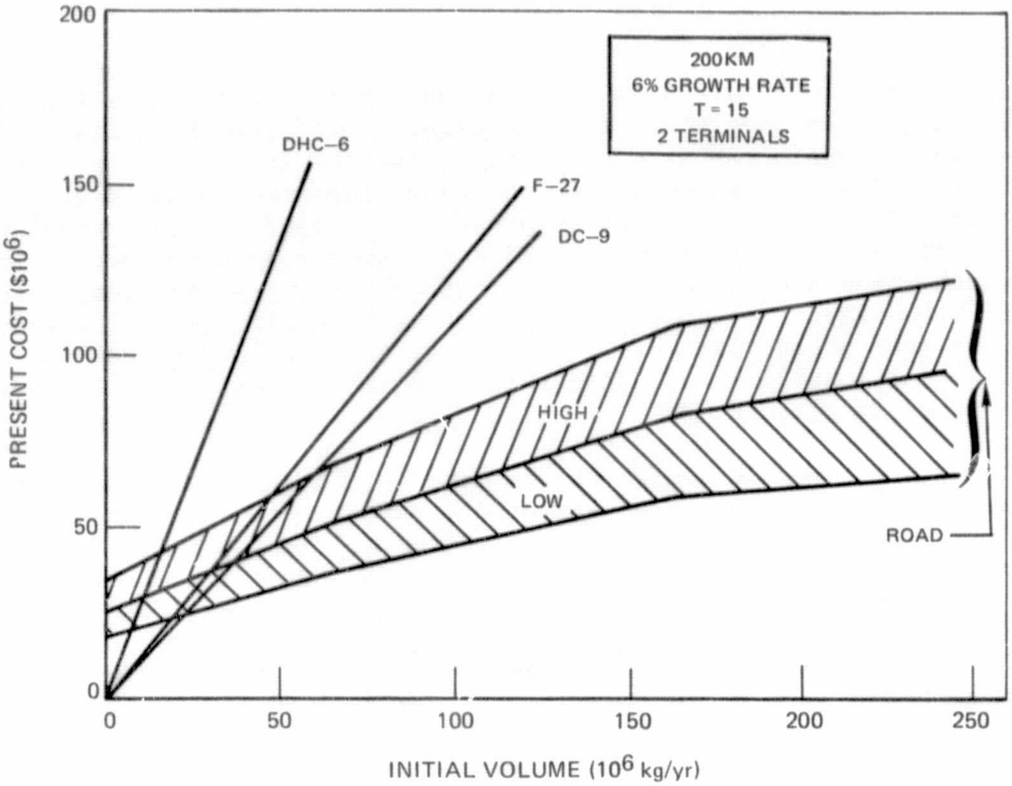
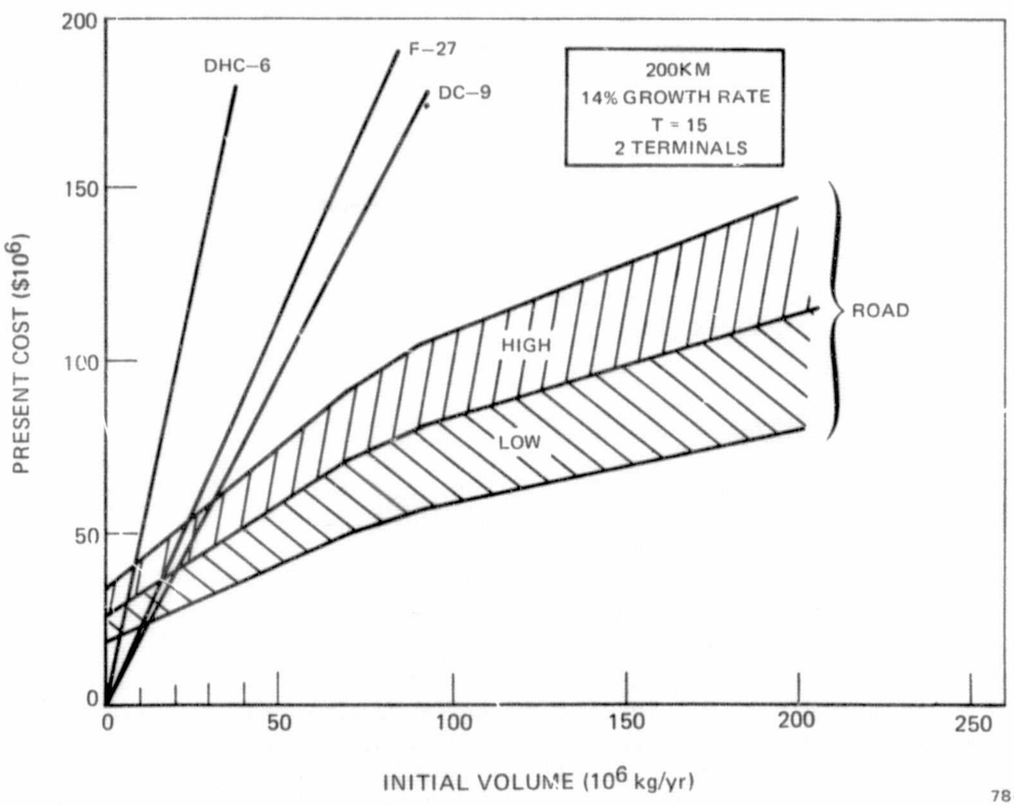
FIG. 29

ROAD VS AIR COSTS





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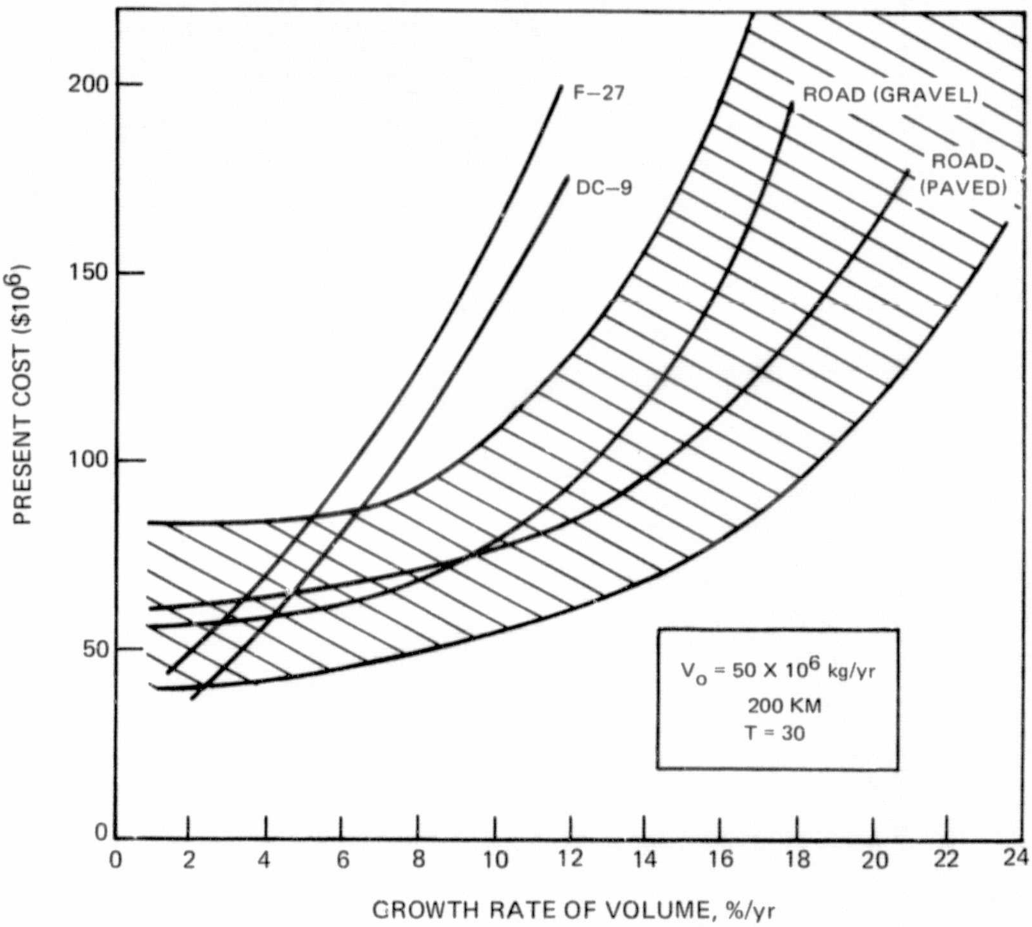
Since a discount rate of 10 percent was used (See Appendix D), it is of interest to consider how these results might be affected by a higher rate which would be consistent with scarcity of capital in LDCs. The higher percentage of fixed investment cost for roads compared to air would suggest an advantage for air under these conditions. However, because the low-volume region where air is competitive is based on earth road construction, and since earth roads are assumed to be reconstructed every four years, the discount rate effect is not as great as it would be if the entire road investment were an initial cost. For the first case in Fig. 28, a 20 percent rate changes the DHC-6 intercept points very little while the DC-9 points move to about 30 percent higher initial volumes.

Although the results shown can be used in a normative sense to plan the transport requirements of an undeveloped area, uncertainties in road costs and anticipated demand make this very difficult. For example, Fig. 30 illustrates several cost curves for road and air, with a band to indicate the range of possible road costs. The most economical alternative is strongly dependent on knowledge of the physical characteristics of the region and one's confidence in forecasting future demand in a highly uncertain environment. Nevertheless, the generalized results will be used as a "screening model" to make some preliminary estimates of aircraft feasibility. Figs. 31 and 32 show enlargements of the regions in which airplanes are competitive with road transport. The appropriate air technology is clearly influenced by the expected growth rate and the road costs. (Note scale change in initial volume between figures.) That is, if a high growth rate is forecast, larger aircraft such as the DC-9 are out of contention and the most economical choice would proceed from a DHC-6 to an F-27 and then an earth road as initial volume increases. Of course, many other factors affect decisions in developing a transport system, including political factors. In a purely economic comparison, the air mode is certainly a better alternative to development of a road system for low-density routes (under 5 x 10^6 kg/yr) with low growth rates, or at least as a precursor to road construction until larger traffic volumes and settlement between population centers justifies a road network. These figures will be utilized in the next section.

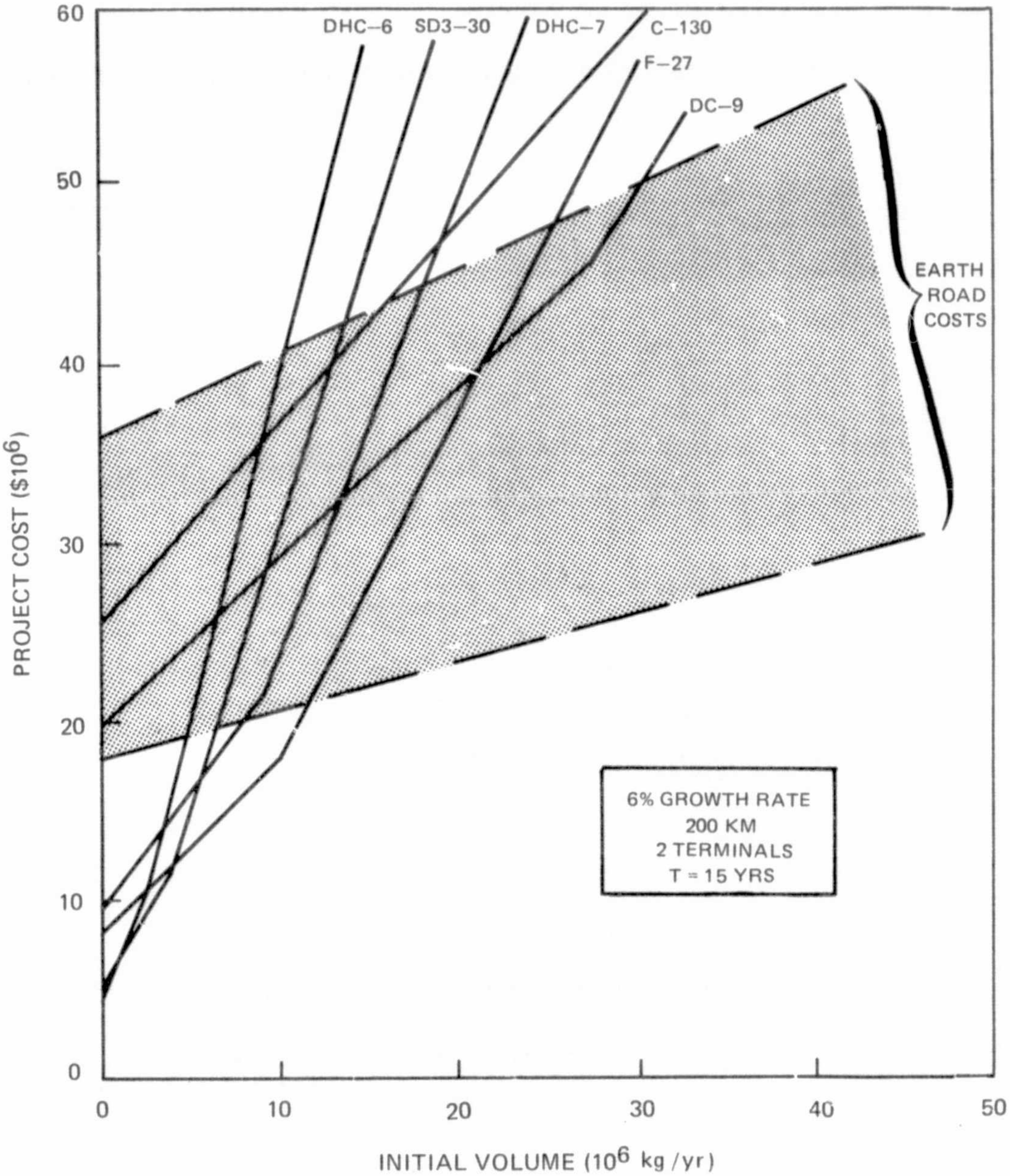
Case Studies in Brazil and Indonesia

In an attempt to relate the foregoing analysis to conditions in the study countries, the development of remote regions of Brazil and Indonesia was postulated. Population centers without present road connections or scheduled air service were identified in these areas, and their possibilities for growth assessed. To predict passenger and cargo demand, existing service in remote areas was tabulated in terms of the capacity offered on routes where air is the predominant mode. Using the populations of the city-pairs and the distances between them, a simple gravity model was constructed to estimate passenger and cargo flows. Next, the population centers likely to be developed and their likely links with other centers were established. Typically, these included one link with a considerable

AN EXAMPLE OF ROAD VS AIR COST AS A FUNCTION OF GROWTH RATE



COMPARISON OF COSTS FOR AIRPLANES COMPETITIVE WITH ROAD TRANSPORT



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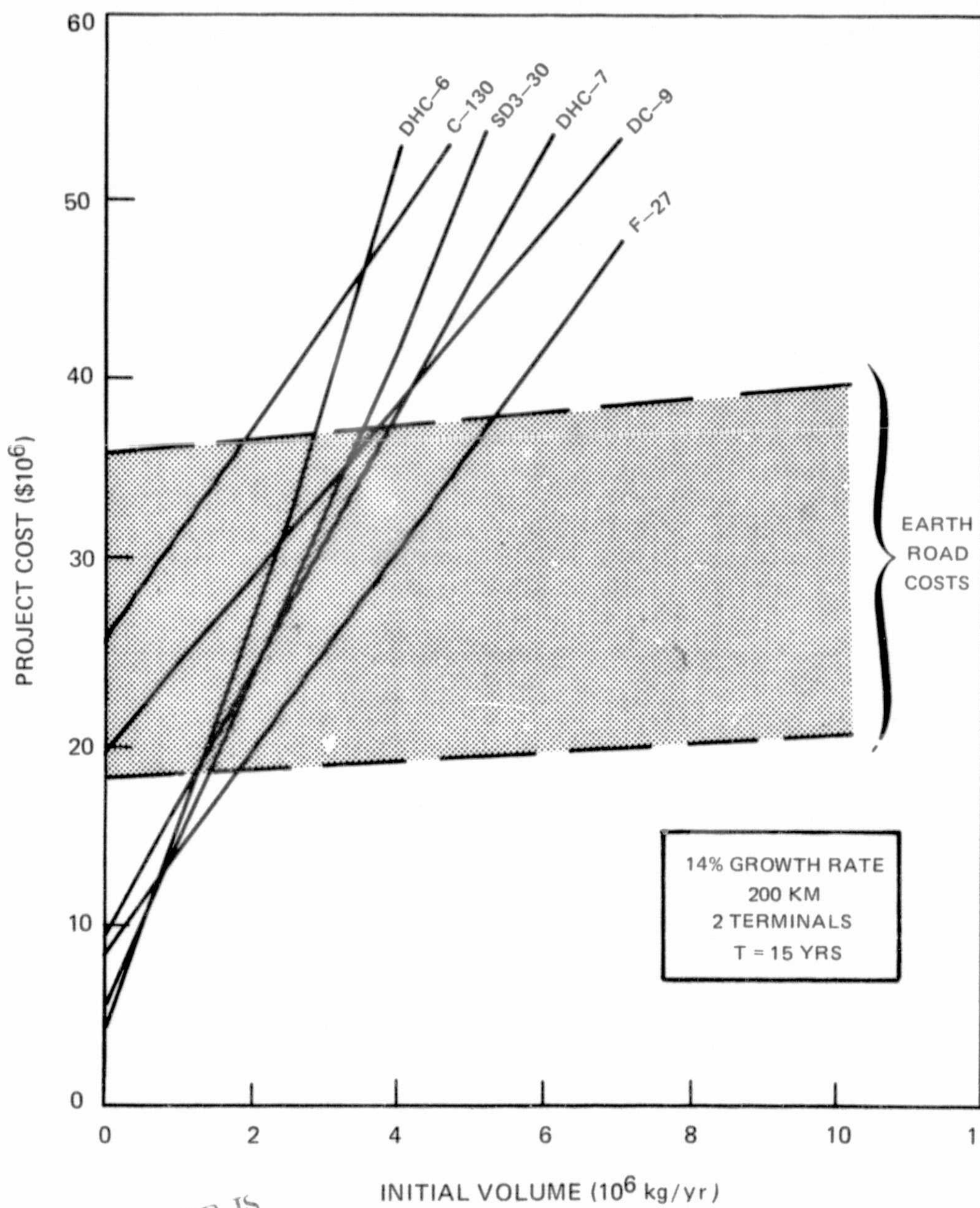
COMPARISON OF COSTS FOR AIRPLANES COMPETITIVE WITH ROAD TRANSPORT



amount of estimated traffic and others which would be legs of an itinerary, as in current operations. Flows were predicted, using the gravity model calibrated with current populations for each city, and assigned to the hypothesized network.

Although this analysis may appear reasonable, it must be emphasized that lack of data upon which to validate even this simple model makes the results quite speculative. Not only are city-pair traffic data difficult to assemble, but even recent population estimates for small towns and cities are often unavailable. Tenuous assumptions were required to complete the analysis, and the results should therefore be interpreted with these limitations in mind.

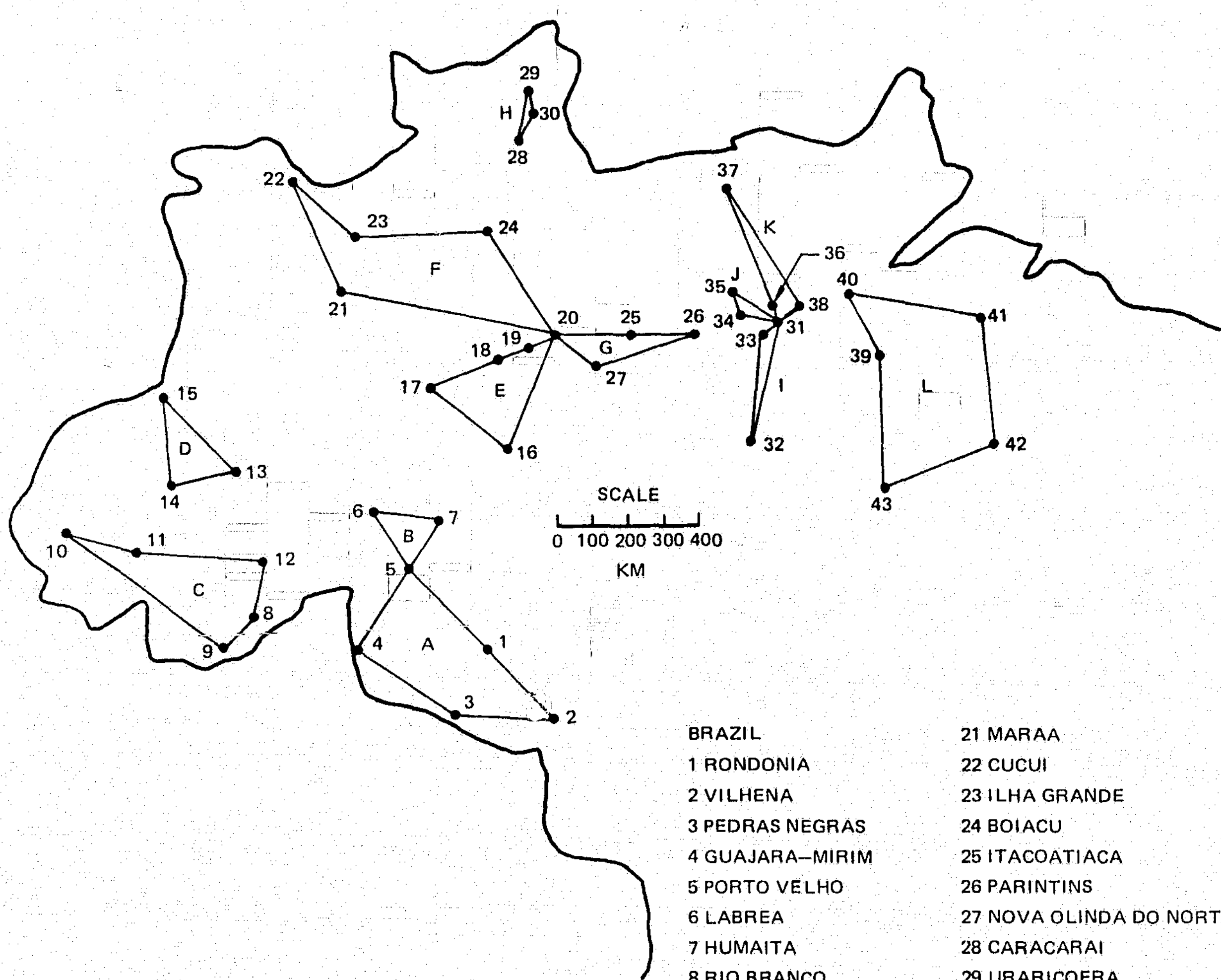
Passenger travel was related to cargo traffic, as found from the analysis of existing flows. Passengers were assumed to be transported by bus rather than auto; it was found that bus operating cost ($/passenger-km) is only slightly higher than truck operating cost on an equivalent ($/kg-km) basis (Ref. 59). For practical purposes, passenger flows were converted into an equivalent kg-km basis in order to compare the total flow by each mode (truck vs. air).

The resulting air networks, depicted in Figs. 33 and 34, consist of three to five stops in a circuit or itinerary, with the origin typically being the largest population center. A total of 22 circuits was established, 12 in Brazil and 10 in Indonesia. The pertinent date for each circuit are given in Table 9. These hypothesized networks represent new areas of development rather than growth of existing routes. The regions in which they are located are presently lacking in surface infrastructure. The most appropriate competing surface mode (road, river, ocean) was identified and its circuity measured. In Brazil, four routes were in competition with a road system, the remainder being competitive with river transport. In Indonesia, four circuits were competitive with road, and the remainder with inter-island ocean transport.

It was assumed that these routes, regardless of the competitive mode, provide an approximate indication of the range of future volumes which can be expected in these development areas. As such, the actual competing mode was disregarded. Instead, the range of origin-to-destination (O-D) volumes represented by these typical routes was used as a basis for assessing the overall feasibility of developing a road infrastructure relative to relying solely on air transportation.

By comparing the estimated route volumes with the ranges of volumes corresponding to air and road, the most appropriate mode could be selected for each route, as shown in Table 10. (Although there may be some variation in air costs for different distances, these are relatively small and would not significantly affect the results.) From Table 10 it appears that a substantial percentage of future routes can utilize air as a primary means of transport, although this conclusion is based on a very limited data sample. Some of these routes can alternatively be served by

BRAZILIAN CASE STUDY ROUTES IN THE AMAZON



BRAZIL
1 RONDONIA
2 VILHENA
3 PEDRAS NEGRAS
4 GUAJARA–MIRIM
5 PORTO VELHO
6 LABREA
7 HUMAITA
8 RIO BRANCO
9 XAPURI
10 CRUZIERO DO SOL
11 TARQUACA
12 BOCA DO ACRE
13 SANTOS DUMONT
14 EIRUNEPE
15 BENJAMIN CONSTANT
16 MANICORE
17 COARI
18 ANAMA
19 MANACAPURU
20 MANAUS
21 MARAA
22 CUCUI
23 ILHA GRANDE
24 BOIACU
25 ITACOATIACA
26 PARINTINS
27 NOVA OLINDA DO NORTE
28 CARACARAI
29 URARICOERA
30 BOA VISTA
31 SANTAREM
32 TUCUNARE
33 BELTERRA
34 OBIDOS
35 ORIXIMINA
36 ALENQUER
37 MALOCA
38 MONTE ALEGRE
39 ALTAMIRA
40 ALMEIRIM
41 CAMETA
42 MARABA
43 SAO FELIXO

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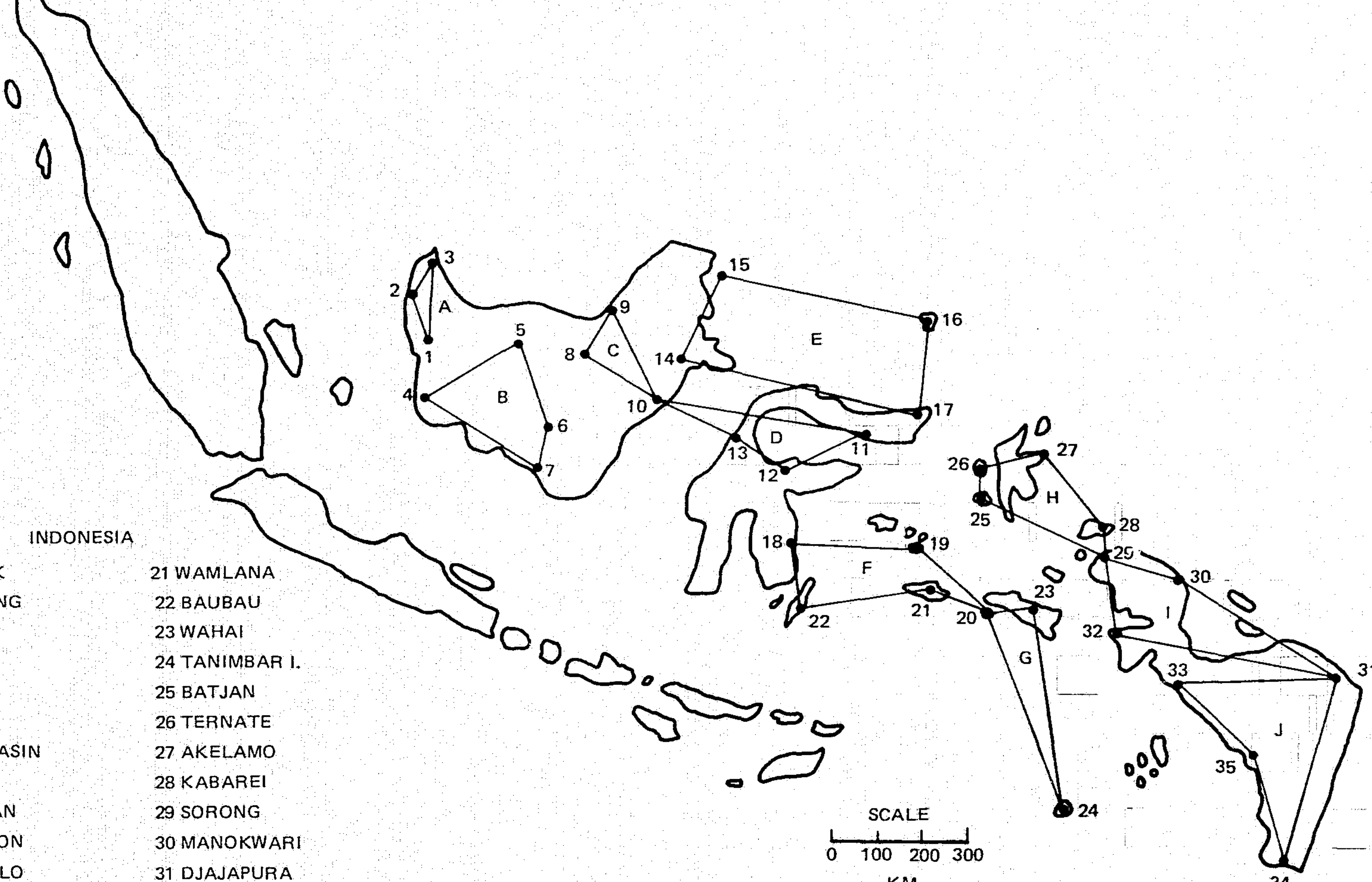
INDONESIAN CASE STUDY ROUTES ON OUTER ISLANDS



INDONESIA

1 PONTIANAK
2 SINGKAWANG
3 PALOH
4 KETAPANG
5 SINTANG
6 PAHANDUT
7 BANDJERMASIN
8 KALASIN
9 LONGNAWAN
10 BALIKPAPON
11 GORONTALO
12 POSO
13 DONGALA
14 SAMARINDA
15 TARAKAN
16 TAHUNA
17 MANADO
18 KENDARI
19 SANANA
20 AMBON
21 WAMLANA
22 BAUBAU
23 WAHAI
24 TANIMBAR I.
25 BATJAN
26 TERNATE
27 AKELAMO
28 KABAREI
29 SORONG
30 MANOKWARI
31 DJAJAPURA
32 FAKFAK
33 KAKENAU
34 MERAUKE
35 AGATS

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FIG. 34

TABLE 9

CHARACTERISTICS OF LOW-DENSITY ROUTES IN BRAZIL AND INDONESIA

Route No.	No. of Terminals on Route	Total Route Distance (km)	Longest Stage (km)	Estimated Route Volume (10^6 kg/yr)	Annual Movements (10^9 kg-km)
Brazil					
1	5	1510	350	7.5	2.1
2	3	570	200	21.0	4.1
3	5	1440	570	14.1	2.6
4	3	720	290	2.5	0.5
5	4	1020	350	94.3	11.9
6	5	1950	620	0.2	0.1
7	4	680	240	103.8	18.4
8	3	350	170	4.1	0.3
9	3	670	330	191.3	7.7
10	3	280	140	58.0	5.3
11	4	870	370	108.0	8.6
12	5	1640	380	3.8	1.5
					63.1
Indonesia					
1	3	410	200	69.6	7.8
2	4	1310	510	21.5	4.1
3	3	940	420	0.6	0.2
4	4	1480	690	12.4	4.9
5	4	2430	880	13.7	6.6
6	5	1610	500	7.3	3.0
7	3	1320	580	13.0	3.3
8	5	1170	430	17.1	3.3
9	4	2240	920	1.5	0.7
10	4	1800	660	1.8	0.5
					34.4
MEAN	3.9	1200	445	34.9	4.4
STD. DEV.	0.8	600	215	49.5	4.4
				767.1	97.5

TABLE 10

MODE SELECTION FOR
CASE STUDY ROUTES

Number of routes, given as % by mode

	6% Growth Rate			14% Growth Rate		
	Air	Air or Road	Road	Air	Air or Road	Road
Brazil	42	16	42	8	25	67
Indonesia	40	50	10	30	0	70
AVERAGE	41	32	27	18	14	68

TABLE 11

MODE SELECTION FOR
CASE STUDY ROUTES

Annual movements in kg-km, given as % by mode

	6% Growth Rate			14% Growth Rate		
	Air	Air or Road	Road	Air	Air or Road	Road
Brazil	7	11	82	0	4	96
Indonesia	13	65	22	1	0	99
AVERAGE	9	30	61	0	2	98

water rather than road, thereby making air less competitive. However, assuming the case-study routes provide a reasonable indication of the range of volumes that can be expected, the results approximately indicate the expected overall share of aircraft use in these remote areas.

Even though air has been shown to be appropriate for the transport of low volumes, the actual cargo movement (kg-km) by air relative to the total (see Table 11) is rather small, reflecting the fact that it will be the lowest-density routes which can utilize air effectively*. Also, at higher growth rates of traffic, roads are more easily justifiable (see Fig. 30), making air less feasible as a primary means of transport. Once the road is constructed, the use of air does not necessarily decline, since small airplanes can continue to provide needed emergency, high-value, perishable, and other time-dependent transport.

Alternative Scenarios

In the foregoing calculations, air was evaluated in terms of its cost of operation over the entire 15-year period. It may also be possible that air can be used as an interim solutin for a shorter period of time. That is, use of air would postpone investment in a road such that the associated savings would be just offset by the higher cost of air operation. Such a strategy would be most appropriate in times of capital shortage, or high opportunity cost of capital. For each of the case-study routes which were uncompetitive with air, costs of interim use of air were computed. The period of time is one for which air is less expensive than road, as indicated in Fig. 35. Besides delaying investment, such a strategy might eliminate a number of earth road "reconstructions" during the interim period. Nevertheless, it was found that no savings would be realized by this initial use of air compared to an "all-road" system. This finding suggests that, if projected demand for the 15-year project period requires an earth road connection, it is best to begin construction immediately.

Although an economic comparison of air and road transportation systems favors the latter for all but very low volumes, there are important differences in service levels which have not been accounted for. Without even considering differences in transit time between the two modes, there are still some very important limitations on the year-round, all-weather use of earth roads. They may be virtually impassable during the tropical rainy seasons of Brazil and Indonesia. Passengers and cargo may be severely delayed due to frequent mechanical breakdowns on these rudimentary roads, thereby making it impossible to rely on the road system except for short-distance, local traffic.

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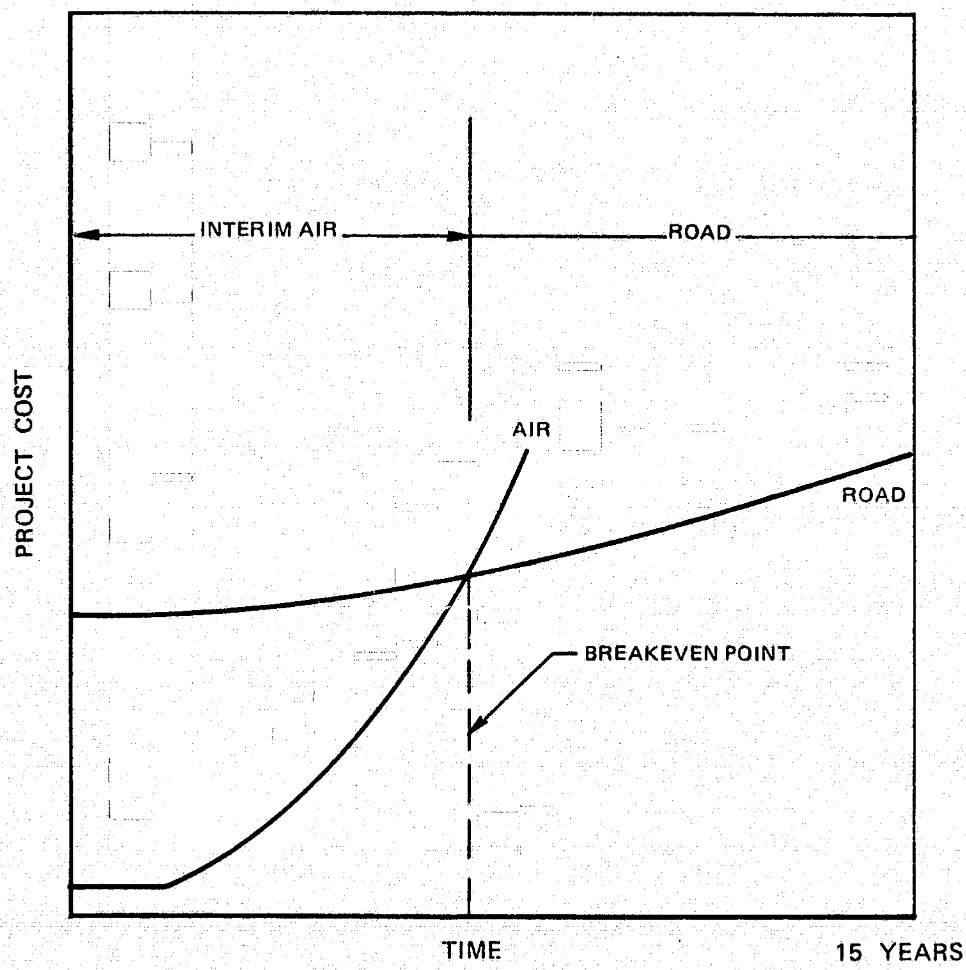
* The air network was structured to accommodate traffic on the densest link (100 percent load factor), while the remaining links on a circuit would result in an overall load factor of about 60 percent. From examination of flows, this was found to be a reasonable approximation.

AN EXAMPLE OF THE USE OF AIR AS AN INTERIM MODE



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Several possible solutions exist to improve service under these circumstances. The first is to utilize aircraft to supplement road transport during these periods of poor weather, assuming aircraft can operate under these conditions. Another solution is to upgrade the roads to all-weather pavement, even though the most economical solution is still an earth road. Alternatively, the paved road can be built only when justified by demand, using air as an interim solution. That is, an earth road is initially constructed, supplemented by air if washouts occur, followed by paving at a later time. This alternative is less expensive than building a paved road initially (at low volumes), since it was found that even an interim all-air operation can usually compete considering the savings involved in delaying the high investment cost of paving. These higher-service options involve additional aircraft requirements beyond those at very low volumes when only air is used. Finally, at higher volumes, only a paved road is justifiable for routine transport, while air becomes primarily a supplementary mode, in the broad sense of the word. Since small population centers connected by roads (earth or paved) are likely to be at a relatively low level of commerce, the typical air penetration results in small volumes that are still best served by small airplanes. These airplanes are of the same type used during the initial growth of the infrastructure.

The possible sequences or stages of transport development are summarized in Table 12. This table shows a logical progression of transport mode development and the role of aircraft in each stage, based on the results of the case studies and the generalized analyses. The intermediate-volume regime (approximately 5 to 30 million kg/yr) offers opportunities for use of air, since cost tradeoffs occur in this regime such that air can be used exclusively, at least part of the time.

It is apparent that exact transport requirements cannot be forecast with any degree of certainty in a developing region where there are so many unknown factors which affect its development, growth rate, and transport costs. The analysis has served to define the appropriate alternatives for various combinations of these variables, such that intelligent decisions can be made regarding the transport infrastructure. From the results of the case study and the generalized analysis, an upper bound on a competitive aircraft appears to be one somewhat smaller than an F-27. Smaller aircraft are even more likely candidates, but it does not appear that a larger aircraft could be utilized economically as a substitute for surface network development.

Sociopolitical Considerations

The planning balance sheet approach described in Appendix D and empoyed in the previous section for remote mining was applied to the low-density transport application to account for noneconomic factors in mode choice. Results are given in Table 13, showing that the air mode

TABLE 12

STAGES OF TRANSPORT DEVELOPMENT

Initial Traffic Volume	Mode	Relative Level of Service	Relative Cost
< 2-10 million kg/yr (see Figs. 31 and 32)	Air only	Good	-
5-10 million kg/yr up to 30 million kg/yr (see Figs. 31 and 32)	Earth Road	Poor	Low
	Interim air use, then earth road	Better during initial growth	Higher than above
	Earth road, supplemented by air during road disruptions	Fair	Low, depending on the extent of road damage and maintenance costs
	Earth road, supplemented by air, then paved road as justified by volume	Good	Higher than before, depending on traffic volume, but less costly than a paved road from the start
	Paved road	Good	High
> 30 million kg/yr	Earth, gravel, or paved, depending on volume. Air used as an "emergency" mode.	Fair to Good	–

c-2

TABLE 13

SOCIOPOLITICAL COMPARISON

Low-Density Transport

OBJECTIVES	UNITS OF MEASUREMENT	WEIGHTS	Air Rank	Air Score	Roads Rank	Roads Score
IMPLEMENTATION						
Open Service Expeditiously	Months	4	5	20	1	4
Minimize Foreign Exchang Req'mts.	$	6	3	18	5	30
Min. Need for Expatriate Labor (Constr)	Person-Years	3	3	9	5	15
Avoid Instit. Delays at Inter'l Level	Prob. of Months	1	--	--	--	--
Secure High Salvage Value	$ or Equiv.	1	5	5	2	2
Subtotal		15		52		51
OPERATION						
Provide for Maximum Reliability	Prob. Days of Service Interr./yr	7	5	35	1	7
Provide for Maximum Safety	Anticip. Level of Damage Claims/yr	5	5	25	3	15
Min. Need for Expatriate Labor (Oper.)	Person - Years	3	2	6	5	15
Subtotal		15		66		37
SOCIO-ECONOMIC DEVELOPMENT						
Create Jobs for Available Work Force						
- In Construction	Person - Years	4	3	12	5	20
- In Operation/Maint.	No. of permanent jobs	7	2	14	5	35
Foster Upgrading of Tech. Skills	No. of skilled work trained/yr	5	5	25	3	15
Provide Reliable & Affordable Means of Mobility for General Pop.	No.Person-Km	5	2	10	5	25
Provide Fast & Comfortable Means of Mobility for General Population	Time Distance	5	5	25	2	10
Provide for Emergency Services	Time Distance	4	5	20	2	8
Encourage Establ. of Secondary Industries	Probability	3	3	9	5	15
Build-up of a Multipurpose Long-Range Infrastructure Network	Policy Judgment	2	3	6	5	10
Subtotal		35		121		138
RESOURCE UTILIZATION						
Conserve Energy, Part. Imported Fuel	Barrel Equiv/yr	7	2	14	5	35
Protect Physical Environment	Tons of Emiss./yr	5	5	25	2	10
Maximize Access to Primary Materials	Policy Judgment	8	5	40	3	24
Subtotal		20		79		69
POLITICAL						
Upgrade National Defense Capability	Policy Judgment	6	5	30	4	24
Promote Political Stability and National Unity	Policy Judgment	6	5	30	4	24
Generate National Pride	Policy Judgment	3	5	15	2	6
Subtotal		15		75		54
GRAND TOTAL		100		393		349

achieves a clear superiority to roads in three categories -- operational, resource utilization, and political considerations -- and is close in the remaining categories. The result is a considerable advantage for air in the final total score. Although an air system is not as good as a road network in promoting socio-economic objectives, it does offer enough support in this category to achieve a competitive ranking.

These results suggest that, for low-density routes, an air-based system has clearly desirable features. In future development and growth of remote regions, the number of such low-density routes will be significant. However, the total transport volume (kg-km) carried by air will still be relatively small. Results are particularly sensitive to expected growth rates and road costs. Consequently, remote regions isolated by terrain and weather-related factors, and growing slowly, should continue to rely on air for the foreseeable future.

TROPICAL FORESTRY

The forests of the world represent an important resource which is largely untapped in the tropical latitudes where LDCs are concentrated. Timber is unique among other resources in being renewable and in large supply throughout the world. Over half of the world's forests are located in developing countries. These are particularly significant since they are mostly hardwood forests whose value and utility will be increasing in the future. Demand for forest products increases with population and income, but the available supply in developed countries is acknowledged in the literature to be approaching an upper limit. Even now, tropical timber production is growing at a faster rate than production in temperate climates. This trend is expected to accelerate as the supply of temperate conifers further tightens while new uses of tropical hardwoods are found, such as in paper and pulp production.

For developing countries, this expected increase in tropical forestry will represent greater self-sufficiency in capital-intensive industries, such as paper and pulp, with savings in needed foreign exchange. Increasing exports accompanied by more local processing will contribute to a more favorable balance of trade and improved employment possibilities. National plans of LDCs incorporate these objectives, as noted earlier. However, many impediments which hamper growth still exist, including technological problems of proper forest utilization and wood transport.

The following table shows the relative forest areas and harvesting figures for the top ten countries in the world.

TEN COUNTRIES WITH THE LARGEST FOREST AREAS IN THE WORLD (Ref. 62)

Country	Forest Area 1,000 ha*	ha* per capita	Estimated 1,000 m^3	Yearly removal from 1 ha
U.S.S.R.	738,117	3.1	380,400	0.52 m^3
Canada	420,328	19.1	111,872	0.25 m^3
Brazil	335,100	3.8	167,080	0.50 m^3
U.S.A.	292,721	1.5	336,158	1.15 m^3
Australia	207,267	17.2	13,757	0.06 m^3
Congo Dem. Rep.	129,141	7.7	11,588	0.08 m^3
Indonesia	121,177	1.1	100,994	0.83 m^3
China	96,380	0.1	169,000	1.75 m^3
Angola	72,000	13.4	6,459	0.89 m^3
Columbia	69,400	3.5	25,235	0.36 m^3

* ha = hectares

The table shows that six of the top ten countries are LDCs. Both Brazil and Indonesia are among these leading producers of timber, although their activities are currently concentrated in the more developed and accessible regions of these countries. The figures in the table are averages which show the relative intensities of their production.

Development of forest resources occurs in several stages. Initially, forests are seen as an impediment to settlement, with no value except as fuel. Land areas are cleared by burning the forest in the process of attempting to initiate necessary agricultural activity. The burned wood provides nutrients for the generally poor soil, but as these nutrients become depleted and leaching occurs, the land rapidly loses its productivity. This "slash-and-burn" technique has very often been a precursor to development in remote areas, accompanied by road development and haphazard settlement.

In the second stage, the forest is recognized as a resource, with efforts made to extract useful species. Most of these operations are on a small scale and use the least costly means of cutting and transport. This activity usually supplements agriculture and provides employment and income once a market is established. Unfortunately, the abundance of available land results in little effort at replanting the species removed, which are also the most valuable ones. This selective cutting technique is known as "high-grading," and is the most common method of lumbering in the developing countries (Refs. 63, 64). Unfortunately, little processing of the lumber is done on-site to increase its value and provide further employment and revenues. The rough wood is exported to generate foreign exchange, but the country of origin receives only a fraction of its ultimate value.

In the final stage, the development of an integrated forest industry results in production of a range of products and utilizes all species most effectively. Such an industry might produce some combination of sawn lumber, veneers, plywoods, pulp, paper products, and even furniture and wood crafts. Assuming appropriate species were available and the large capital investment for such a venture could be justified, transport options for domestic and/or export would include the air mode for the highest-value commodities of a semi-finished or finished nature. (In the next section, this type of forestry is incorporated as a factor in the development of an airport/industrial city, the output of which contributes to the future demand for a large cargo airplane.) In addition to increases in unit value with each stage of processing, there is a significant decrease in density (over 25 percent reduction) from fresh-cut roundwood to such items as flooring and furniture parts, thereby making these items even more suitable for air transport.

An interesting and more direct need in development of a large-scale forest industry in tropical regions is that of providing accessibility to a remote forest. Lack of accessibility is one of the biggest problems hampering further development of tropical forests. Sparse surface road networks and a shortage of adequate transport facilities result in exploitation of only the most readily available stands, such as near rivers and close to existing roads. Low road standards, frequent flooding during heavy rainfall seasons and lack of knowledge of interior species place strong limitations on lumbering of remote areas. The high costs of lumbering do not currently justify air operation in these areas. However, in a longer planning period, as demand grows and new markets are found, these vast timber-rich regions will become commercially feasible for lumbering and forest industries. At that time, a different transport technology which would overcome the difficulties of surface networks could be appropriate. Also, as will be seen, there are some very important environmental considerations which can preclude an extensive road network necessary for large-scale extraction. These underlying presumptions are the basis for examining air transport alternatives for logging and further transport of forest products.

Transport Problems in Tropical Logging

Transportation is most often the largest component of the selling price of lumber and forest products. The exact proportion depends on the particular product and consumer, and is difficult to generalize. However, the transport share is on the order of 25 percent of the final selling price. It is interesting to compare the breakdown of transport cost components for domestic and tropical hardwood producers. Table 14 shows that, for domestic production, a large proportion of the total transport cost is from the forest to the first stopping point (Ref. 65). Although the surface infrastructure is developed, the relative scarcity of hardwoods makes their extraction costly. The analogous component for tropical producers is less than half that of the US domestic producers, in current operations, because present tropical operations are concentrated in the most accessible regions. The situation is likely to change as forestry moves into more remote regions, assuming the higher-quality stands and better markets can justify the higher costs which will result in higher f.o.b. prices.

For small yields (m^3/hectare) in particular, large areas of forest must be harvested to maintain a reasonable wood output. Such large-scale lumbering operations may introduce economies elsewhere in the production chain, but will increase the stump-to-site costs because of longer log transport distances. Also, costs supplying these more remote areas will increase, such that this component of the transportation cost will grow in importance relative to other costs. It is also the most fruitful area for technological improvements in transport, which could lower this cost and make such development possible.

TABLE 14

AVERAGE TRANSPORT COSTS FOR HARDWOOD PRODUCERS
(Ref. 65)

US Domestic

	Cost Element	\$/1000 bd ft	\$/m^3 *
1.	From forest to mill (or first stopping point)	22	9.33
2.	From mill (or first stopping point) to user	18	7.63
3.	Storage and interest charges	6	2.54
	Total	46	19.51
	Total less Cost Element #1	24	10.18

Tropical

	Cost Element	\$/1000 bd ft	\$/m^3 *
1.	From forest to first stopping point	10	4.24
2.	From first stop to port of exportation	5	2.12
3.	Port charges	5	2.12
	F.O.B. Transport Cost	20	8.48
4.	Ocean freight	68	28.84
5.	U.S. port charges	7	2.97
6.	Inland freight to storage	4	1.70
7.	Storage and interest charges	4	1.70
8.	Re-delivery to user	28	11.87
	Total	131	55.56
	Total less Cost Element #1	121	51.31

* 1000 board feet = 2.358 m^3

Further transport of timber to the port of export (Item 2 for tropical forestry in Table 14) is presently not a large component of the transportation cost, but will increase appreciably as distances to the port become greater. For example, the cost of floating logs is about $.010/m^3$-km, based on African experience. Assuming this least costly method is used from the first stop to the port of exportation, the current cost of $2.12/m^3$ converts to an average distance of only 200 kilometers. It is unlikely that any other mode of transport can be substituted for this form of transport when it is readily available, even for longer distances. Similarly, ocean freight charges can be lowered if improvements, such as more widespread containerization, occur in that mode.

In summary, as tropical forests continue to be developed, transport costs will increase, thereby making innovative forms of transport more likely candidates. This is particularly true for the stump-to-site transport of logs, which usually requires an extensive network of logging roads, especially for lower yields. These lower yields, as will be seen, may be necessary if environmentally acceptable development is to occur. But higher costs will be acceptable once good markets develop and better uses for tropical hardwoods are found.

Logging Applications

For purposes of analysis, a remote forest in Brazil was chosen as an example. The results may easily be generalized to apply to Indonesia or another tropical LDC rich in timber. The area considered for forest development in Brazil is in the state of Roraima, in the north central part of the country. Data for the region were obtained from Project RADAM reports, as documented in Volume 8 of the series (Ref. 36). The forest area, depicted in Fig. 36, is bounded to the north by an ecologically sensitive area which has been recommended as a forest preserve by the Project RADAM experts. To the south is an area of annual floods which has also been recommended for preservation. The dense tropical forest portion is most suitable for commercial development and contains the species considered most valuable for domestic and export markets. Table 15 gives pertinent data relating to the forest. The estimated value includes the entire range of the products which could be produced from harvesting at the maximum yield. The prices are f.o.b. port; that is, all transport costs up to the port of export are included.

There are several important restrictions to the possible development of this region. Since the commercially viable yield consists of approximately 2/3 of the entire tree cover, such intensive lumbering would be certain to have detrimental environmental consequences. The jungle is a very delicate balance of interacting elements; letting sunlight penetrate the dense forest canopy has been shown to result in possibly irreversible destruction of the environment (Ref. 64). Therefore, it is necessary to

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RORAIMA FOREST AREA

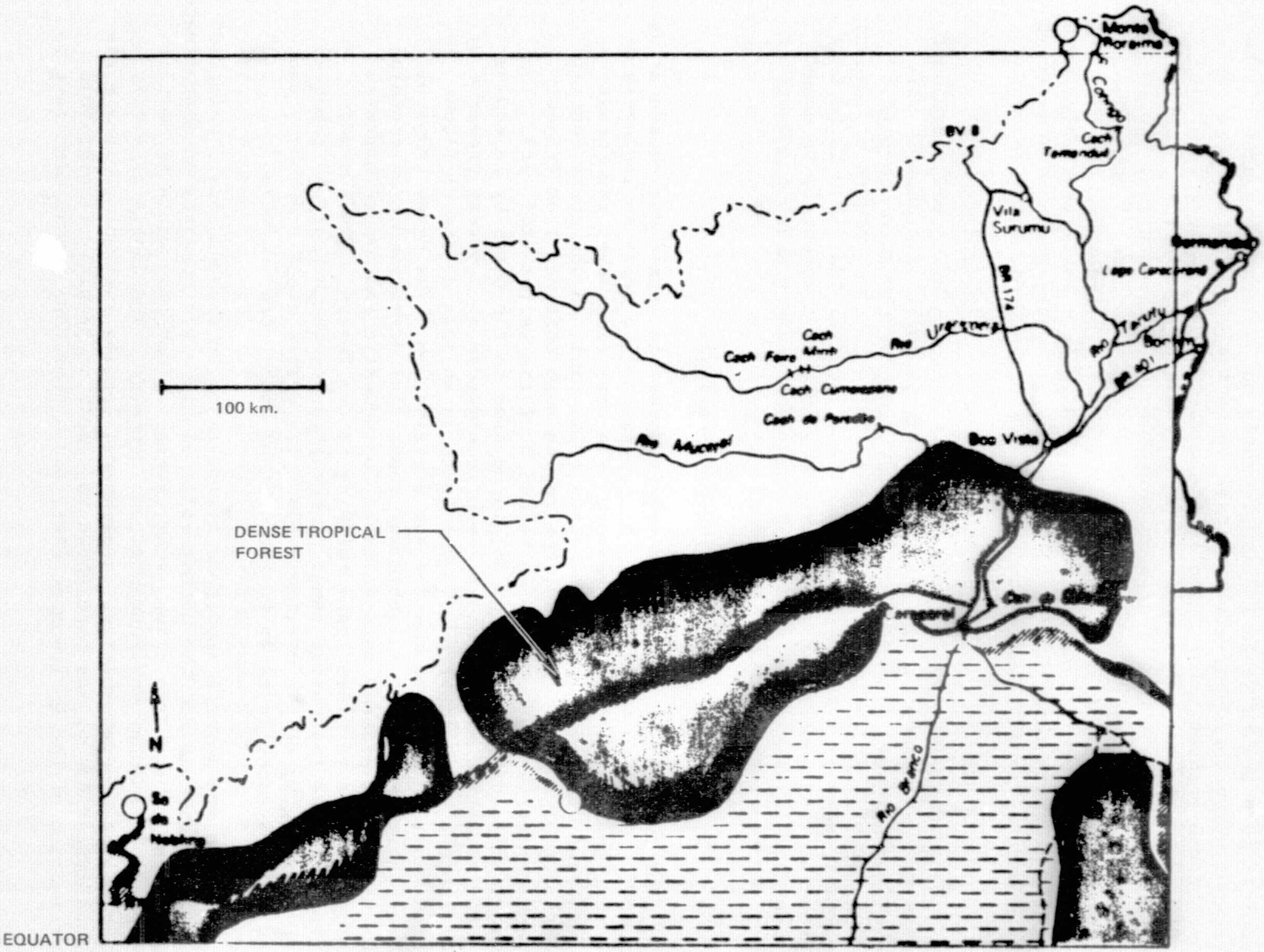

FIG. 36

TABLE 15

FOREST CHARACTERISTICS OF THE RORAIMA REGION

Area:	43,000 km^2 = 4.3 x 10^6 hectares (54 km x 800 km)
Yield:	50 to 60 m^3/ha (about 35 trees)
Density of wood:	1000 kg/m^3
Tree size:	1.6 m^3/tree, or 1600 kg/tree
Est. value of end prod.:	\$60/m^3 domestic, \$110/m^3 export
Potential value of prod.:	\$17.1 billion

harvest at a lower yield, although the maximum allowable yield is yet unknown. Another factor to consider is that operating machinery and building roads can also lead to damage, so the clearing necessary for these surface networks should be minimized. Selective cutting seems most appropriate for lumbering in these types of environments, at least until more is known about the potentially devastating effects of more intense cultivation. This limits the species extracted to only the most valuable ones, certainly more valuable than the averages shown in Table 15. The result will be higher costs of harvesting and transport, but these increased costs will be offset by the higher values of the extracted species

This "high-grading" of species is similar to that already being done on a small scale. However, on a larger scale, the process would be much better managed, such that no net depletion of these species would occur. If feasible, the mixture of species could be gradually altered toward a more commercially acceptable variety, as has been suggested in Ref. 64.

The importance of preserving existing ground cover, aside from prevention of leaching and soil nutrient depletion, lies in maintaining the precarious structure of the ecosystem. Many interactions among plants and animals occur which, if disturbed, could lead to widespread ecological devastation. Much concern has already been voiced about the effects of the Trans-Amazon Highway. For example, it has been observed that humans in undisturbed forests are rarely molested by insects, while the insect problem is unmanageable in cleared areas and settlements. The uncontrolled settlement of people as a result of the road system has already left areas of wasteland. Severely disturbed areas (such as road rights-of-way and dense settlements) in tropical rain forests do not have the ability to regenerate unless left alone for perhaps 100 years or more. Consequently, the desirability of an extensive network of roads, particularly that required for logging, must be seriously questioned. These limitations present an opportunity for innovative transport solutions not dependent on surface rights-of-way.

Analysis

Figure 37 shows the typical sequence of operations involved in logging and log transport. After the tree has been felled and cut to an appropriate size, it is dragged to the nearest feeder road. This may be done manually for very short distances or, more likely, by a tractor or skidder, as will be discussed later. The logs are loaded on a truck and delivered via the feeder and access roads to the first stopping point. This may be a transhipment point or the site of a sawmill or processing plant. In the latter case, the conventional air mode is a viable alternative for further shipment of high-value products.

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TYPICAL FOREST LOGGING AND TRANSPORT SCHEME

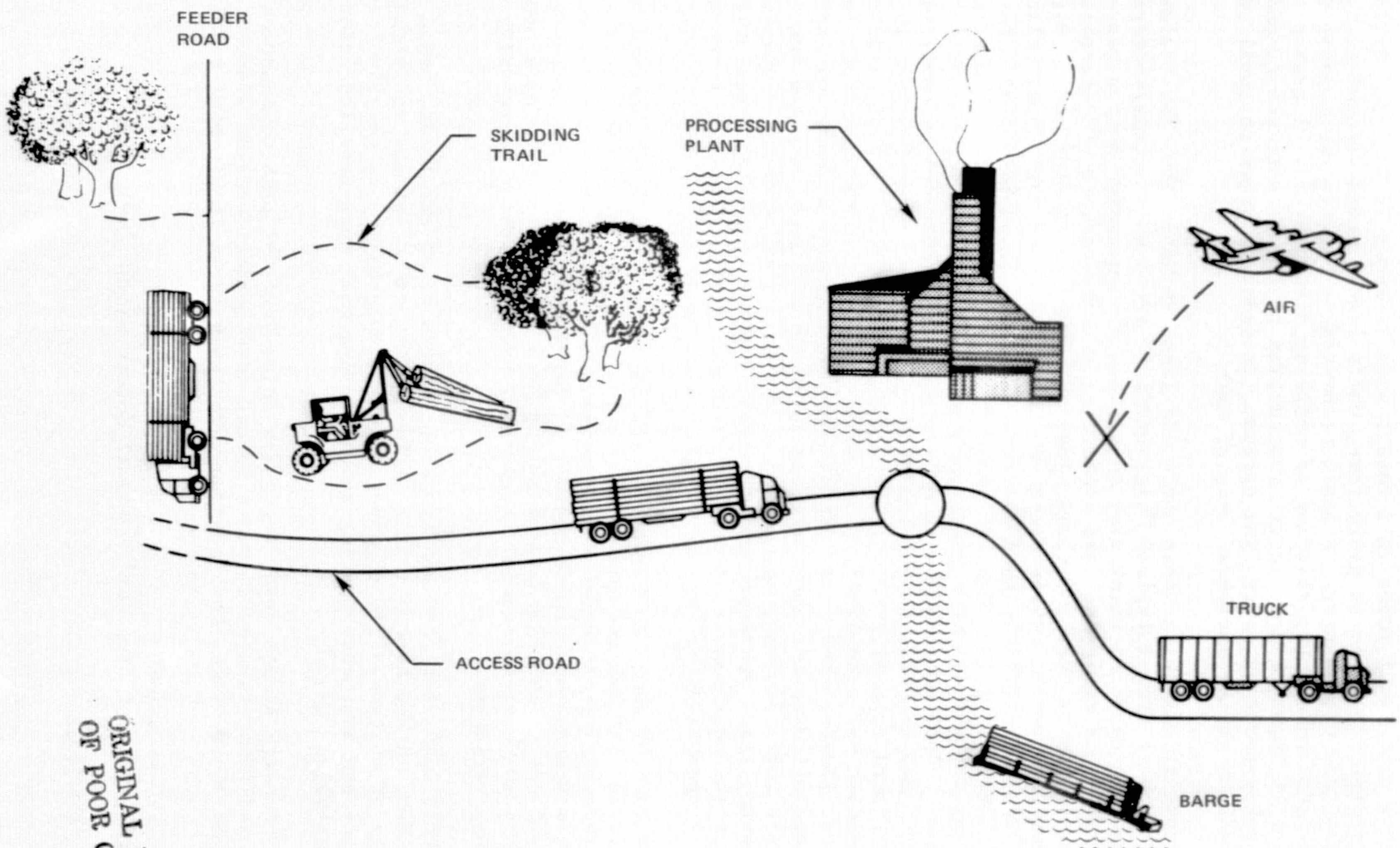

FIG. 37

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The network of roads in a forest area is shown in Fig.38. Skidding trails essentially go to every tree, while feeder roads accumulate logs delivered by ground machinery. A basic trade-off is between the spacing of feeder road(s) and the skidding or crawling distance ($\bar{d}$). Increased spacing of roads reduces their construction cost but increases ground machinery operating costs. The optimum, in order to minimize total costs, will depend on the variable costs.of each.

Factors affecting these costs are given in Table 16. The yields considered range from a typical "high-grading" yield of one tree/hectare to the maximum yields which might also be typical of the entire Amazon region. The type of ground equipment used depends on a large variety of interrelated factors, such as terrain, yield, load size, and so on (Ref. 66). Basically, skidders are small, rubber-tired vehicles capable of high speed relative to tractors, in relatively good terrain. They are cheap to operate, but have limited drawbar pull. Crawler tractors have the capability of making a clearing for a trail or a road, in addition to greater drawbar pull than skidders. They can operate in more rugged and softer ground conditions. However, due to their slower speeds they are less productive than skidders and are more expensive to operate. The possible necessity of skidding trail preparation was considered, using costs consistent with experience in tropical forests (Ref. 66). Using nomographs based on operating experience in tropical countries, productivity for each equipment type was found and the unit cost ($/$m^3$-km) calculated as a function of skidding distance, load size, trail preparation and terrain. The assumed 1000-hour utilization of the equipment is typical of tropical conditions which severely limit surface operations during the rainy season.

Figure 39 shows an example of the optimization process carried out for each yield. It was recognized that actual terrain conditions would result in more circuity of feeder roads and skidding trails, and this was accounted for by a terrain adjustment factor, as described in the literature (Ref. 67). An analytical expression was employed for the optimum feeder road spacing, which is more complicated than shown, but which essentially depends on these variables.

Unit costs for road and truck operations on access roads, based on experience in the Amazon region of Venezuela, are discussed in Appendix C. A range of costs must be considered due to uncertainty of terrain conditions. More precise estimates are impossible unless much more detailed information is available.

Necessary access road length was calculated for each combination of yield and forest output*. Since forest development proceeds along a presumed 54-km swath, the road would be built in an incremental fashion.

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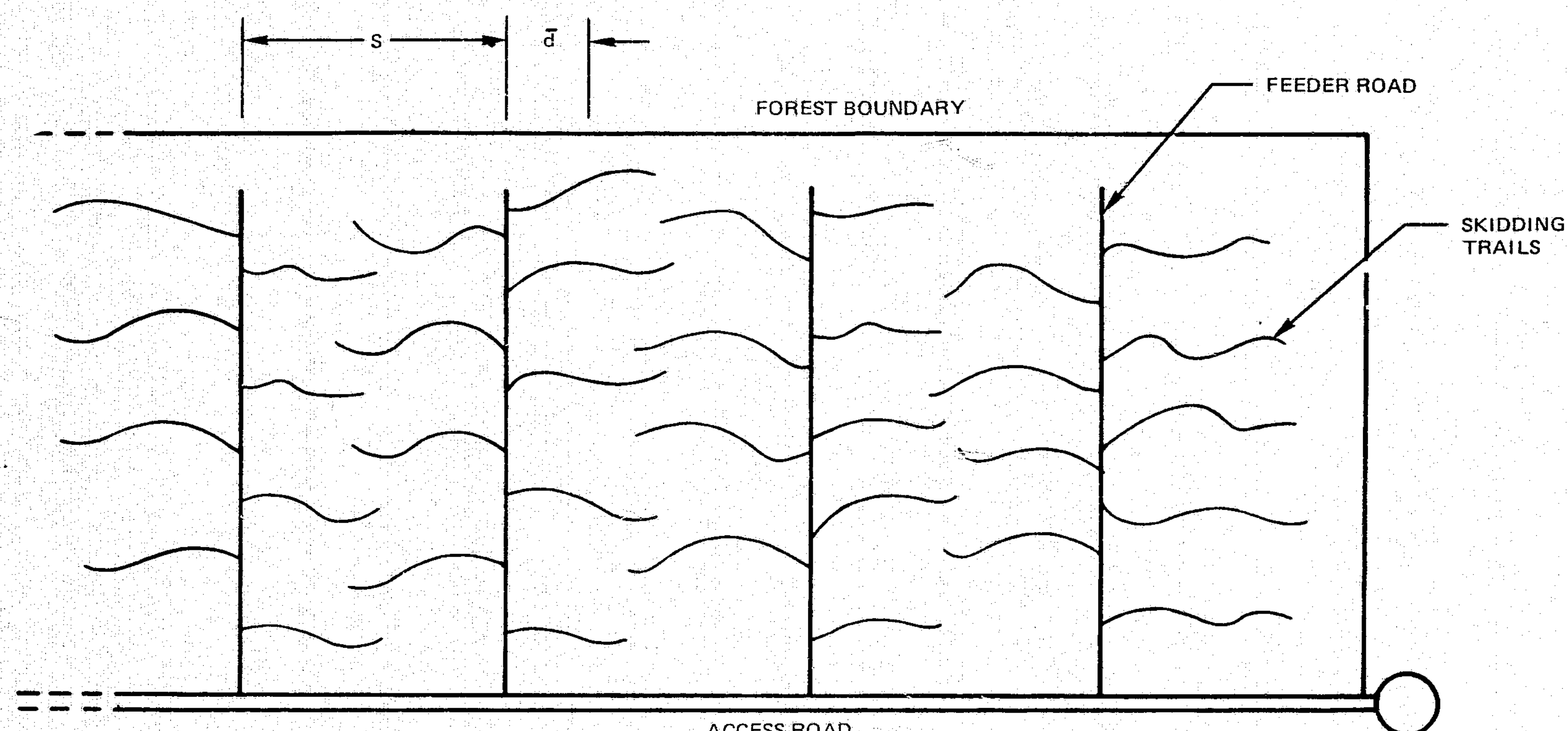
* Yield [m^3/ha] x Area [ha] = Annual forest output [m^3]

GROUND–BASED LOGGING AND TRANSPORT NETWORK



S = OPTIMUM ROAD SPACING
$\bar{d}$ = MEAN SKIDDING OR CRAWLING DISTANCE

FIG. 38

TABLE 16

DETERMINANTS OF LOGGING COSTS

Yield

- "High-grading" 1.6 m^3/ha (1 tree/ha)
- Typical yield 12.8 m^3/ha (8 trees/ha)
- Maximum yield 57.6 m^3/ha (36 trees/ha)

Ground equipment

- Skidders
- Crawlers
- Both

Skidding trail preparation

- $400/km

Load size

- 3.2 m^3 or 6.4 m^3 for 130 HP skidder

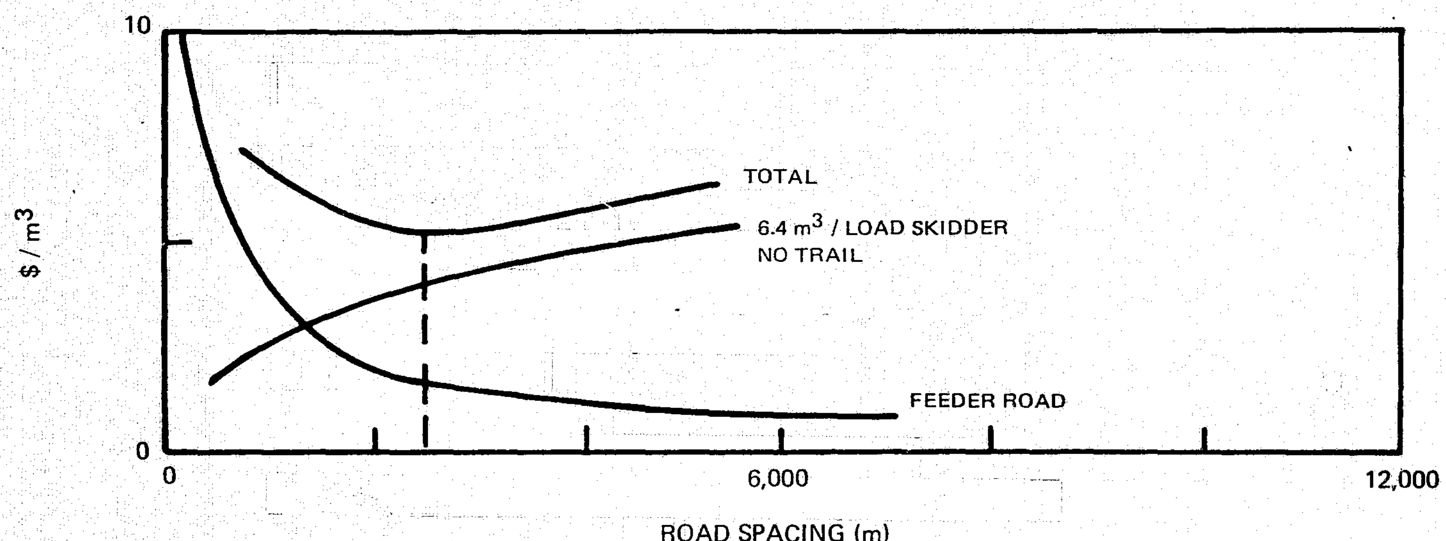
Effective working time

- 6 hrs/day

Typical cost

- $20/hr for 130 HP skidder, plus crew
- $2000/km for feeder road

OPTIMIZATION LOGGING COSTS



OPTIMUM ROAD SPACING = K $\sqrt{\text{ROAD CONST. COST / SKIDDER COST x YIELD}}$

WHERE K = TERRAIN ADJ. FACTOR

FIG. 39

That is, only the length of road necessary to gain access to one year's forest output would be built annually, in order to minimize capital investment. The road type would be chosen to minimize the sum of capital and truck operating costs; i.e., earth roads are best suited for low volumes, while higher volumes justify a better surfaced road in order to reduce truck operating costs. Since no applicable data were available for lumber truck operating costs, costs for a range of truck sizes used in regular commerce were assumed. The following are the cost components used in the analysis:

- Skidding and/or tractor costs
- Feeder road costs
- Access road costs
- Truck operations

Two remaining cost elements in logging and transport operations were not considered: the loading and unloading costs and the ground crew costs. Since these costs would be approximately the same for both surface and air systems and are relatively small, they would not affect the comparison and were omitted.

The costs of the harvesting operations were computed for a range of outputs (m^3/yr) up to 2 x 10^6 m^3/yr. The annual output is a management decision which should take into account other costs and factors such as further processing, market economics, costs of sawmilling plants, and so on. There are trade-offs such as the number of sawmills per unit area vs. transport costs which are not made here but which would dictate the appropriate output for a lumbering plant. For each level of output, the project life was determined. The project life is the length of time necessary to make one "pass" through the forest area of the case study. The frequency of harvesting (or "passes") depends on the growing cycle of the trees, environmental considerations and other factors to be considered by the decision maker. The cash flows for the surface system were discounted at a 10 percent opportunity cost of capital over the project life period, and an average annual cost was computed.

The alternative to the road-based system described is an air vehicle which could perform the same function without the necessity of an extensive network of logging roads. These vehicles would perform the line-haul transport of cut timber. In addition, they would be expected to be capable of loading and unloading logs without landing.

Figure 40 shows the simplified network for harvesting a forest area by air. The variable r_n represents the average annual distance traveled to harvest each rectangular section of the forest. As the total output (annual number of trees) increases, required travel distances also increase. Moreover, for a given output, a smaller yield will result in greater travel distances.

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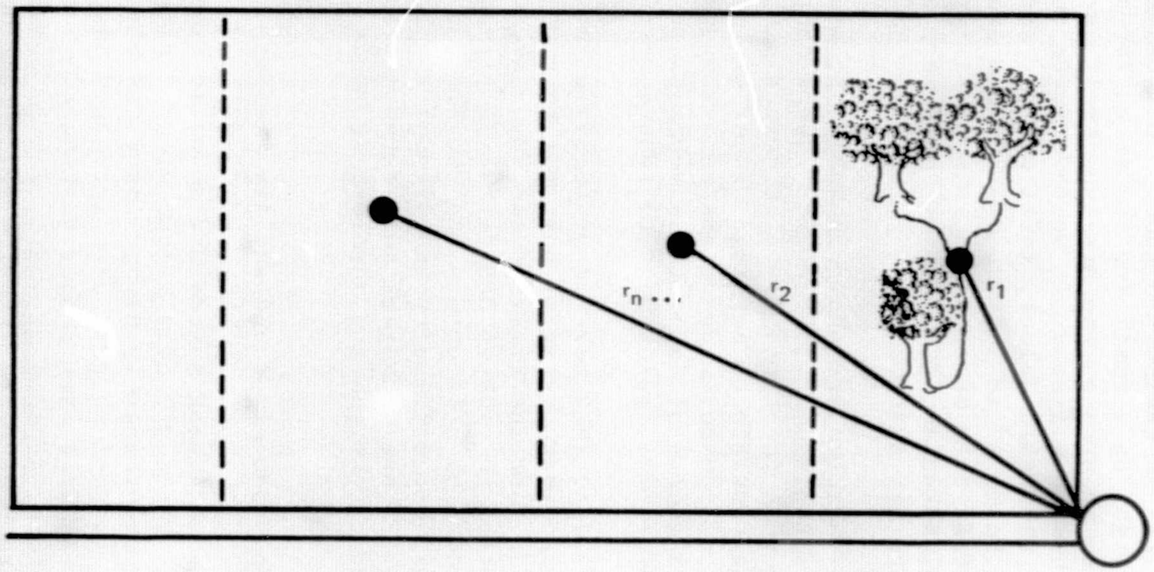
AIR LOGGING AND TRANSPORT



$r_n = f$ (TOTAL OUTPUT, YIELD)

NO. OF VEHICLES = f (r_n, PAYLOAD, CRUISE SPEED, LOAD / UNLOAD TIME)

FIG. 40

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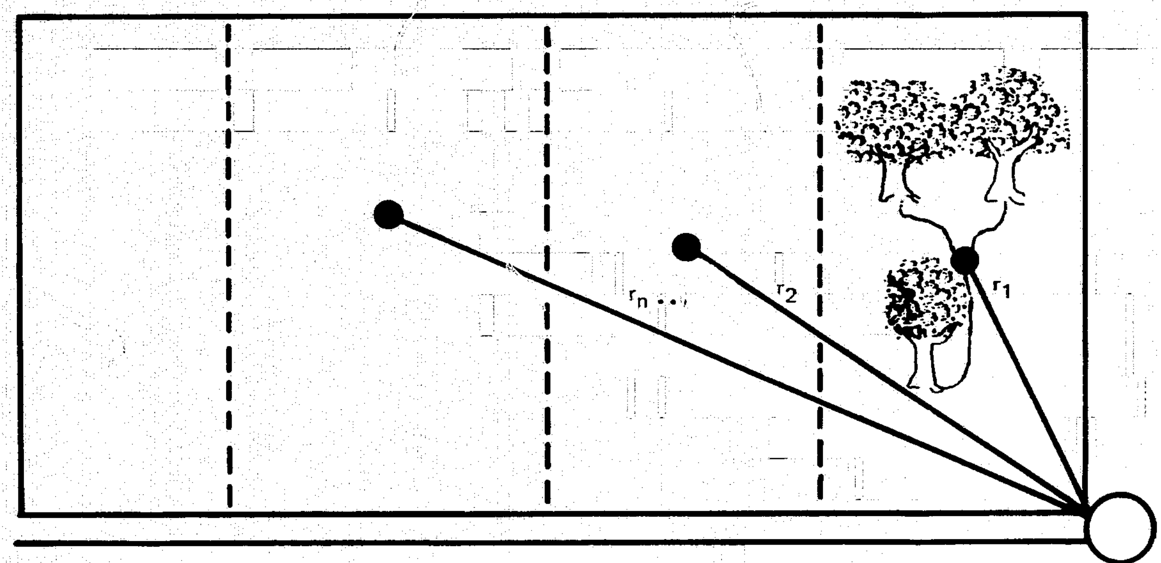
AIR LOGGING AND TRANSPORT



r_n = f (TOTAL OUTPUT, YIELD)

NO. OF VEHICLES = f (r_n, PAYLOAD, CRUISE SPEED, LOAD / UNLOAD TIME)

FIG. 40

With these operational requirements in mind, a wide range of existing and hypothetical future air vehicles was chosen in this preliminary evaluation. These vehicles, performance data for which are presented in Table 17, include two helicopters (Refs. 67, 68), a small and a large airship (Ref. 69), and a helicopter-assisted heavy-lift airship (Ref. 70). The S-58T has a payload of about 1 felled tree, compared to about 5 trees for the S-64. The latter would require some maneuvering to pick up the full payload. The larger vehicles (airships) necessitate a ground collection system to accumulate the loads. This might be a small log loader and/or skidder which could be transported from area to area by the airship itself, or which could maneuver itself into these new areas. It would precede the airship along with the ground crews, who would select, fell, debark, and cut the trees to size. The crews would be moved in and out of the area from the operational base on the first and last trip of each day. To simplify the preliminary evaluation, loading/unloading and ground crew costs were assumed to be the same for both ground and air systems.

The economics of these vehicles are shown in Table 18, assuming a rather conservative annual utilization of 1500 hours. These data were computed using direct operating cost equations given in Appendix C, but with revised operating conditions appropriate to logging. Hovering times for the loading/unloading operations were chosen to be consistent with previous experience (Ref. 71). The DOC components of each of the vehicles are shown in Fig. 41, indicating areas for potential improvement to reduce operating cost.

Since the analysis described here is primarily economic, some technical disparities among the candidate vehicles have not been considered. For example, it is not clear that the airships can hover with enough precision and for a long enough time to pick up and deliver a pre-aggregated load of logs. On the other hand, the helicopters and the HLA can perform loading/unloading operations without difficulty and without the ballast control required of an airship. These technical considerations are taken up in the section concerning research and development needs.

Comparison of Ground and Air Systems

Results for the ground-based system are shown in Figs. 42 and 43 in terms of average annual costs per unit volume of wood extracted. Lower-yield harvesting resulted in significantly higher costs, as expected. Increasing the rate of production (annual output) also increased costs due to the necessity of transporting logs over longer distances. The appropriate yield, as mentioned before, depends on environmental considerations and the ability of the forest to regenerate itself. The annual output will depend on future economies of scale for sawmills, processing plants, or costs of further shipment to market. That determination is beyond the scope of this analysis. Typically, sawmills currently process from 50,000 m^3 to 150,000 m^3 of wood annually, but their size may well increase in the future.

TABLE 17

PERFORMANCE SUMMARY FOR AIR VEHICLES

Logging Application

		S-58 T	S-64	Small airship	HLA	Large airship
Payload	kg	1560	7540	27,700	69,560	111,450
Cruise Speed	km/hr	235	175	130	111	97
Productivity	10^6 kg·km/hr	0.37	1.32	3.60	7.72	10.81
Range	km	470	370	965	185	3220

TABLE 18

ECONOMICS SUMMARY FOR AIR VEHICLES

Logging Application

Utilization ≡ 1500 hr/yr

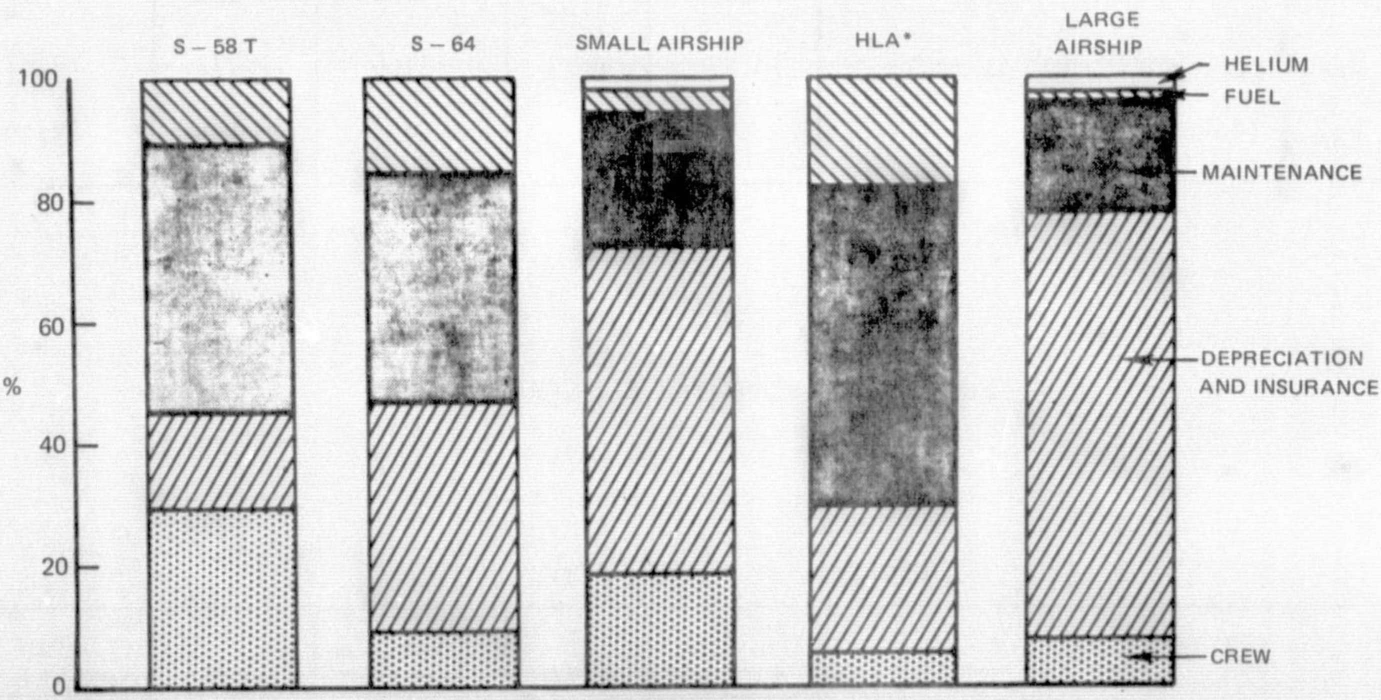
		S-58 T	S-64	Small airship	HLA	Large airship
DOC*	\$/bl-hr	410	1325	1415	4470	3195
Unit price	$\$10^6$	0.91	6.5	10.0	14.0	40.0
DOC/ Productivity	$\$10^{-3}$/kg·km	1.12	1.01	0.39	0.58	0.30
Unit price/ Productivity	$\frac{\$\cdot hr}{kg\cdot km}$	2.48	4.93	2.78	1.43	3.70

* Not identical to calculated values in Appendix C because of different operational assumptions.

DOC COMPONENTS FOR AIR VEHICLES

LOGGING APPLICATION

UTILIZATION = 1500HRS / YR



* HELIUM COST INCLUDED BUT TOO SMALL TO SHOW UP.

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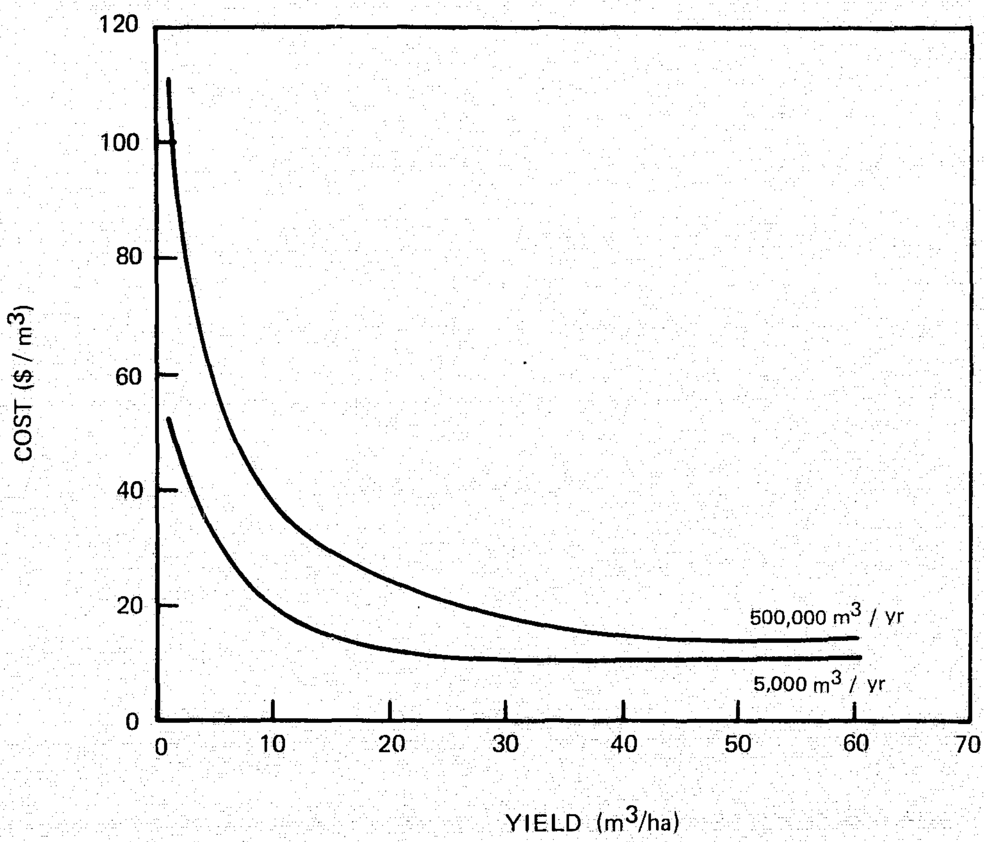
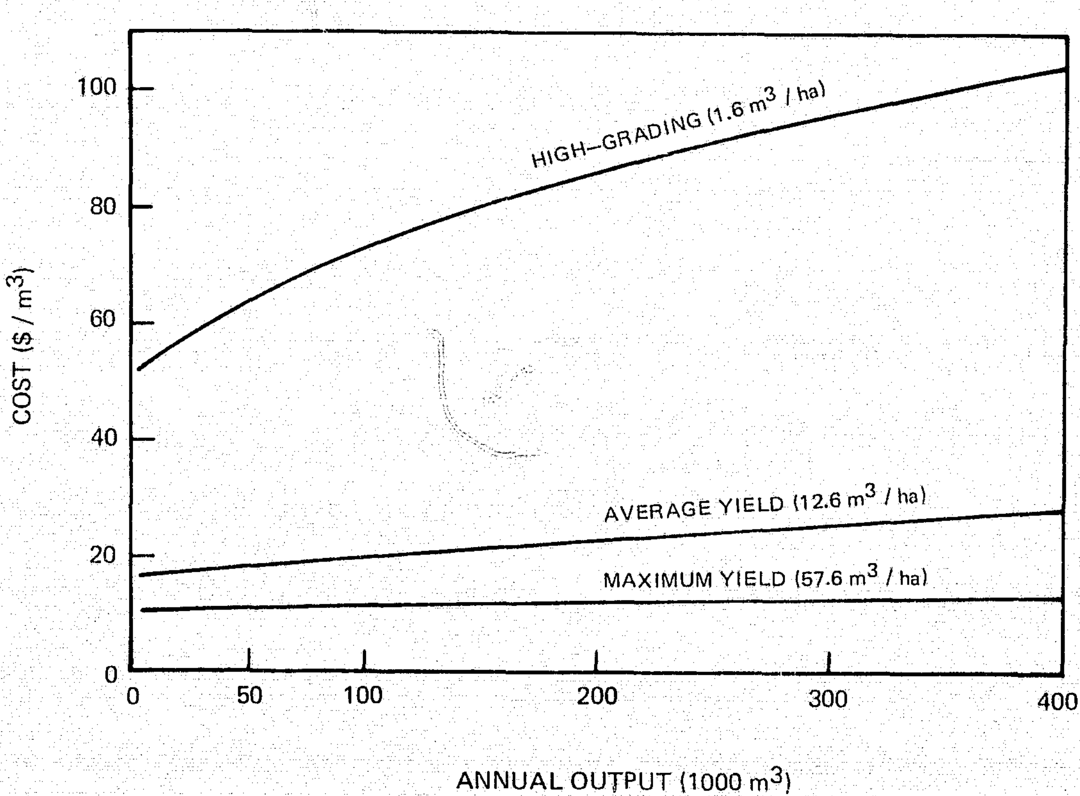
GROUND–BASED LOGGING AND ROAD TRANSPORT



GROUND–BASED LOGGING AND ROAD TRANSPORT



The economic comparison between the road and air systems is illustrated in Fig. 44 for a typical forest yield. It is stressed that this comparison is based on economics alone, with the intention of identifying technology opportunities. The comparison shows that, unless there are severe terrain obstacles or extenuating circumstances, helicopters are clearly unsatisfactory in economic terms for this type of forestry. The HLA, a hybrid with economics strongly influenced by its rotor system components, is also a poor economic alternative to roads. Airships compare more favorably with roads, although they are always inferior, particularly for annual outputs below the level of productivity of one vehicle, as indicated by the dashed lines. There is insignificant difference between the costs of the two airships at high annual outputs. Therefore, the choice would be determined by other considerations, such as the number of sawmills per unit area and the growth cycles of the trees harvested. A network of sawmills could be connected by road for further transport, or could also be served by the airships.

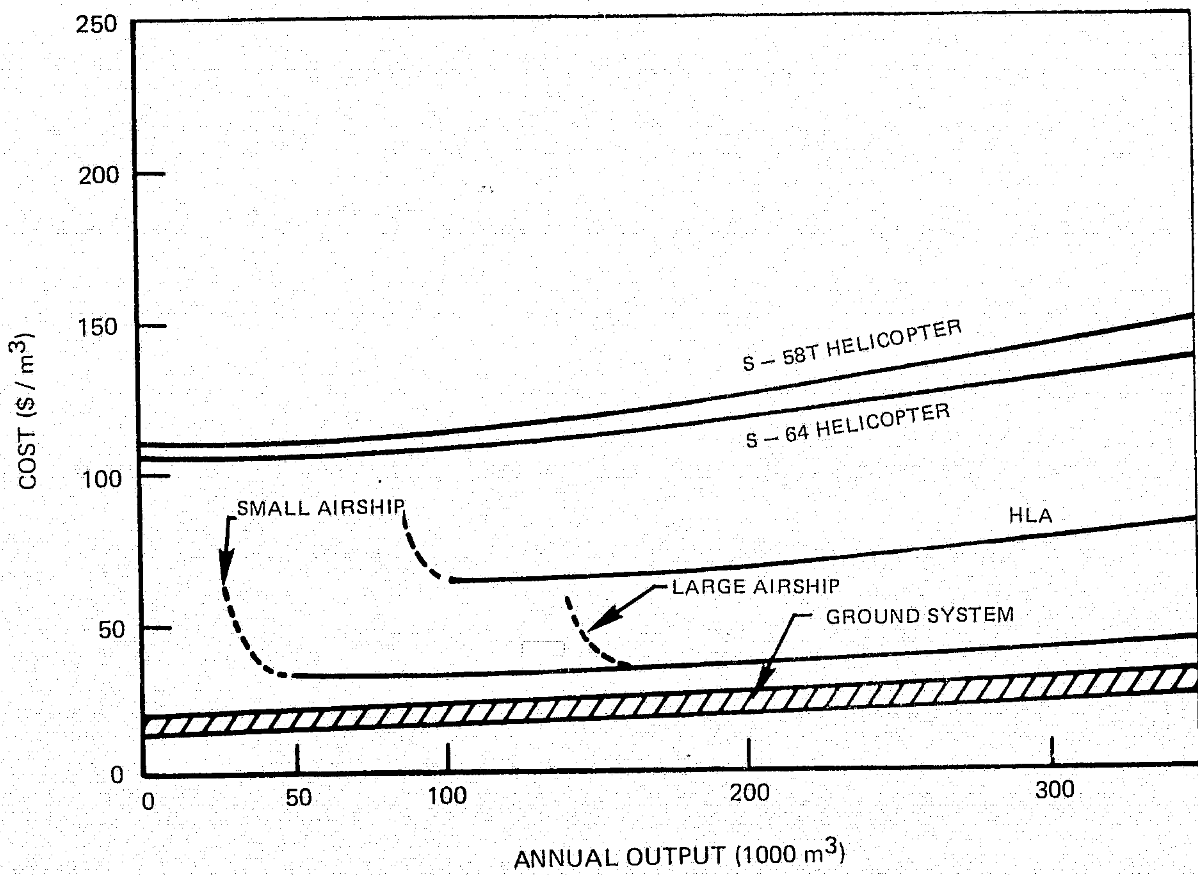
In a high-grading (low-yield) operation (Fig. 45), a small airship could actually be competitive with a ground system, although overall costs would be understandably higher than in Fig. 44 because of the much lower yield. The annual output range of interest is consistent with current sawmill capacities, but a larger operation could be competitive if a number of "collection points" were established. It appears that, for a wide range of outputs, a network of airship operations could be established that would be at least as cost-effective as a conventional road system. This conclusion presumes the necessity and/or desirability of a high-grading operation, which, as has been stated, could become a requirement in topical forestry, subject to further research.

Although a Brazilian forest was used as the model in the above comparison, the analysis can be adapted to any tropical forest region by selecting road costs appropriate to the environment. For example, to reflect Indonesia's more rugged environment, road costs were increased and the use of crawler tractors instead of skidders was assumed. These assumptions escalated road costs such that the lowest costs were at the upper limit of the band of uncertainty for the road costs shown in Figs. 44 and 45. Therefore, results from the preceding analysis can be considered valid for Indonesia as well, with a somewhat enlarged competitive range of outputs in Fig. 45.

There are obviously other considerations involved in the use of airships, including technical, operational, and social problems. Technical problems, including safe, rapid mooring and stabilization of the airships during loading and unloading, are discussed in a later section. If these problems cannot be overcome, then the HLA becomes the most competitive air vehicle, although its economics are clearly inferior to roads, and the market value of tropical hardwoods would have to escalate significantly to justify forest development by this method. In a practical operation, some ground equipment would be required to aggregate the loads (included in the airship costs), though to a much smaller extent than in completely road-based systems. An effective loading/unloading system requiring minimum clearing of the forest

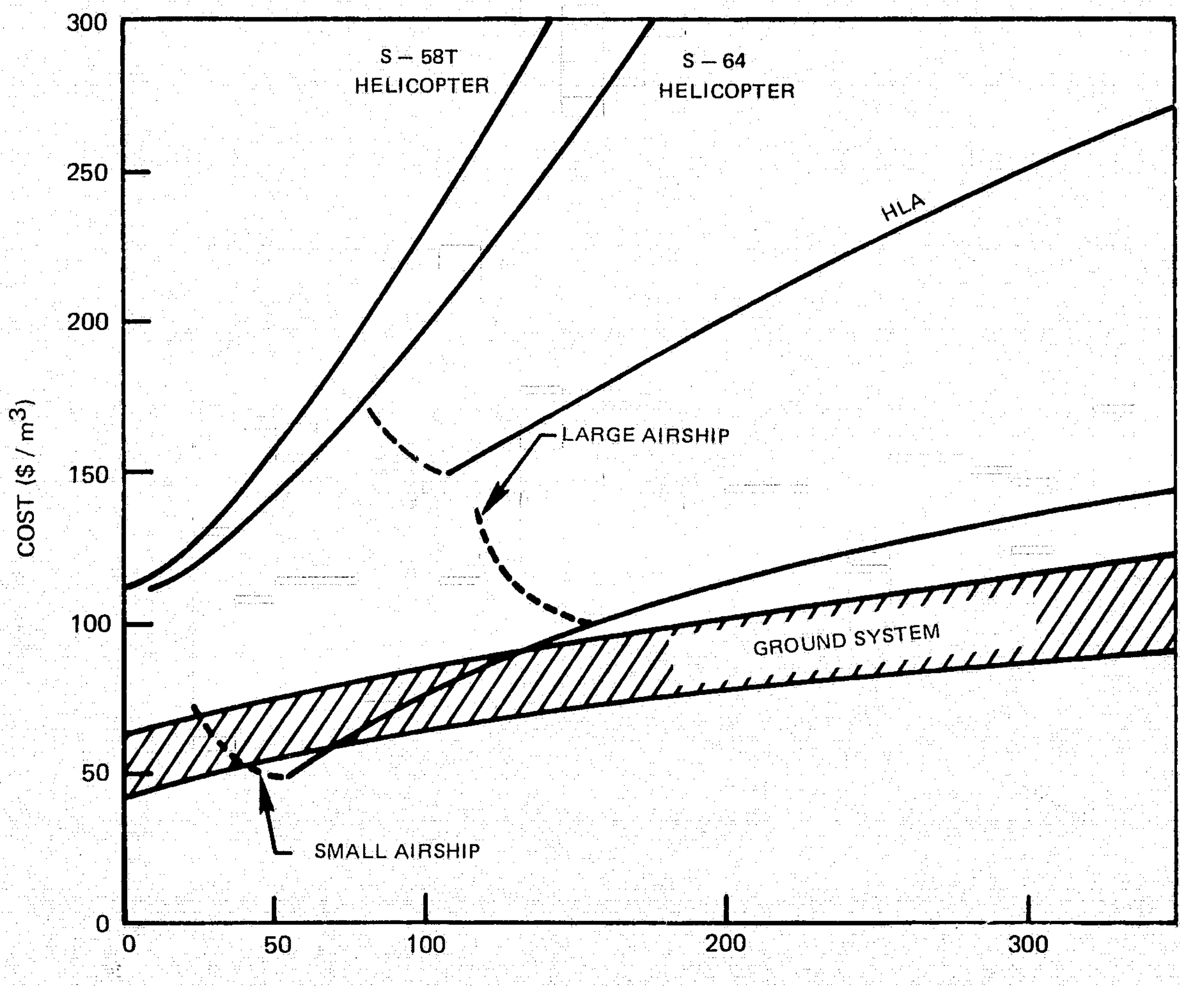
TYPICAL YIELD BY GROUND VS. AIR

(12.8 m^3/ha)



HIGH–GRADING BY GROUND VS. AIR

(1.6 m^3/ha)



would be necessary to minimize disruption, and the ability to carry crews and equipment (including small skidders or loaders) has been assumed. It is essential that vehicle utilization be high. Therefore, operations must be well-planned and managed wisely. Close coordination between ground crews and operators and careful scheduling of loads are required, and navigation systems must be precise enough so that loads can be easily located without unnecessary delays.

If these prerequisites can be met, the use of an airship offers many advantages in tropical logging. Currently, much waste occurs due to poor cutting practices and damage to trees during hauling or floating. The latter is particularly hazardous since many logs are denser than water, a fact which is often not known until logs are actually immersed. Delays in hauling timber often result in spoilage and uncontrolled drying, thereby making the logs commercially useless. By promptly locating and transporting these logs to the sawmill with an airship, most of these problems could be overcome. An airship allows rapid and accurate surveillance of the forest region for purposes of management, selection of species and disease control, without disturbing the area. In addition, if harvesting were not done in the systematic, increasing-radius manner presumed in the analysis, there would be very little increase in cost of the airship operation. For a road network, on the other hand, less than optimal planning would result in longer access roads with much subsequent unutilized capacity. Road circuity, which was not specified in the analysis, would further compound this problem.

In summary, a technologically advanced airship offers good possibilities for lumbering operations, particularly in low-yield harvesting. Overall, it compares favorably with road-based methods which are inherently cheap but which require a dense network of logging roads. These conventional practices may not be possible in future tropical forest exploitation due to ecological dangers. In a large, well-managed forest development, an airship could be fully utilized for transport, exploration, and forest management purposes. But further R&D will be required to improve certain performance aspects of the vehicles and to adapt them for this application.

Sociopolitical Considerations

The tropical forestry application is unique among the primary applications identified in this study in that its primary benefits are noneconomic. Therefore, while the economic evaluation described in the preceding section showed airships could be competitive with a road network in a tropical logging environment, it would be expected that the airship would be favored in the sociopolitical analysis. This result is demonstrated in Table 19, which presents the sociopolitical comparison in the same format described in the preceding cases.

Because of the selective nature of this application, a number of specific objectives do not apply, particularly in the socio-economic development and political categories. Therefore, the overall scores are necessarily lower than in the previous evaluations for remote mining and low-density transport. Nevertheless, the overall result shows that air enjoys a clear

TABLE 19

SOCIOPOLITICAL COMPARISON

Tropical Forestry

OBJECTIVES	UNITS OF MEASUREMENT	WEIGHTS	Air Rank	Air Score	Roads Rank	Roads Score
IMPLEMENTATION						
Open Service Expeditiously	Months	4	5	20	1	4
Minimize Foreign Exchang Req'mts.	$	6	2	12	5	30
Min. Need for Expatriate Labor (Constr)	Person-Years	3	5	15	3	9
Avoid Instit. Delays at Inter'l Level	Prob. of Months	1	--	--	--	--
Secure High Salvage Value	$ or Equiv.	1	5	5	2	2
Subtotal		15		52		45
OPERATION						
Provide for Maximum Reliability	Prob. Days of Service Interr./yr	7	5	35	4	28
Provide for Maximum Safety	Anticip. Level of Damage Claims/yr	5	4	20	5	25
Min. Need for Expatriate Labor (Oper.)	Person - Years	3	1	3	5	15
Subtotal		15		58		68
SOCIO-ECONOMIC DEVELOPMENT						
Create Jobs for Available Work Force						
- In Construction	Person - Years	4	1	4	5	20
- In Operation/Maint.	No. of permanent jobs	7	3	21	5	35
Foster Upgrading of Tech. Skills	No. of skilled work trained/yr	5	5	25	2	10
Provide reliable & Affordable Means of Mobility for General Pop.	No.Person-Km	5	--	--	--	--
Provide Fast & Comfortable Means of Mobility for General Population	Time Distance	5	--	--	--	--
Provide for Emergency Services	Time Distance	4	5	20	2	8
Encourage Establ. of Secondary Industries	Probability	3	--	--	--	--
Build-up of a Multipurpose Long-Range Infrastructure Network	Policy Judgment	2	--	--	--	--
Subtotal		35		70		73
RESOURCE UTILIZATION						
Conserve Energy, Part. Imported Fuel	Barrel Equiv/yr	7	4	28	5	35
Protect Physical Environment	Tons of Emiss./yr	5	5	25	1	5
Maximize Access to Primary Materials	Policy Judgment	8	5	40	1	8
Subtotal		20		93		48
POLITICAL						
Upgrade National Defense Capability	Policy Judgment	6	--	--	--	--
Promote Political Stability and National Unity	Policy Judgment	6	--	--	--	--
Generate National Pride	Policy Judgment	3	5	15	1	3
Subtotal		15		15		3
GRAND TOTAL		100		288		237

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superiority over roads, primarily because of the very large difference in the ranking of resource utilization objectives. The airship provides a means of gaining access to timber resources, even in remote areas with difficult terrain. At the same time, it minimizes unfavorable environmental effects and is fairly good in fuel efficiency compared to ground-based transport.

The impact of an air-based logging system on employment is a very important consideration in its ultimate feasibility. As an alternative to trucks, the airship replaces truck drivers with highly skilled airship pilots. However, the fact that the airship enables development of forest areas otherwise inaccessible provides a stimulus for additional employment opportunities. It also allows for a more controlled human settlement pattern, since the rapid transport of employees allows for concentrated population centers which can be better served by surface roads. The forest area is then devoid of population and interfering activities detrimental to the proper utilization of the forest.

The advantage shown here for the airship may even appear to be understated because the resource utilization category is allocated only 20 percent of the total weight in the scoring process. However, since several objectives were not ranked for this application, the resource utilization allocation is actually 28 percent of the total. Also, since roads were determined to be clearly superior in only the operational objectives, almost any revision of the weighting process would tend to favor the air mode.

AIRPORT/INDUSTRIAL CITY

The airport/industrial (A/I) city concept is of interest not only for its impact on the transportation system of a country but also for its stimulus to regional development. Because the national goals of Brazil call for such developments (Ref. 32), because resources in Brazil are vast and their locations remote, and because the needed data are readily available for Brazil, it was chosen as the case-study country for the A/I city concept. While the concept was not studied for Indonesia, it is a valid concept for that country as well, as it is for many countries, both developing and developed.

The airport/industrial city was also studied to determine its possible impact on the need for large cargo aircraft (LCA) in Brazil, LCA being the fourth major aircraft application chosen for detailed analysis. Because a major function of an A/I city will be to enlarge the international trade in high-value exports, air cargo requirements of the A/I city would be expected to add significantly to the national requirement, which is growing rapidly in Brazil.

In this section, the development of an A/I city is studied in some detail, culminating in a projection of its export market out to the year 2005. This projection is then integrated with that for the general-commodity export market in the following section, an analysis which ends up with an estimate of cargo aircraft requirements, including the LCA.

A/I City Concept

The A/I city concept advanced in 1968 by Col. E. N. Hall (Refs. 21 and 22), consists of a symbiotic arrangement of a regional airport surrounded by a large area dedicated to income-producing nonresidential functions -- manufacturing, recreation, traveler accommodations, freight handling. As noted in Ref. 46, this area is surrounded by a narrow belt which contains the "downtown" of a conventional city. All residential areas, with their shopping centers, recreational and educational facilities, are outside this belt. Much of the land would be left in its natural state and/or placed under cultivation, for aesthetic, recreational, and ecological reasons. An efficient mult-modal transportation system would be used to interconnect the various parts of the area.

The airport serves to attract industry, and both the airport and industry can be used to attract new residents; industry and the residents would then furnish the travel demand to support the airport. The result is a well-balanced city in which all elements interact for the greatest mutual benefit, and which can be developed with minimal demand on the national resources.

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NUCLEUS OF AIRPORT INDUSTRIAL CITY

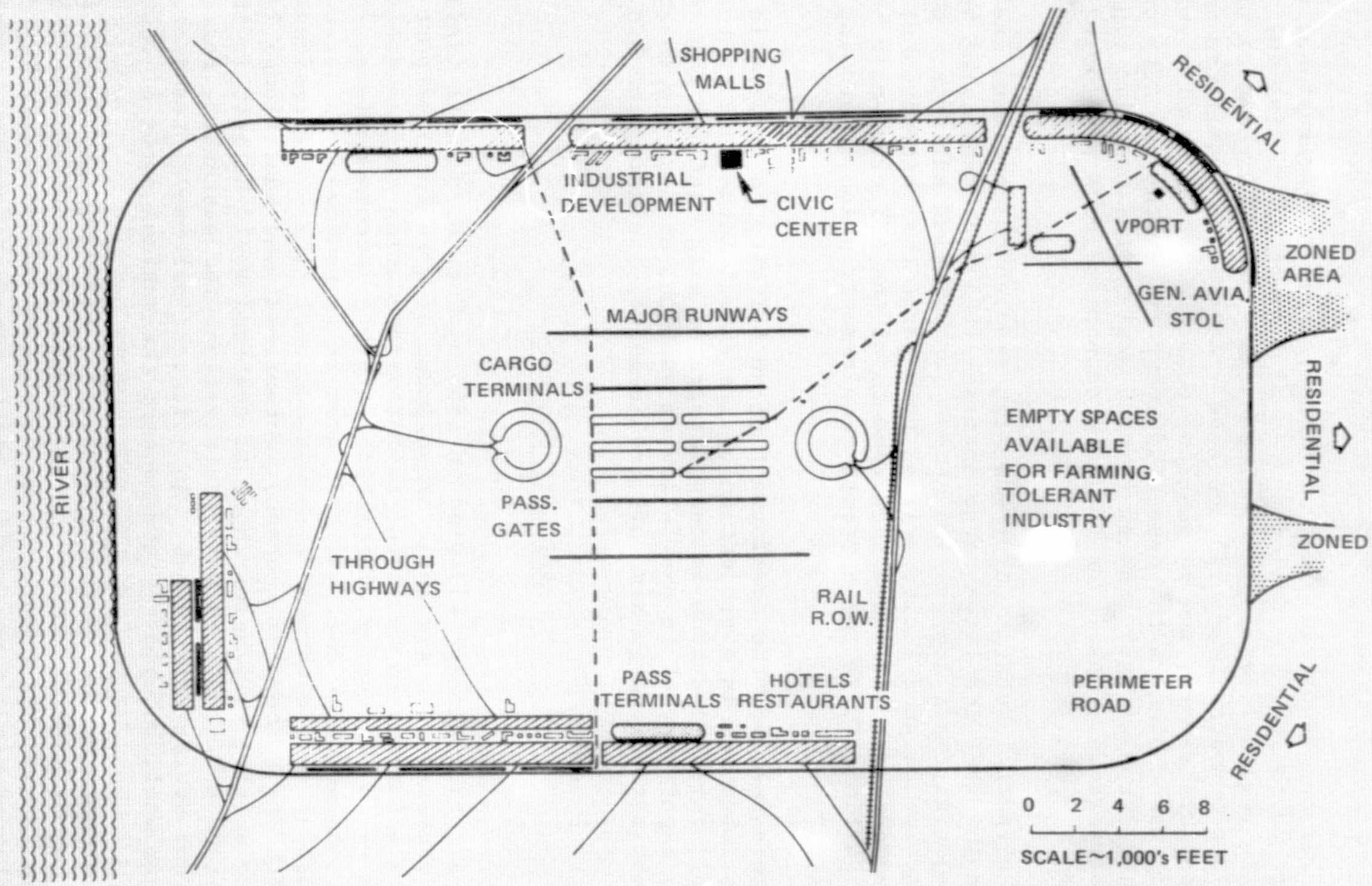

FIG. 46

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NUCLEUS OF AIRPORT INDUSTRIAL CITY

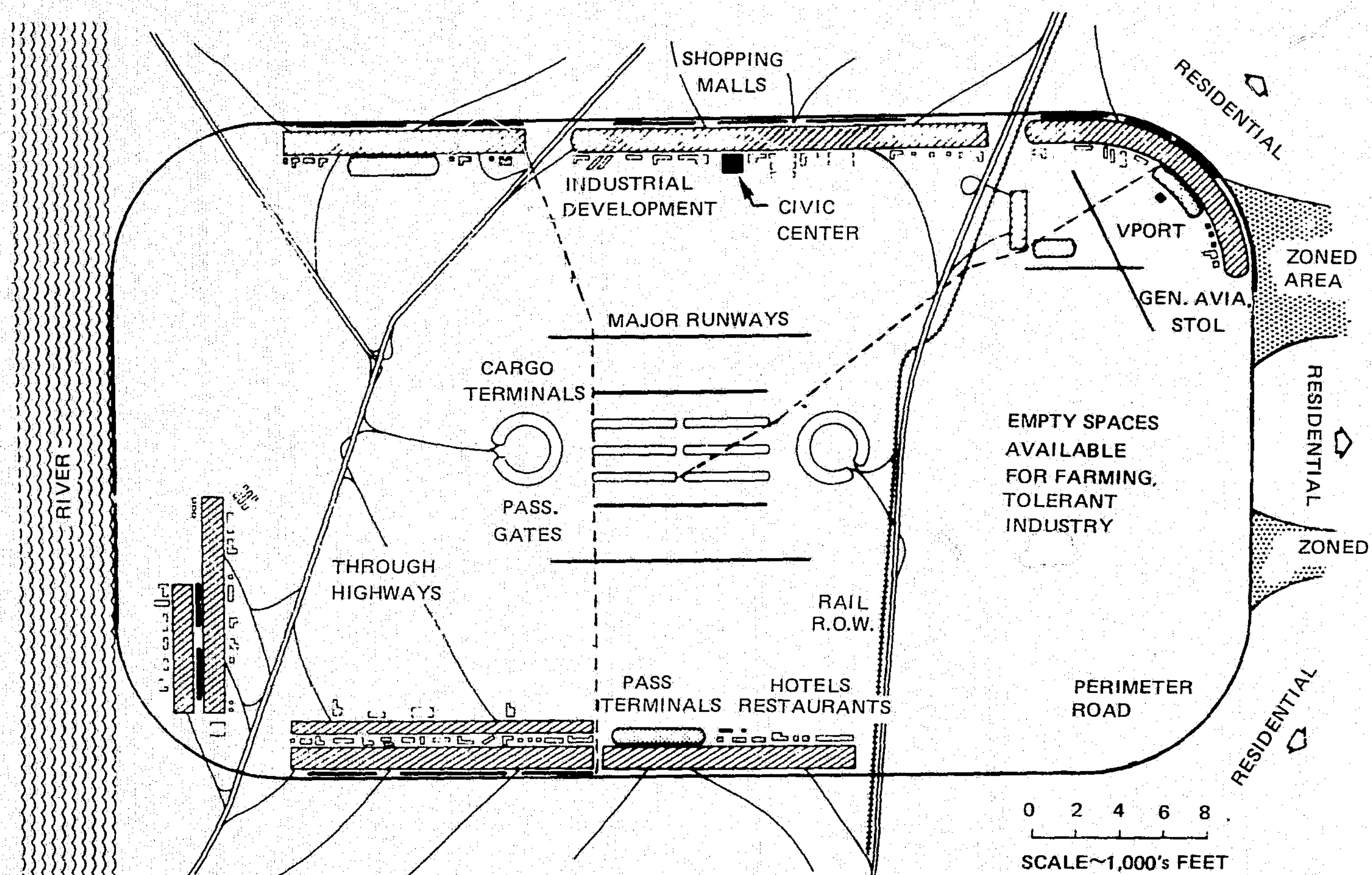

FIG. 46

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In order to be successful, such a city requires a large, presently sparsely populated area located at a potential nexus of inter-regional and worldwide air traffic routes, preferably (but not necessarily) on a river or on the ocean, with adequate water supply and (potentially) adequate energy supply. The Government must be dedicated to the development of its resources and have the means for implementing its plans. The development of such a city requires very careful planning and control to assure the proper time phasing of all major events and activities.

Brazil is in a position to take advantage of the benefits of this concept, because it can satisfy all of these conditions. The concept is of special interest in this study because it provides an orderly approach to development and growth of undeveloped regions. The Amazon region of Brazil appears to be particularly suited to application of the A/I concept because of the enormous potential of that region for agriculture, mineral extraction, forestry and livestock ranching, and because the Brazilian government has embarked on an ambitious long-range program to promote the growth of settlements throughout the region (Ref. 35).

A/I City Analysis

As described in Appendix F, the site selected for a case study of the A/I city concept is at the city of Santarem, in the Amazon region in north central Brazil, about 1000 km west of the coastal city of Belem along the Amazon river. Santarem has a population of about 140,000; it currently has air service by B-737s to other cities in Brazil, and is located at the confluence of two major rivers, the Amazon and the Tapajos. It is 600 km, by air, east of the major interior city of Manaus, an international gateway with air service to Miami, Los Angeles, Tokyo, and Paris, with connecting service to other cities in the US and Europe.

The Curua-Una hydroelectric plant is just 70 km away from Santarem, and many other potential hydroelectric sites are within a feasibile transmission distance. The availability of electric power, plus heavy deposits of bauxite within 200 to 300 km, by river, suggests the development of an aluminum-based industry at a Santarem A/I city. Together with significant timber and cattle resources, a significant potential exists for rapid regional development through the unique capabilities of an air-centered transportation system. Excellent river transportation for the raw materials which could be processed at a Santarem A/I city is provided by the Amazon itself, which extends west to Manaus (720 km away) and, beyond, into the State of Amazonas, by the Rio Negro west of Manaus, and by the Tapajos River which is navigable to the city of Itaituba, 300 km to the south.

The remoteness of typical A/I city locations in Brazil, even from Santarem which is the least remote of those considered in the study, makes it clear that point-to-point transfer of products from Santarem to any of its logical markets would be practical only by air for any product which has significant value added or time value. While shipment of raw materials, such as timber or mineral ores, might be more economical by surface mode because of the low unit value of the product and the relatively high cost of air transportation, the distillation of the raw material into a finished or partially finished form at the site adds to the feasibility of air shipment.

Air transportability is a difficult factor to define quantitatively, particularly for a situation involving a developing country, because of the lack of data. A cursory examination of how air transportability varies with value of product is seen in Fig. 47, as derived from Commerce Department data (Ref. 72) for a series of selected US import products. Figure 47 shows that, for export from all supplier countries to the US, a product must have a unit value of at least $1 per kg before it begins to have some potential for air transportation in competition with ocean vessels. For some products, air transportability doesn't start below unit values of about $10 per kg. As the product unit value increases along any correlation line, the percent of the total product transported by air increases significantly. At $4.50 per kg, as much as 35 percent of some products are shipped by air. At $22/kg, between 20 percent and 80 percent is shipped by air.

These data are for US imports from all countries, some of which have modern transportation systems and cargo handling equipment. For exports from developing countries, often with virtually no transportation infrastructure between the interior and an ocean port, the value of air transportation, in terms of time saved (see Appendix F), and in terms of cost saving implied by the travel time values given, is expected to be immeasurably greater. This argument is particularly compelling in a region such as the deep Amazon rain forest.

For Brazil, the value of product which begins to be air transportable should be below the 0-percent intercepts ($1 to 10/kg) shown in Fig. 47. This contention is somewhat substantiated by Fig. 48 which shows a similar plot for imports from the Latin American Free Trade Association. A corresponding plot, though with fewer products with which to work, is Fig. 49, for US imports from Brazil (Refs. 72,73). These data provide a starting point by showing that product unit values on the order of $2 per kg and greater should have <u>significant</u> air transportation potential. Based on Figs. 48 and 49, the correlation lines show the beginning of air transportability in the neighborhood of 90¢ per kg of product value. Some products of a perishable nature could be transported by air at even lower values, particularly from interior Brazil with its poor internal transportation system.

With this background as a guideline, it is useful to examine product values for one or more "value-added chains" starting with the raw materials found in interior Brazil. For the Santarem region, these raw materials would be timber, cattle and, particularly, aluminum. For timber, a typical

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U.S. IMPORTS

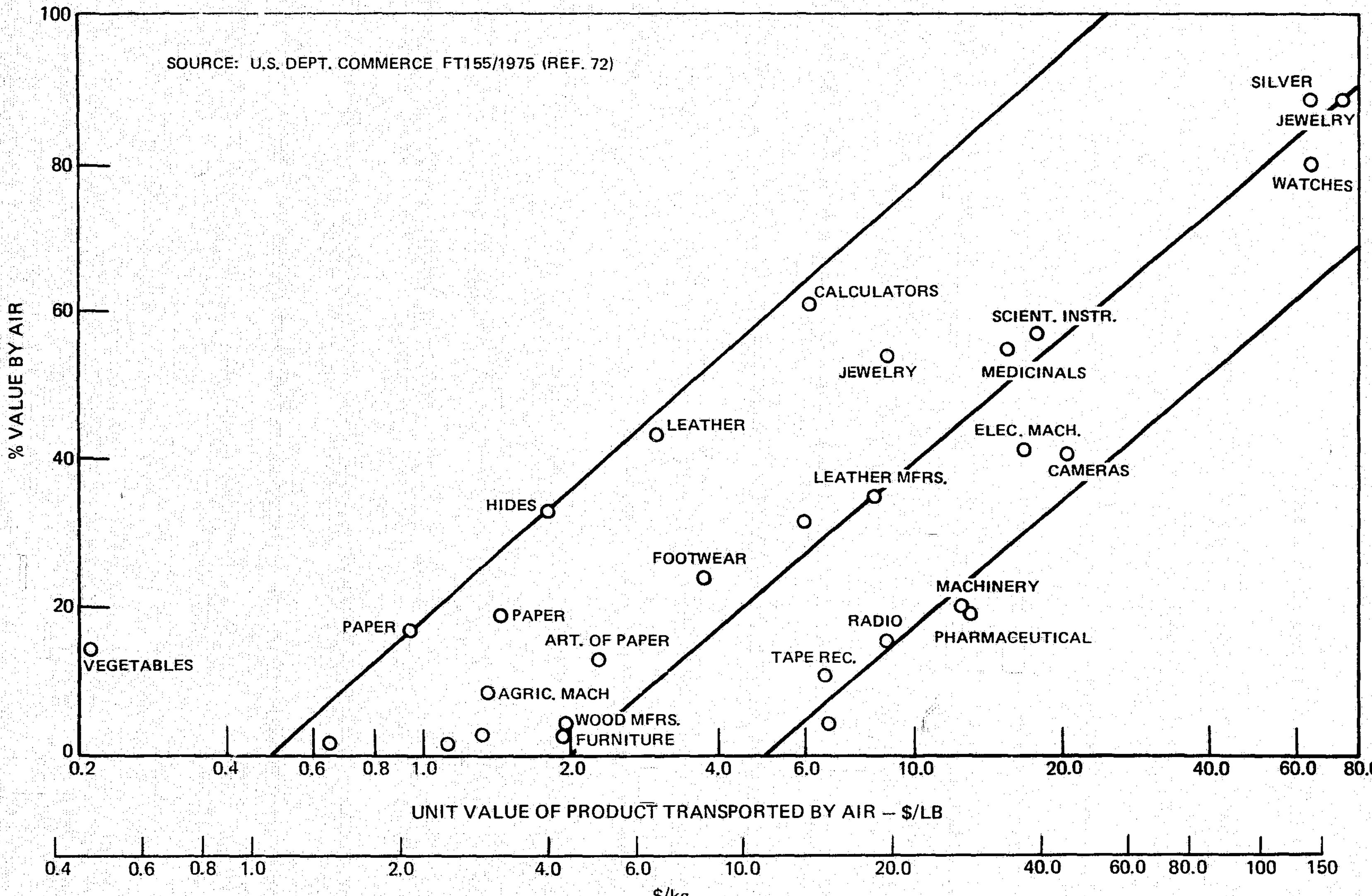

FIG. 47

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U.S. IMPORTS FROM LATIN AMERICAN FREE TRADE ASSOCIATION

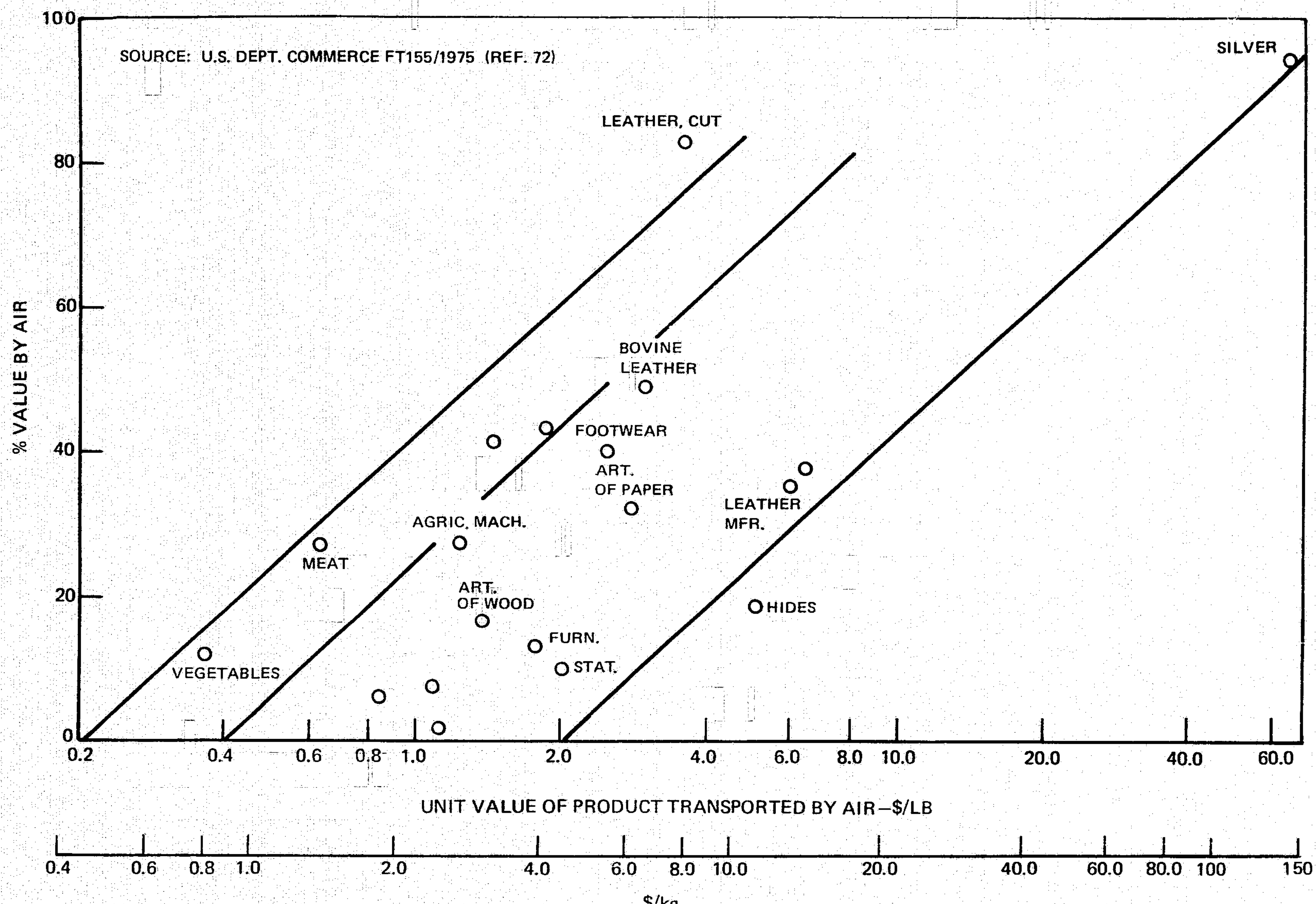

FIG. 48

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U.S. IMPORTS FROM BRAZIL

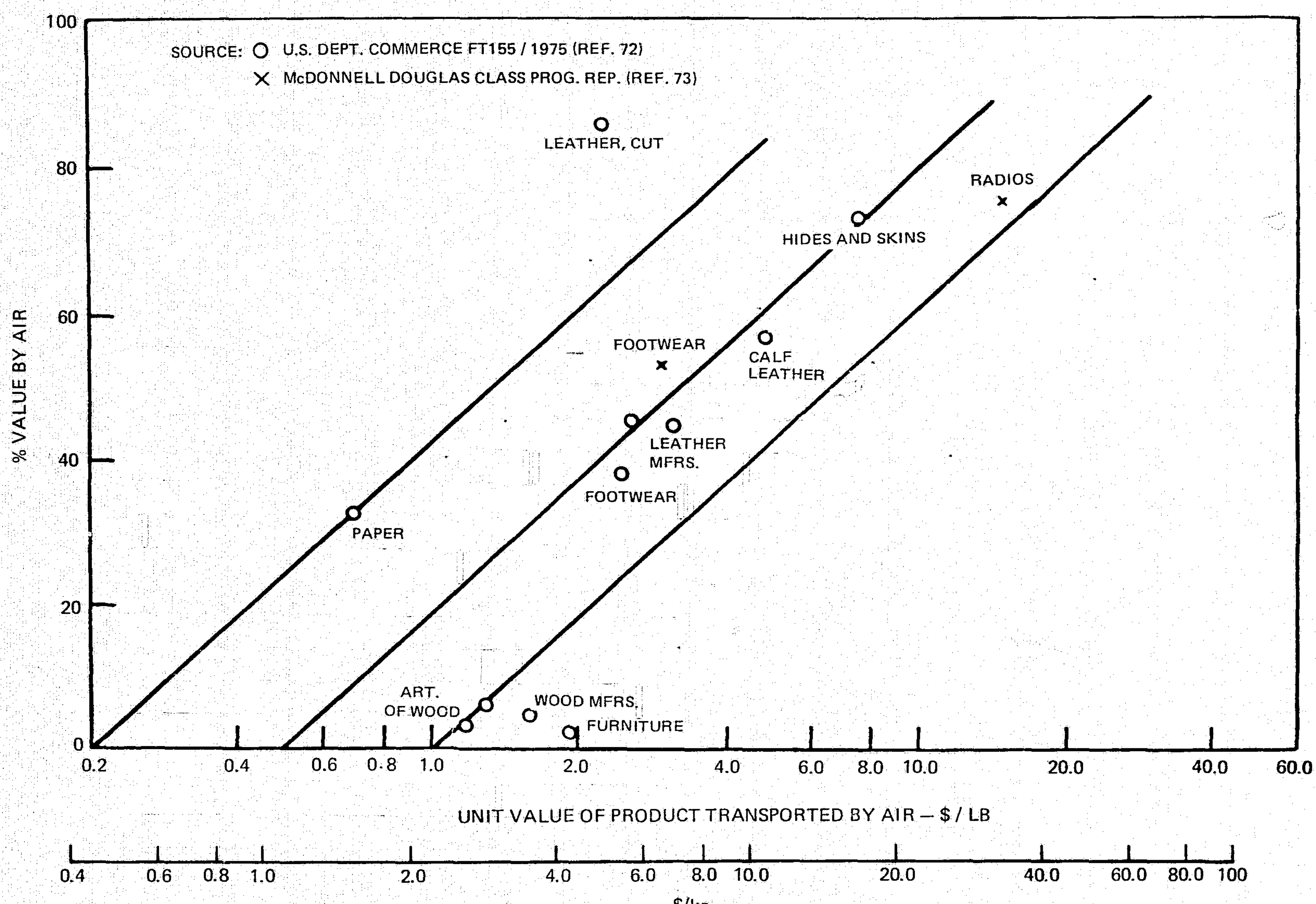

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FIG. 49

value-added chain would start with rough timber and progress, through local processing, to hardwood logs, hardwood lumber, plywood and veneers, wood articles, and furniture. Another value-added chain for timber would be pulpwood, paper bags and boxes, and stationery. For cattle, a value-added chain would be cattle hides, leather, footwear, and leather manufactures. A branch of the cattle value-added chain would include various cuts of meat. A value-added chain for aluminum would start with bauxite and alumina, and would progress through primary aluminum, rolled and cast aluminum, and on up to complete aluminum products such as aluminum windows, electrical apparatus, and aircraft parts.

For these value-added chains, unit values can be established to see how far up the chain local processing must go before a viable situation exists for air transportability and the development of an A/I city.

Some results for the timber and livestock industries are summarized in Table 20. These data were assembled from several sources, including the 1972 US Census of Manufacturers (Ref. 74), 1975 US General Imports (Ref. 72), and Project RADAM (Ref. 36). Although the basic industry structure is patterned after US experience in each case, factors which adapt the data to the study country environments have been introduced. For example, the timber chain is based entirely on processing of hardwoods because the tropical forests in Brazil and Indonesia consist mainly of hardwood species.

Because of the heavy concentrations of bauxite in the Santarem region, it was decided that the emphasis in the Santarem A/I city analysis would be on examining the feasibility of developing an aluminum-based industry at that location. This development is described, in detail, below. However, to gain confidence that this emphasis would be logical, a summary of commodities, derived from the basic metals industries, was prepared. In all cases these commodities are ones which are presently imported from Brazil. This summary, which is shown in Table 21, illustrates the high percentages of these products which are presently shipped by air. Also shown in Table 21 are the figures for some items in the timber and cattle value-added chains. With sufficiently large investments in the resource and processing industries, large outputs of these commodities may, perhaps, be generated at the proposed A/I city. In the following paragraphs, estimates will be derived of the volumes of air-transportable goods which might, realistically, be generated at such a complex, and the magnitude and frequency of air shipments thereby stimulated.

Development of an Aluminum-Based Industry at Santarem

The traditional approach to exploiting the Santarem bauxite reserves would be to load this ore in large marine vessels to take it to refineries and smelters abroad. It can be postulated that such a "colonial" operation should not be practiced in Brazil, but that it is in the interests of the country to develop its own industrial base, including smelting and the manufacture of aluminum products. It can be further assumed that all this could take place in Santarem directly, and the rest of the discussion will

TABLE 20

VALUE-ADDED CHAINS

<table>
<tr><th rowspan="2">Raw Material</th><th rowspan="2">Product</th><th colspan="2">Fraction of Output, % *</th><th rowspan="2">Unit Export Value $/kg</th></tr>
<tr><th>Incomplete Chain</th><th>End Product</th></tr>
<tr><td>Hardwood Timber</td><td>Roundwood Logs</td><td>100.0</td><td>0</td><td>0.07</td></tr>
<tr><td></td><td>Lumber</td><td>45.0</td><td>10.0</td><td>0.35</td></tr>
<tr><td></td><td>Wood Containers</td><td colspan="2">13.3</td><td>0.46</td></tr>
<tr><td></td><td>Plywood</td><td>3.6</td><td>2.8</td><td>0.33</td></tr>
<tr><td></td><td>Milled Wood Products</td><td colspan="2">2.9</td><td>0.88</td></tr>
<tr><td></td><td>Veneers</td><td>3.8</td><td>0</td><td>1.46</td></tr>
<tr><td></td><td>Furniture</td><td>17.0</td><td>17.0</td><td>2.27</td></tr>
<tr><td></td><td>Decorative Wood Products</td><td>0.1</td><td>0.1</td><td>2.82</td></tr>
<tr><td></td><td>Kraft</td><td colspan="2">3.5</td><td>0.29</td></tr>
<tr><td></td><td>Newsprint</td><td colspan="2">0.8</td><td>0.33</td></tr>
<tr><td></td><td>Printing Paper</td><td colspan="2">2.0</td><td>0.95</td></tr>
<tr><td></td><td>Stationary</td><td colspan="2">0.8</td><td>1.10</td></tr>
<tr><td></td><td>Paper Cartons</td><td colspan="2">4.8</td><td>0.66</td></tr>
<tr><td>Livestock</td><td>Cattle</td><td>100.0</td><td>0</td><td>0.71</td></tr>
<tr><td></td><td>Beef, Veal, (Total)</td><td colspan="2">58.0</td><td>1.28</td></tr>
<tr><td></td><td>Kidney, etc.</td><td colspan="2">4.6</td><td>0.62</td></tr>
<tr><td></td><td>Ground, etc.</td><td colspan="2">15.4</td><td>0.90</td></tr>
<tr><td></td><td>Liver, etc.</td><td colspan="2">1.7</td><td>0.95</td></tr>
<tr><td></td><td>Chuck, etc.</td><td colspan="2">12.5</td><td>1.01</td></tr>
<tr><td></td><td>Rib, etc.</td><td colspan="2">5.1</td><td>1.61</td></tr>
<tr><td></td><td>Rump</td><td colspan="2">1.2</td><td>1.79</td></tr>
<tr><td></td><td>Round</td><td colspan="2">4.0</td><td>1.83</td></tr>
<tr><td></td><td>Loin</td><td colspan="2">12.5</td><td>1.87</td></tr>
<tr><td></td><td>Veal</td><td colspan="2">1.0</td><td>1.85</td></tr>
<tr><td></td><td>Hides</td><td>100.0</td><td>0</td><td></td></tr>
<tr><td></td><td>Finished Leather</td><td colspan="2">20.7</td><td>4.56</td></tr>
<tr><td></td><td>Shoe Cut Stock</td><td colspan="2">3.8</td><td>5.25</td></tr>
<tr><td></td><td>Footwear</td><td colspan="2">61.8</td><td>5.00</td></tr>
<tr><td></td><td>Gloves</td><td colspan="2">0.5</td><td>17.06</td></tr>
<tr><td></td><td>Luggage, handbags, etc.</td><td colspan="2">13.2</td><td>8.09</td></tr>
</table>

* Figures for "incomplete chain" apply when further processing does not take place. Figures for "end product" assume processing continues to last products in chain.

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TABLE 21

SOME U.S. IMPORTS FROM BRAZIL
1975

Schedule A Code	Commodity	Shipments, 1000 kg	Unit Value of All Shipments $/kg	Air Penetration, % Value
696.0	Table Flatware and Cutlery	166	8.55	21.9
711.5	Engines - Int. Comb., Parts	4834	2.29	6.0
714.2	Calc. and Add. Machines	203	30.73	86.5
714.9	Office Machines	80	108.47	99.9
722.3	Elect. Appliances	205	12.04	65.0
724.2	Radio Rec. & Radio-Phono	1901	19.53	42.9
729.4	Elect. Ign. Equipment	767	21.36	88.4
861.2	Spectacles, Frames, etc.	11	11.46	95.0
861.3	Microscopes & Other Opt.	8	14.37	79.5
861.7	Medical Instruments	15	12.92	64.4
862.4	Photo Film	41	12.32	45.2
891.8	Musical Instruments	28	4.89	49.5
897.1	Jewelry	56	22.49	92.0
211.9	Hides and Skins	10	5.51	23.8
611.3	Leather - Calf and Kip	12	8.73	57.0
611.4	Leather - Bovine, NES	670	4.56	45.0
611.9	Leather, NES	246	6.94	55.6
612.2	Saddlery	6	4.92	62.4
612.3	Leather - Footwear	68	5.25	87.0
612.9	Manufactures of Leather	50	2.23	45.8
632.7	Wood Manufacturers - Decor.	121	2.93	4.1
632.8	Articles Manuf. of Wood	2877	0.37	3.2
641.5	Paper and Paperboard	1	0.64	100.0
642.1	Boxes of Paper	3	1.37	40.0
642.9	Articles of Paper	5	4.52	10.0

be devoted to the exploration of this scenario, stressing the maximum possible local development of an industrial base. It should be repeated at this point that it is the announced national policy of Brazil to bring economic and social activity to this region and to tap its tremendous resources through stable development.

This analysis started from two ends:

- Identification of raw material (bauxite) availability
- Establishing the marketability of certain aluminum products.

Starting with the second element, a list of manufactured products that are either aluminum-based, or that include sizable amounts of this metal, was prepared. The list was limited to items which are already exported from Brazil to the US, and for which a significant proportion of trade utilizes air transportation (see Tables 22 and 23). Attention is therefore focused on industries for which relevant skills and knowledge exist in Brazil, and on products for which air is a feasibile transportation option.

The next step was to examine typical markets for products in international trade. The representative markets selected for this study were: Colombia, Venezuela, United States, and Japan. While it was not possible to survey every product, enough items were identified to assure that a market exists for a wide variety of exports. A basic, but reliable assumption, was that products make in Santarem will not constitute enough of a volume to influence the world market in either its ability to absorb them or to cause measureable price changes. In other words, the outside reservoir of demand is likely to be so large that the activities at Santarem will not modify its characteristics. The corollary of this assumption is that products made in this city must be fully competitive in quality and price (which, of course, will include transportation costs) with those manufactured anywhere else.

Keeping in mind the purpose of this study, and avoiding preconceived notions as to specific product lines, a narrowing down of items from the above lists was made. To explore purposefully various possible situations, the deliberate choice was made of products that require a range of manufacturing (value-added) inputs and other components.

A chain of production was identified for an aluminum industrial complex beginning with bauxite mining and the reduction of bauxite to alumina, and continuing through three stages of manufacturing activities. Each manufacturing stage has strong direct linkages to the preceding activities; i.e., primary aluminum production requires inputs of alumina from the mining sector, the production of aluminum casting utilizes outputs from the primary sector, etc. Successive stages of activities involve greater degrees of fabrication and generate products with high value-to-weight ratios.

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TABLE 22

IMPORTS OF SELECTED COMMODITIES: SELECTED FOREIGN MARKETS

SITC		Item	Colombia Amount (10^6kg)	Colombia Value ($1000)	Venezuela Amount (10^6kg)	Venezuela Value ($1000)	Japan (1975) Amount (10^6kg)	Japan (1975) Value ($1000)
283	3	Bauxite	3.4	336	0.6	481	4173.1	71,491
684		Aluminum	15.0	15675	5.3	8618	363.3	331,135
684	2	Alum. Alloy, Worked	3.4	4144	5.2	8282	20.1	37,256
691	2	Alum. Struc. Parts	--	--	0.1	218	0.7	2,591
696		Cutlery	0.1	1395	1.3	6763	NA	20,498
711	5	Auto Engines	6.1	23651	18.7	67985	6.9	49,116
714		Office Machines	1.7	13872	2.7	51926	NA	504,192
714	2	Accounting Machines	0.2	3582	0.6	16816	NA	33,168
724	1	Televisions	0.1	925	0.5	2300	141.2	9,964
724	2	Radios	NA	NA	1.8	16026	2622.7	21,670
725		Domestic Elec. Appl.	NA	NA	10.1	34326	NA	58,142
725	1	Refrigerators	0.4	847	--	--	--	--
725	2	Washing Machines	0.1	308	--	--	--	
729	1	Batteries	0.5	815	1.9	3264	2.4	13,981
729	2	Lamps	--	--	1.2	6634	0.5	11,691
732	8	Motor Veh. Parts	11.9	30504	31.7	76548	--	47,387
812	4	Lighting Equipment	0.2	1154	--	--	NA	NA
861	2	Spectacles & Frames	NA	NA	0.1	1282	NA	36,201
861	3	Optical Instruments	0.1	337	0.1	1767	--	--
861	7	Medical Equipment	0.2	2756	0.6	6076	2.6	61,253
862	4	Film	0.7	4823	1.4	11922	NA	93,178
891	4	Mus. Instr. (String)	--	203	0.5	1940	1.1	9,919
897		Jewelry	NA	469	NA	3558	NA	63,144

Source: Ref. 75

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TABLE 23

U. S. DOMESTIC PRODUCTION AND IMPORTS OF SELECTED COMMODITIES

Schedule A	Item	SIC	Domestic Production $M	Imports $M	Total $M	Imports as % of Total
684 2	Wrought Aluminum	3334	2759.8	75.581	2835.4	2.7
711 5	Auto Engines	3714	22758.9	1256.544	24015.4	5.2
729 4	Elec. auto equip.	3694	2095.1	111.009	2206.1	5.0
714 2	Calc. & Add. Mach.	3574	365.1	335.318	1200.4	27.9
714 9	Office Machines	3579	1455.9	438.976	1894.9	23.1
724 2	Radios	36511	675.7	661.379	1337.1	49.4
812 4	Lighting Fixtures	3645	644.1	59.197	703.2	8.4
861 2	Spectacles & Frames	3851	648.4	101.074	749.4	13.5
861 3	Microscopes	--	947.6	63.338	1010.9	6.3
861 7	Medical Instruments	38410	1612.5	98.836	1711.3	5.8
862 4	Film	38615	1956.6	183.882	2140.4	8.6
891 8	Musical Instruments	3931	719.3	52.885	772.1	6.8
897 1	Jewelry	3931	1330.8	126.953	1457.7	8.7
696	Table Flatware	3914	333.9	119.833	453.7	26.4

Source: Ref. 77

Three alternative development scenarios were defined, corresponding to the stages of aluminum production, and preliminary investigation was carried out to evaluate the availability of critical inputs, such as energy, required to establish an aluminum industry at the Santarem location. Finally, a quantitative analysis was performed to analyze levels of production and commodity shipments associated with an aluminum-based industrial center of the type hypothesized.

Market Analysis

An assessment of the market potential for the list of suggested products was made using domestic production and import data for the selected countries: Columbia, Venezuela, Japan, and the United States. Domestic production data were also collected for Brazil.

United Nations publications provided sources of data for countries other than the United States. Import figures were obtained from Refs. 75 and 76. Data for the United States were taken from Refs. 77 and 78.

Production data for Colombia and Venezuela were fragmentary. Though the data were essentially complete for Japan, differences in accounting conventions made exact comparisons with import data impossible for these three countries.* Nevertheless, examination of the import data alone revealed that significant amounts of all of the commodities under analysis were imported into the three countries. For example, in 1974 Venezuela imported $68 million in auto engines and $16 million in radio receivers. Colombia imported almost $14 million in office machines and $30 million in auto vehicle parts. Japan, even with its large domestic auto industry, still imported $49 million worth of auto engines in 1975. All countries imported sizable amounts of primary aluminum and worked alloys.

It was also possible to work rough conversions on certain of the production data for Japan (primary aluminum, television and radio receivers) and to determine that these imports constituted roughly 25 percent of total Japanese consumption in the case of aluminum, and 10 to 15 percent in the case of televisions and radios.

Production and import data for the US were available in a more consistent form, and it was possible to determine the percentage of consumption (domestic shipments plus imports) which was met by imports. This proportion ranged from 2.7 percent of the total domestic consumption for wrought aluminum to almost 50 percent of the total consumption in the case of radio receivers. Auto engines and auto electrical parts were imported in relatively small quantities, while significant amounts of office machines (23 percent), adding and calculating machines (28 percent), table flatware (26 percent), and eyeglasses (13 percent) were imported.

It is clear then, that a definite import market for all of these commodities exists in the US. A market for most of them exists in Colombia,

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* Production data were in physical units, while import data were in dollar values.

Venezuela, and Japan as well. The ultimate test of international marketability of commodities produced at Santarem would be their projected cost competitiveness. With production costs at competitive levels, and an aggressive export marketing plan, Brazil should be able to find world markets for many of these commodities.

Feasibility of Aluminum Production at Santarem

At this point, the analysis returned to the beginning of the production chain, recognizing that bauxite must first be transformed into alumina and this, in turn, into aluminum. Thus, at least two major production steps are involved; refining and smelting. It was further assumed that the standard processes would be utilized for these production steps:

- Bayer's refining method (consisting of digestion, clarification, precipitation, and calcination
- Hall-Heroult electrolytic smelting process (molten cyrolite bath with carbon electrodes)

As in any manufacturing activity, there are several basic requirements:

- raw materials (or semi-finished products)
- energy
- labor
- capital
- site
- access to markets
- timing

1. Raw Materials

With respect to raw materials, it was assumed that the local deposits of bauxite would be adequate to support the industrial activity. But practically all other material inputs would have to be brought in since the local resource base, not to mention the present local base, is limited. This import is possible, particularly via air or water, but would entail additional costs. As the city develops, and as its industrial base broadens, some of these inputs might be provided locally. In particular, a wood supply for making charcoal is available from the nearby forests.

2. Energy

Energy is probably the limiting element for the type of industry examined here. Aluminum smelting, after all, is among the most energy-intensive industrial activities*, and the search has always been for the cheapest hydroelectric power source.

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* About 4 to 8 kilowatt-hours of electricity are needed to produce 1 pound of aluminum from about 2 pounds of alumina. Also, 0.5 pounds of carbon are consumed. A single smelting cell can produce 2000 pounds per day, and they are usually hooked up in a potline (or potroom) of 50 to 150 cells.

About 80 percent of Brazil's electric power comes from hydroelectric sources. This high reliance on hydro power is expected to continue into the 1990s. It is estimated that less than 10 percent of the country's 200,000 MW of potential hydroelectric power is currently being tapped. Development pressures in the North and Northeast have increased, and several areas in the Amazon region have been identified by the RADAM project as potential locations for hydroelectric facilities.*

One major project in progress is an $810 million dam and generating station on the Tocantins River at Tucurui. This facility, being constructed by a Japanese-Brazilian joint venture (ALBRAS) under the control of ELECTRONORTE, is a part of a $3 billion development, including an alumina plant and aluminum smelter. The powerplant will have a 1850 MW capacity when it goes on stream in 1981. Capacity will be increased to 2700 MW by 1985.

Additional studies are underway on the Xingu and Tapajos Rivers. A small (40 MW) hydro plant is under construction in the Santarem area by Centrais Electricas do Para. The Amazon River flowing past the city cannot be regarded as a major power source because, even though it carries a huge amount of water, the current is slow and there are no falls or rapids. There is no readily available technology to extract this low-density energy, and any such efforts would involve such tremendous and expensive capital improvements as to make the whole operation infeasible.

There are substantial differences in elevation and rapids on the Tapajos River about 170 miles south of Santarem. This is a major river in its own right and, consequently, there is a reasonable assurance that an adequate power supply can be obtained from this source. Several plans of this type have been under consideration.

3. Labor

In order to compete in the world market, the aluminum smelting operations at Santarem would have to be among the most modern possible. This means automation, mechanization, computer control, and relatively little direct labor input.** Since the requirement is for highly skilled workers, the local labor pool cannot be expected to satisfy these needs, and in-migration would be necessary.

The same conditions are also likely to hold for other industries associated directly or indirectly with the aluminum operations. There has been, however, a long-standing tradition of labor migration in Brazil and in the Amazon basin, and thus labor shortage is not likely to be a constraining factor. Highly skilled workers will presumably be attracted from the worldwide reservoir, but they would, of course, expect premium wages.

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* From Brazilian Trends, 1974/75.

** The current man-hour requirement for a ton of aluminum produced is about 12.

4. Capital, Site, and Market Access

It was assumed further that capital availability would not be a problem as long as the entire operation were economically feasible. No difficulties were envisioned in finding a suitable site for the plants because of the open and largely level landscape. The questions related to access to markets were the central issue of this study project, and will be examined at a later point.

5. Timing

With respect to the time horizon for development, experts in construction projects who were consulted indicated that most types of manufacturing plants can currently be prefabricated and assembled on-site within a period of two years. Development of hydroelectric generating facilities, in contrast, requires a minimum lead-time of ten years (5 for design and 5 for construction). The scheduling of energy development projects in the Amazon region, therefore, represents the critical factor in determining the timing at which an aluminum-based industrial activity of the type under examination may be in production. As mentioned, a similar project involving both power generating and primary aluminum production in the area is currently in progress and is scheduled for completion in 1985.

Industrial Development Scenarios

In order to identify the potential demand for transportation associated with an aluminum-based industrial center in the Amazon region of Brazil, three phases of aluminum production capability were hypothesized. Realistic levels of output and input requirements were specified for industrial activity comprising each phase to evaluate transportation demands associated with development. The following procedures were applied:

- A chain of activities associated with aluminum was identified by examining input linkages between industrial sectors (at the four-digit SIC level). The US BEA input-output tables provided the data for this study (Ref. 79).* Specific sectors selected for analysis required inputs of aluminum and were related to product groups identified previously by the research team as Brazilian exports (see Market Analysis section).

- Development scenarios (or production phases) were next formulated in quantitative terms. The first phase hypothesized local production of primary aluminum products for export. The second and third phases added local production of various intermediate and final products.

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* It may be noted that the technologies in use for the US at the time these data were compiled may differ somewhat from those adopted for production in Brazil. This analysis was intended to provide only order-of-magnitude estimates and should be interpreted accordingly.

Levels of output were defined by assuming that one primary aluminum plant of median size for the US* would be located at Santarem. Local output of bauxite ores was assumed to be sufficient to supply this plant. Output levels for sectors manufacturing intermediate and final products were defined to be consistent with the local availability of primary aluminum products.

- Input-output analysis was applied to evaluate the local economic base and imports necessary to support production hypothesized for each phase. Estimated input requirements included labor, energy, and materials.**

- At this stage, the value of products and input requirements had been identified and expressed in terms of US price levels (base year 1972). A final step was performed to evaluate the physical quantities of products and inputs associated with each project phase, and the value-to-weight ratios for commodities requiring transportation services.

Figure 50 and Tables 24 through 26 illustrate the three production phases analyzed. The first phase (Table 24) involves local production of primary aluminum products such as ingots and structural shapes for export. In this phase, the industrial base at Santarem would be one step beyond activities presently carried out in the region; i.e., extraction of bauxite and reduction of ores to alumina. A single primary aluminum plant was hypothesized, producing approximately 100,000 tons of products annually.

In the second phase, activities which fabricate intermediate industrial products from primary aluminum inputs would be added to the local industrial base. These are aluminum casting, and rolling and drawing of aluminum, operations which fabricate products such as sheets and wire. Output levels for these intermediate sectors were determined by allocating one-third of the local output of primary and intermediate products. As indicated in Table 25, the value of exports more than doubled, from $47 million to $114 million, and local production tripled, from $52 to $150 million, when intermediate production was added to the economic base under the hypothesized assumptions.

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* Data on median plant size was available from the US Census of Manufacturers (Ref. 74). The assumption of a single plant is not restrictive, since results can be scaled to apply to smaller or larger plants as well as more than one plant.

** The analysis employed the direct-requirements tables of the input-output model. These data indicate a production function for each sector; that is, the quantity of various inputs required per unit output in each relevant activity. Note that only direct input requirements have been evaluated. Both the economic base at the city and import requirements would actually be larger than this analysis indicated due to local multiplier effects.

HYPOTHESIZED ALUMINUM COMPLEX

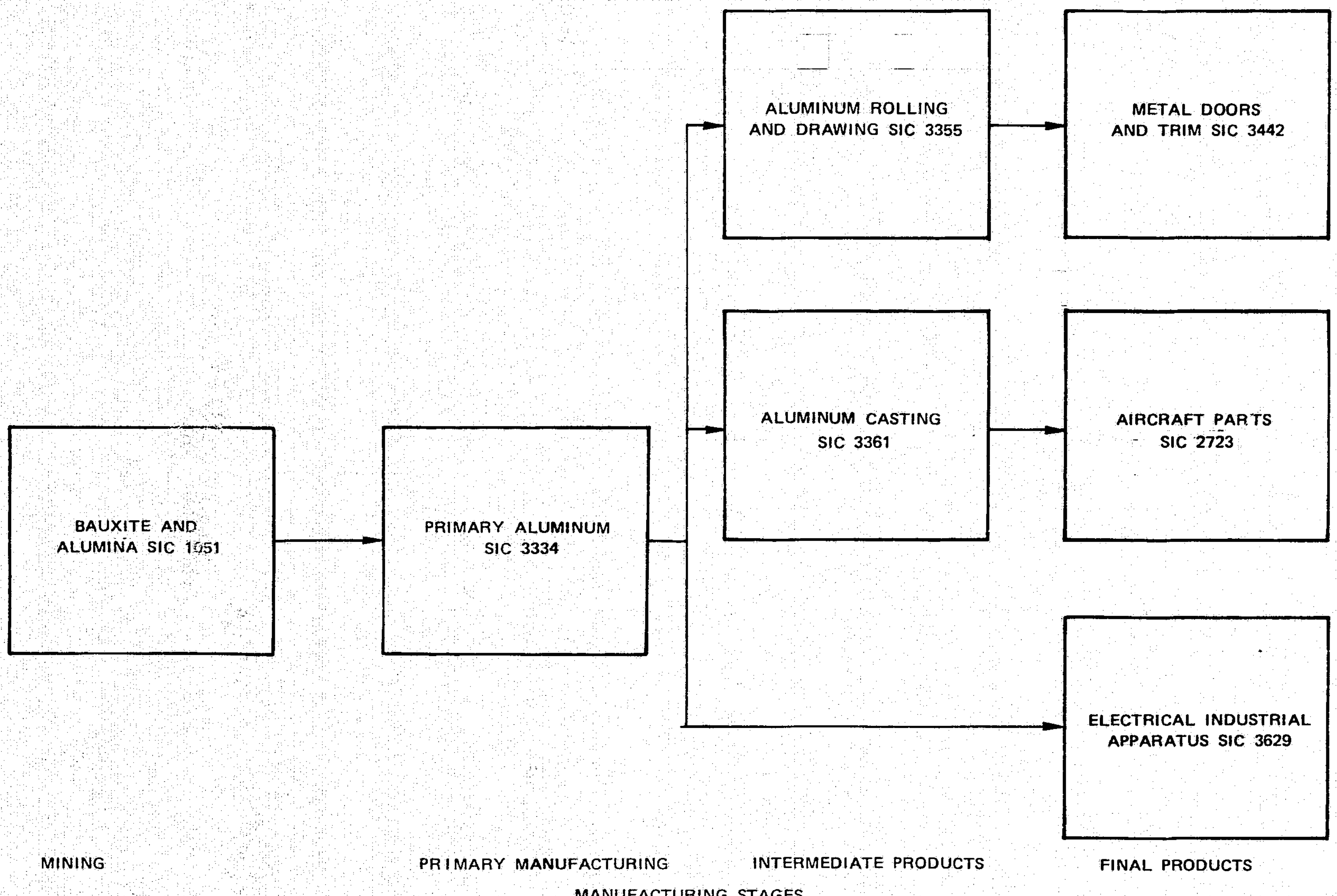

FIG. 50

TABLE 24

PHASE 1, ALUMINUM INDUSTRIAL COMPLEX
PRIMARY MANUFACTURING
(THOUSANDS OF U.S. DOLLARS)

Sector	Output	Local Forward Linkage	Exports	No. of Median Sized U.S. Plants
Mining				
Bauxite & Alumina	3,737.0	3,737.0	0.0	- -
Primary Mfg.				
Primary Aluminum	47,843.0	0.0	47,843.0	1.0
TOTAL	51,580.0	3,737.0	47,843.0	

TABLE 25

PHASE 2, ALUMINUM INDUSTRIAL COMPLEX
PRIMARY AND INTERMEDIATE PRODUCTS
(THOUSANDS OF U.S. DOLLARS)

Sector	Output	Local Forward Linkage	Exports	No. of Median Sized U.S. Plants
Mining				
Bauxite & Alumina	3,737.0	3,737.0	0.0	- -
Primary Mfg.				
Primary Aluminum	47,843.0	31,895.3*	15,947.7	1.0
Intermediate Products				
Aluminum Rolling and Drawing	32,837.2	0.0	32,863.5	6.8
Aluminum Casting	65,429.0	0.0	65,429.0	15.0
TOTAL	149,846.2	35,632.3	114,240.2	

* Linkages to aluminum rolling and drawing and aluminum casting industries

TABLE 26

PHASE 3, ALUMINUM INDUSTRIAL COMPLEX
PRIMARY, INTERMEDIATE AND FINAL PRODUCTION

(Thousands of U.S. Dollars)

Sector	Output	Local Forward Linkage	Exports	No. of Median Sized U.S. Plants
Mining				
Bauxite & Alumina	3,737.0	3,737.0	0.0	- -
Primary Mfg.				
Primary Aluminum	47,843.0	47,843.0*	0.0	1.0
Intermediate Products				
Alum. Rolling & Drawing	32,863.5	16,431.8**	16,431.8	10.2
Alum. Casting	65,429.0	32,714.5***	32,714.5	22.5
Final Products				
Alum. Doors & Windows	91,401.2	0.0	91,401.2	21.9
Elec. Indus. Appar.	324,225.3	0.0	324,225.3	45.6
Aircraft Parts	422,668.0	0.0	422,668.0	14.9
TOTAL	988,167.0	100,726.3	887.440.8	

* Linkages to aluminum rolling and drawing, aluminum castings and industrial apparatus sectors

** Linkage to door and window manufacturing

*** Linkage to aircraft parts sector

The third phase would further expand the economic base of the industrial complex by adding a forward linkage to three selected final product groups. These are: electrical industrial apparatus produced with inputs of primary aluminum, doors and windows fabricated from rolled aluminum sheets, and a sector manufacturing aircraft parts which is linked to the aluminum casting industry. The aircraft parts and metal door sectors were assumed to absorb fifty percent of the output of the local aluminum rolling and casting sectors. The production of industrial apparatus was allocated one-third of the local primary aluminum production, with the remaining two-thirds of primary products again utilized as raw materials for intermediate sectors, as in phase 2. Under these assumptions, regional exports would consist of both intermediate and final products. As indicated in Table 26, the addition of the third manufacturing stage would boost the value of regional output to nearly $1 billion, with regional exports of nearly $900 million.

Tables 27, 28, and 29 show the dollar value of all inputs required in each phase, aggregated at the 2-digit SIC level. For Phase 1, the primary aluminum process would require large inputs of chemicals, petroleum, and electricity, in addition to alumina.

The addition of the intermediate manufacturing processes of aluminum casting and aluminum rolling and drawing would alter the distribution of inputs significantly. Primary metals would play a major role, accounting for one-third of the total factor costs. Utilities, transportation, and wholesale and other services would become much more important, comprising about 15 percent of the total. Phase 3 adds three advanced manufacturing processes, more than quadrupling the input requirements of primary metals, and causing a twenty-fold increase in the input of fabricated metals, chiefly aluminum. The demand for electric power would increase by a factor of three over that in phase 2. Similarly, inputs of services and advanced manufacturing sectors (such as machinery) would be greatly expanded, while the primary manufacturing and food sectors would hardly be affected. An exception is paper products, of which some $16.5 million would be consumed by the electric industrial apparatus industry.

Table 30 shows the output in physical dimensions (10^6 kg and units) for each of the three phases, based on US prices. Demand for transportation for export of finished products would be the same for both phases 1 and 2. This results from the fact that, in phase 1, all of the primary aluminum output would be exported, while in phase 2, the portion of primary aluminum which was not exported would ultimately leave the area in the form of rolled and cast aluminum shapes.

Phase 3 would result in greatly increased transportation requirements, as the final processes of manufacturing doors, aircraft parts, and electrical aparatus would result in large weight gains. However, the value-to-weight ratio would increase still further, rendering air transportion more appropriate for output of this final phase of production.

TABLE 27

SUMMARY OF INPUT REQUIREMENTS:
PHASE 1 - PRIMARY MANUFACTURING

(Thousands of U.S. Dollars)

SECTOR	BAUXITE	PRIM AL	AL R&D	AL CAST	DOORS	EL APP	AIRC PRT			TOTAL
AGR	0.	C.	0.	C.	0.	0.	0.	0.	0.	0.
MIN	11.	3963.	0.	C.	0.	0.	0.	0.	0.	3975.
CONSTR	39.	162.	0.	0.	0.	0.	0.	0.	0.	202.
ORDN	0.	0.	0.	C.	0.	0.	0.	0.	0.	0.
FOOD	0.	169.	0.	C.	0.	0.	0.	0.	0.	169.
TOBAC	0.	C.	0.	0.	0.	0.	0.	0.	0.	0.
TEXT	0.	25.	0.	0.	0.	0.	0.	0.	0.	25.
APPAR	0.	12.	0.	0.	0.	0.	0.	0.	0.	12.
LUMB	22.	1.	0.	0.	0.	0.	0.	0.	0.	23.
FURN	0.	C.	C.	0.	0.	0.	0.	0.	0.	0.
PAPER	1.	5.	C.	0.	0.	0.	0.	0.	0.	6.
PRINT	0.	2.	0.	0.	0.	0.	0.	0.	C.	2.
CHEM	113.	1118.	0.	0.	0.	0.	0.	0.	0.	1230.
PETROL	20.	1315.	0.	0.	0.	0.	0.	0.	C.	1335.
RUBBER	21.	7.	0.	0.	0.	0.	0.	0.	0.	28.
LEATHER	0.	14.	0.	0.	0.	0.	0.	0.	0.	14.
SC&G	5.	155.	0.	0.	0.	0.	0.	0.	0.	160.
PR MET	47.	1134C.	0.	0.	0.	0.	0.	0.	C.	11387.
FAB MET	19.	1C.	0.	C.	0.	0.	0.	0.	0.	29.
MACH	269.	35.	0.	0.	0.	0.	0.	0.	0.	304.
EL MACH	7.	312.	0.	0.	0.	0.	0.	0.	0.	319.
TRANS EQ	6.	1.	0.	0.	0.	0.	0.	0.	0.	7.
SCI INST	0.	5.	0.	0.	0.	0.	0.	0.	C.	5.
MISC MFG	5.	1419.	C.	0.	0.	0.	0.	0.	0.	1425.
TRANS	117.	479.	0.	0.	0.	0.	0.	0.	0.	596.
COM&PU	97.	4316.	0.	0.	0.	0.	0.	0.	C.	4413.
WH&RET	91.	58C.	0.	0.	0.	0.	0.	0.	C.	671.
FIRE	239.	332.	0.	C.	0.	0.	0.	0.	0.	570.
SERV	37.	33C.	0.	0.	0.	0.	0.	0.	0.	368.
GOVT	5.	11.	C.	0.	0.	0.	0.	0.	0.	16.
IMPORTS	1055.	4766.	0.	0.	0.	0.	0.	0.	0.	5821.
OTHER	828.	84CC.	C.	0.	0.	0.	0.	0.	C.	9233.
W&S	682.	8553.	0.	0.	0.	C.	0.	C.	0.	9235.
	3737.	47843.	0.	0.	0.	0.	0.	0.	0.	51580.

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TABLE 28

SUMMARY OF INPUT REQUIREMENTS:
PHASE 2 - PRIMARY & INTERMEDIATE PRODUCTS

(Thousands of U.S. Dollars)

SECTOR	BAUXITE	PRIM AL	AL R&D	AL CAST	DOORS	EL APP	AIRC PRT			TOTAL
AGR	0.	C.	C.	C.	0.	0.	0.	0.	0.	0.
MIN	11.	3963.	16.	278.	0.	0.	0.	0.	0.	4268.
CONSTR	39.	162.	157.	180.	0.	0.	0.	0.	C.	539.
ORDN	0.	0.	1.	0.	0.	0.	0.	0.	0.	1.
FOOD	0.	169.	C.	11.	C.	0.	0.	0.	0.	180.
TOBAC	0.	C.	0.	0.	0.	0.	0.	0.	0.	0.
TEXT	0.	25.	C.	0.	0.	0.	0.	0.	0.	25.
APPAR	0.	12.	19.	81.	0.	0.	0.	0.	0.	113.
LUMB	22.	1.	23.	33.	0.	0.	0.	0.	0.	78.
FURN	0.	C.	C.	13.	0.	0.	0.	0.	0.	13.
PAPER	1.	5.	7.	167.	0.	0.	0.	0.	0.	180.
PRINT	0.	2.	2.	7.	0.	0.	0.	0.	0.	11.
CHEM	113.	1116.	67.	687.	0.	0.	0.	0.	0.	1984.
PETROL	20.	1315.	51.	215.	0.	0.	0.	0.	C.	1601.
RUBBER	21.	7.	6.	152.	0.	0.	0.	0.	0.	186.
LEATHER	0.	14.	6.	4.	0.	0.	0.	0.	0.	24.
SC&G	5.	155.	1.	292.	0.	0.	0.	0.	0.	452.
PR MET	47.	11340.	17437.	25417.	0.	0.	0.	0.	0.	54241.
FAB MET	19.	10.	76.	192.	0.	0.	0.	0.	0.	297.
MACH	269.	35.	36.	9126.	0.	0.	0.	0.	0.	9466.
EL MACH	7.	312.	3.	886.	0.	0.	0.	0.	0.	1208.
TRANS EQ	6.	1.	2.	407.	0.	0.	0.	0.	0.	416.
SCI INST	0.	5.	5.	129.	0.	0.	0.	0.	0.	140.
MISC MFG	5.	1419.	2.	48.	0.	0.	0.	0.	0.	1474.
TRANS	117.	479.	530.	868.	0.	0.	0.	0.	C.	1994.
COM&PU	97.	4316.	692.	1609.	0.	0.	0.	0.	0.	6715.
WH&RET	91.	580.	626.	770.	C.	0.	0.	0.	G.	2067.
FIRE	239.	332.	324.	918.	0.	0.	0.	0.	0.	1812.
SERV	37.	330.	637.	893.	0.	0.	0.	0.	0.	1897.
GOVT	5.	11.	21.	77.	C.	0.	0.	0.	0.	114.
IMPORTS	1055.	4766.	636.	0.	C.	0.	0.	0.	0.	6456.
OTHER	828.	8406.	5958.	2571.	0.	0.	0.	0.	0.	17762.
W&S	682.	8553.	5496.	19396.	0.	0.	0.	0.	C.	34127.
	3737.	47843.	32837.	65429.	0.	0.	0.	0.	0.	149846.

TABLE 29

SUMMARY OF INPUT REQUIREMENTS
PHASE 3 - PRIMARY, INTERMEDIATE, & FINAL PRODUCTS
(Thousands of U.S. Dollars)

SECTOR	BAUXITE	PRIM AL	AL R&D	AL CAST	DOORS	EL APP	AIRC PRT			TOTAL
AGR	0.	C.	0.	0.	0.	0.	0.	0.	0.	C.
MIN	11.	3963.	16.	278.	6.	78.	0.	0.	0.	4353.
CONSTR	39.	162.	157.	180.	153.	291.	832.	0.	0.	1814.
ORDN	0.	0.	1.	0.	4.	0.	0.	0.	0.	5.
FOOD	0.	169.	0.	11.	C.	0.	0.	0.	0.	18C.
TOBAC	0.	C.	0.	0.	0.	0.	0.	0.	C.	C.
TEXT	0.	25.	0.	C.	0.	0.	0.	0.	C.	25.
APPAR	0.	12.	19.	81.	125.	333.	378.	0.	C.	949.
LUMB	22.	1.	23.	33.	428.	421.	8.	0.	0.	936.
FURN	0.	0.	0.	13.	187.	150.	0.	0.	0.	351.
PAPER	1.	5.	7.	167.	955.	16409.	883.	0.	0.	18428.
PRINT	0.	2.	2.	7.	16.	33.	824.	0.	C.	883.
CHEM	113.	1118.	67.	687.	914.	4747.	174.	0.	C.	7820.
PETROL	20.	1315.	51.	215.	179.	925.	777.	0.	0.	3482.
RUBBER	21.	7.	6.	152.	60.	3299.	119.	0.	C.	3665.
LEATHER	0.	14.	6.	4.	4.	20.	25.	0.	0.	73.
SC&G	5.	155.	1.	292.	5201.	4623.	1525.	0.	C.	1180C.
PR MET	47.	1134C.	17437.	25417.	27326.	50198.	74527.	0.	0.	2C6292.
FAB MET	19.	1C.	76.	192.	9500.	12283.	30558.	0.	0.	52638.
MACH	269.	35.	36.	9126.	227.	31022.	28494.	0.	0.	69209.
EL MACH	7.	312.	3.	886.	35.	35553.	1673.	0.	0.	38469.
TRANS EQ	6.	1.	2.	407.	19.	470.	45969.	0.	0.	46875.
SCI INST	0.	5.	5.	129.	29.	255.	115.	0.	0.	539.
MISC MFG	5.	1419.	2.	48.	38.	39.	153.	0.	0.	1705.
TRANS	117.	479.	530.	868.	1325.	2816.	3401.	0.	0.	9536.
COM&PU	97.	4316.	692.	1609.	1212.	3058.	7185.	0.	0.	18170.
WH&RET	91.	58C.	626.	770.	3244.	10467.	9627.	0.	C.	25405.
FIRE	239.	332.	324.	918.	2536.	2316.	2539.	0.	0.	9204.
SERV	37.	33C.	637.	893.	1629.	2989.	9691.	0.	0.	16206.
GOVT	5.	11.	21.	77.	116.	252.	696.	0.	0.	1179.
IMPORTS	1055.	4766.	636.	0.	0.	4253.	4450.	0.	0.	15160.
OTHER	828.	8406.	5958.	2571.	13013.	16984.	48632.	0.	0.	96391.
W&S	682.	8553.	5496.	19396.	22919.	119941.	149411.	0.	0.	326397.
	3737.	47643.	32837.	65429.	91401.	324225.	422668.	0.	0.	988140.

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TABLE 30

SANTAREM ALUMINUM INDUSTRY SUMMARY

	Value of Output Exported ($1,000)	Unit Price ($/kg)	Quantity of Output Exported (10^6 kg)
PHASE 1: PRIMARY MANUFACTURING			
Primary Aluminum	47,843.0	0.46	103.3
PHASE 2: PRIMARY AND INTERMEDIATE MANUFACTURING			
Primary Aluminum	15,947.7	0.46	34.5
Aluminum Rolling & Drawing	32,863.5	0.89	36.8
Aluminum Casting	65,429.0	2.04	32.0
PHASE 3: PRIMARY, INTERMEDIATE, AND FINAL MANUFACTURING			
Aluminum Rolling & Drawing	16,431.8	0.89	18.4
Aluminum Casting	32,714.5	2.04	16.0
Aluminum Doors & Windows	91,401.2	3.77	24.4
Electrical Industrial Appar.	324,225.3	2.59	125.1
Aircraft Parts	422,668.0	23.70	17.8

Development of a Livestock Industry at Santarem

By contrast with the process for development of an entirely new, high-technology industry, such as the aluminum industry described above, the analysis of a livestock industry was concerned more with scope than with form because livestock raising is already a major industry in Amazonia. According to Ref. 35, the Polamazonia Plan is to have 5 million head of cattle in the Amazon region by 1983, which is 5.7 percent of Brazil's 1974 herds. The plan also calls for the establishment of 4 meatpacking plants, each with 300,000 head/year capacity.

While the assumption is certainly an arbitrary one, and perhaps somewhat optimistic, it was assumed that the Santarem A/I city itself would process an amount equal to this total by 1985. This would not be the total production of Amazonia, since by that time the total is expected to grow beyond the 1983 plan. However, it is reasonable to assume that the large majority of production would be at Santarem, given the development of the A/I city, because of the excellent facilities, manpower, and transportation capacity it would provide.

According to data for the US cattle industry (Ref. 80), the slaughter rate for cattle is 0.356 head slaughtered per head on the farm. Assuming the same ratio for Brazil, the 5 million head assumed to be available for processing at Santarem would result in a slaughter rate of 1.78 million per year. Translated into weight units, at 499 kg per head, the production rate would be 888 x 10^6 kg per year. Again, based on US data, usable meat products amount to about 277 kg per head and usable hides are about 11 kg per head, the remainder being waste as far as high-value-added product is concerned, though useful for fertilizer, lower-quality animal feed, etc.

A summary of this industry, broken down into production phases as in the case of the aluminum industry discussed above, is given in Table 31. Primary production is 888.1 x 10^6 kg/yr of live cattle. Once intermediate (phase 2) production is achieved, two-thirds of the cattle produced would go into meat and hide production, but with a 52 percent weight loss in the process. The remaining one-third would still be left as live-cattle production, distributed to meat packing plants outside the area, as in the case of phase 1 production. Once the industry was fully developed (phase 3), all cattle production would go into either meat or leather products. Of the 88.1 x 10^6 kg/yr cattle production, this amounts to 403.7 x 10^6 kg/yr meat production and 20.2 x 10^6 kg/yr of leather products. Unit values for all of these products were derived from US industry experience as reported in either Ref. 74 or Ref. 80.

Development of a Timber Industry at Santarem

Similarly to the livestock industry described above, the timber industry was assumed to develop in phases, starting with the production of timber and progressing through phases involving sawmill/pulpmill operations and on into the production of wood and paper products. The scope of the timber industry

TABLE 31

SANTAREM LIVESTOCK INDUSTRY SUMMARY

	Value of Output Exported ($\$10^6$/yr)	Unit Value $/kg	Quantity of Output Exported (10^6 kg /yr)
PHASE 1: PRIMARY PRODUCTION CAPABILITY			
Cattle	626.6	.71	888.1
PHASE 2: INTERMEDIATE PRODUCTION CAPABILITY			
Cattle	208.8	.71	296.0
Meat	344.2	1.28	269.2
Hides	44.1	3.28	13.4
PHASE 3: FINAL PRODUCTION CAPABILITY			
Meat	516.2	1.28	403.7
Leather Products	108.8	5.39	20.2

was postulated based on US experience as reported in Ref. 74, but modified to correspond to an industry based exclusively on hardwoods. A chain of output products for a hardwood-based timber industry is depicted in Fig. 51, which shows the distribution of products by weight and indicates the waste at each stage. In the three phases of development of the timber industry, the output of the primary phase (logging) would be roundwood logs. The second phase would involve processing in sawmills and pumpmills, with lumber and paper (kraft and newsprint) as the additional outputs. The assumption made in this phase was that two-thirds of the logs would be processed into phase 2 products. Finally, in phase 3, the full range of wood and paper products shown at the ends of the various chains in Fig. 51 would be produced. The percentages of each product were based on the assumption that all logs would be processed according to the chains in Fig. 51, with a volumetric loss of 21.6 percent due to waste, and an additional 30 percent weight loss in drying. A complete summary of these industry phases is provided in Table 32, which is in the same format as the previous tables for the aluminum and livestock industries. Unit values for the various products were based on Brazilian exports, where available, or on US Census of Manufactures data in Ref. 74.

Summary of Santarem Potential Output

Having developed the potential output of the three basic industries postulated to comprise the exportable product of the Santarem A/I city, it was possible to summarize the output in a form which could be examined for its air transportability and the required cargo aircraft to handle the product. It was first necessary to postulate a time schedule for the development of the A/I city.

A summary of results by industry and by development phase is provided in Table 33. The dates at which the respective outputs could be achieved, and the scale of each industry in terms of raw material output, are shown in the left-hand columns of the table. The center columns show the annual volume of output in each product category. Thus, for the aluminum industry, the entire output in the first stage would be in the form of primary product, but in the second stage some of this output would be processed into intermediate products. Finally, the third-stage output would consist only of intermediate and final products, and total output volume would increase because the final products would be fabricated both of aluminum and input materials other than aluminum.

The right-hand columns of Table 33 summarize the associated values of the output products for each stage of development. These data were based on export values since it was expected that the primary markets for goods produced at the A/I city would be international rather than domestic.

When all outputs were aggregated by year the result was a projection of exportable products for which estimates could be made of the percentages which would go by air. Summaries of total output by product are provided in Tables 34, 35, and 36 for the three industries analyzed. Also shown for each product are the unit export values and the corresponding air

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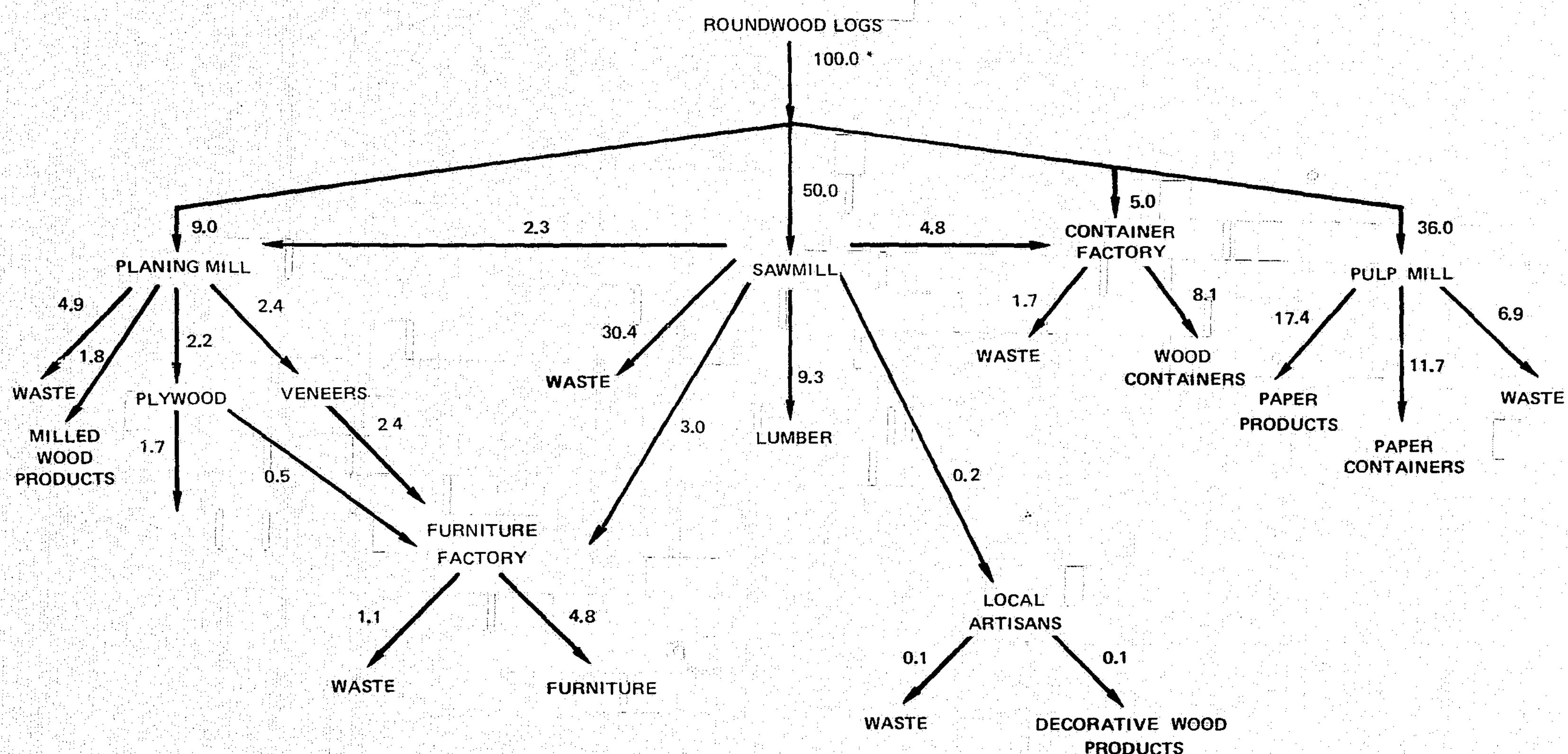
HARDWOOD TIMBER INDUSTRY

CHAIN OF OUTPUT PRODUCTS



* ALL FIGURES INDICATE PERCENT OF LOG WEIGHT. LOG DENSITY IS 1000 kg/m^3.
VOLUMETRIC WASTE IS 21.6%. DRYING WEIGHT LOSS IS 30%.

FIG. 51

TABLE 32

SANTAREM TIMBER INDUSTRY SUMMARY

	Value of Output Exported ($\$10^6$/yr)	Unit Value $/kg	Quantity of Output Shipped (10^6kg/yr)
PHASE 1: PRIMARY PRODUCTION			
Logs	66.2	0.066	1000.2
PHASE 2: INTERMEDIATE PRODUCTION CAPABILITY			
Logs	22.1	0.066	333.4
Lumber, Paper	167.1	0.353	473.5
PHASE 3: FINAL PRODUCTION CAPABILITY			
Lumber, Paper	32.8	0.353	93.0
Wood Products	172.4	1.015	169.9
Paper Products	190.0	0.653	290.9

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TABLE 33

SUMMARY OF SANTAREM INDUSTRIAL DEVELOPMENT SCENARIO

Industry	Phase of Development	Projected Implementation	Scale of Operation	Exportable Outputs: Amount, 10^6 kg/yr Stage:1	2	3	Total	Exportable Outputs: Value, $\$10^6$/yr Stage:1	2	3	Total
Aluminum	1. Primary Manufacturing	1982	200×10^6 kg of Bauxite (1 Primary Aluminum Plant)	103.3	-	-	103.3	47.843	-	-	47.843
	2. Intermediate Products (1)	1982-1985	22.8 Plants	34.5	68.9	-	103.3	15.948	98.292	-	114.240
	3. Final Products (2)	1985-1995	116.1 Plants	0	34.4	167.3	201.7	0	49.146	838.295	887.441
Livestock	1. Ranching	1978-1985	5×10^6 head	888.1	-	-	888.1	626.6	-	-	626.6
	2. Meatpacking, Hides (1)	1980-1985		296.0	282.6	-	578.6	208.8	388.3	-	597.1
	3. Meat & Leather Products (3)	1985-1990		0	403.7	20.2	423.9	0	516.2	108.8	625.0
Timber	1. Logging	1980-1983	1×10^6 m^3/yr	1000.2	-	-	1000.2	66.2	-	-	66.2
	2. Sawmill/Pulpmill (1)	1980-1985		333.4	473.5	-	806.9	22.1	167.1	-	189.1
	3. Finished Wood & Paper (4) Products	1985-1990		0	93.0	460.8	553.8	0	32.8	362.4	395.2

*Stage of production

(1) 2/3 of Stage 1 products are transformed into Stage 2 products.

(2) All Stage 1 products are transformed to Stage 2 products.
¼ of Stage 2 products are transformed into Stage 3 products.

(3) All Stage 1 products are transformed into Stage 2 products.
All hides in Stage 2 are tranformed into Stage 3 leather products.

(4) All Stage 1 products are transformed into Stage 2 products. Volumetric loss is 21.6%. Drying causes additional 30% weight loss. 83% of Stage 2 products are transformed into Stage 3 products.

TABLE 34

ALUMINUM INDUSTRY EXPORTS

Industry	Product Group	Product	Export Output, 10^6 kg/yr 80	85	90	95	00	05	Export Value $/kg	% Air Penetration
Aluminum	Primary Manufacture	Ingots	0	34.4	17.2	0	0	0	0.46	0
	Intermediate Products	Sheets, Wire	0	36.8	27.7	18.4	23.5	27.2	0.89	0
		Castings	0	32.0	24.0	16.0	20.4	23.6	2.03	16.4
	Final Manufacture	Doors and Windows	0	0	12.2	24.4	31.1	36.1	3.77	32.8
		Electric Industrial Appliances	0	0	62.6	125.1	159.7	185.1	2.59	22.8
		Aircraft parts	0	0	8.9	17.8	22.7	26.3	23.70	81.9

TABLE 35

LIVESTOCK INDUSTRY EXPORTS

Industry	Product Group	Product	Export Output, 10^6 kg/yr 80	85	90	95	00	05	Export Value $/kg	% Air Penetration
Livestock	Cattle	Live Animals	888.1	295.7	0	0	0	0	0.71	0
	Meat	Organs	0	30.8	49.9	69.9	88.9	97.1	0.71	0
		Ground Meat	0	75.3	121.6	169.6	216.8	236.8	0.90	0
		Chuck	0	60.8	98.0	137.0	175.1	191.4	1.01	0
		Rib	0	24.5	39.0	55.3	70.8	77.1	1.61	10.1
		Rump	0	5.4	9.1	12.7	15.4	17.2	1.79	12.9
		Round	0	19.05	30.8	42.6	55.3	59.9	1.83	13.5
		Loin	0	60.8	98.0	137.0	175.1	191.4	1.87	14.2
		Veal	0	4.5	7.3	10.0	12.7	14.5	1.85	13.9
	Hides	Hides & Skins	20.0	10.0	0	0	0	0	3.28	0
	Leather	Finished Leather	0	2.1	4.2	5.9	7.5	8.7	4.56	37.9
		Shoecut Stock	0	0.4	0.8	1.1	1.4	1.6	5.25	41.7
		Footwear	0	6.2	12.4	17.4	22.3	25.9	5.00	40.4
		Gloves	0	0.1	0.1	0.1	0.2	0.2	17.06	73.2
		Luggage, Etc.	0	1.3	2.7	0.4	4.8	5.5	8.09	53.2

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TABLE 36

TIMBER INDUSTRY EXPORTS

Industry	Product Group	Product	Export Output, 10^6 kg/yr						Export Value $/kg	% Air Penetration
			80	85	90	95	00	05		
Timber	Logs	Roundwood Logs	0	333.4	0	0	0	0	0.07	0
	Mill	Lumber/Pulp	0	473.5	93.0	130.5	166.5	193.0	0.35	0
	Wood Products	Wood Containers	0	0	80.9	113.5	144.9	167.9	0.46	0
		Plywood	0	0	22.0	30.9	39.5	45.7	0.33	0
		Wood Products	0	0	18.0	25.2	32.1	37.3	0.88	0
		Veneers	0	0	0	0	0	0	1.46	7.4
		Furniture	0	0	48.0	67.3	85.9	99.6	2.27	19.3
		Dec. Wood Art.	0	0	1.0	1.4	1.8	20.7	2.82	25.1
	Paper Products	Kraft	0	0	85.0	119.2	152.1	176.4	0.29	0
		Newsprint	0	0	20.0	28.0	35.7	41.5	0.33	0
		Printing Paper	0	0	49.0	68.7	87.7	101.7	0.95	0
		Paper Containers	0	0	117.0	164.1	209.5	242.9	0.66	[illegible]
		Stationery	0	0	20.0	28.0	35.7	41.5	1.76	12.0

penetrations. These penetrations were estimated on the basis of Fig. 49. Even though some of the articles in Fig. 49 appear in the tables, the air penetration estimates were made on the basis of the middle line on the figure, which represents a reasonable average for Brazilian exports. Since exports to countries other than the US are to be expected, the exact points would not necessarily be correct in any case.

The results for air transportable export volume are shown in Fig. 52. It can be seen that meat and aluminum products comprise the largest shares of air freight carried throughout most of the forecast period. Leather goods, primarily by virtue of their high unit values, also contribute significantly.

Although the volume of air-transportable products projected to 2005 in Fig. 52 may appear large, it is a relatively small fraction of even present Brazilian air cargo, as will be shown in the subsequent air cargo forecasts. Nevertheless, the A/I city contribution to export trade could be an extremely important factor in the regional development of Brazil's Amazon basin. Also, the Santarem location was selected only as one good site for such a city. Additional A/I cities might be developed at the other appropriate Amazon sites discussed in Appendix F, contributing exportable products over and above the projections in Fig. 52 and promoting further opportunities for air transport.

Basic Inputs to Santarem A/I City

Tables 27 to 29 give some indication of the inputs required for the aluminum-based industry at Santarem. These inputs are relatively small compared to projected output. Moreover, inputs to the livestock and timber industries are even smaller, relative to outputs, suggesting that a backhaul problem could be expected for all transport modes serving the city, but particularly for international air transport because of its high-value cargo concentration. This backhaul problem must be considered in the context of the total Brazilian air cargo picture, and the subject will be taken up further on.

Some factor inputs which are important to socio-economic objectives, and other national goals which are addressed in the Sociopolitical analysis, are presented in Table 37. These factors include energy, manpower, and capital investment requirements associated with each phase of the three primary industries. The figures quoted in the table come from the same source as the output product data in each case, and were derived in the form of scaling factors related to output volume. The table summarizes the factor inputs scaled to the projected initial output volumes of each product category.

When the initial inputs in Table 37 were projected, according to the corresponding projections of industry output volumes presented earlier, estimates for future input needs were obtained. These projections are

AIR FREIGHT DEMAND AT SANTAREM AIRPORT/INDUSTRIAL CITY

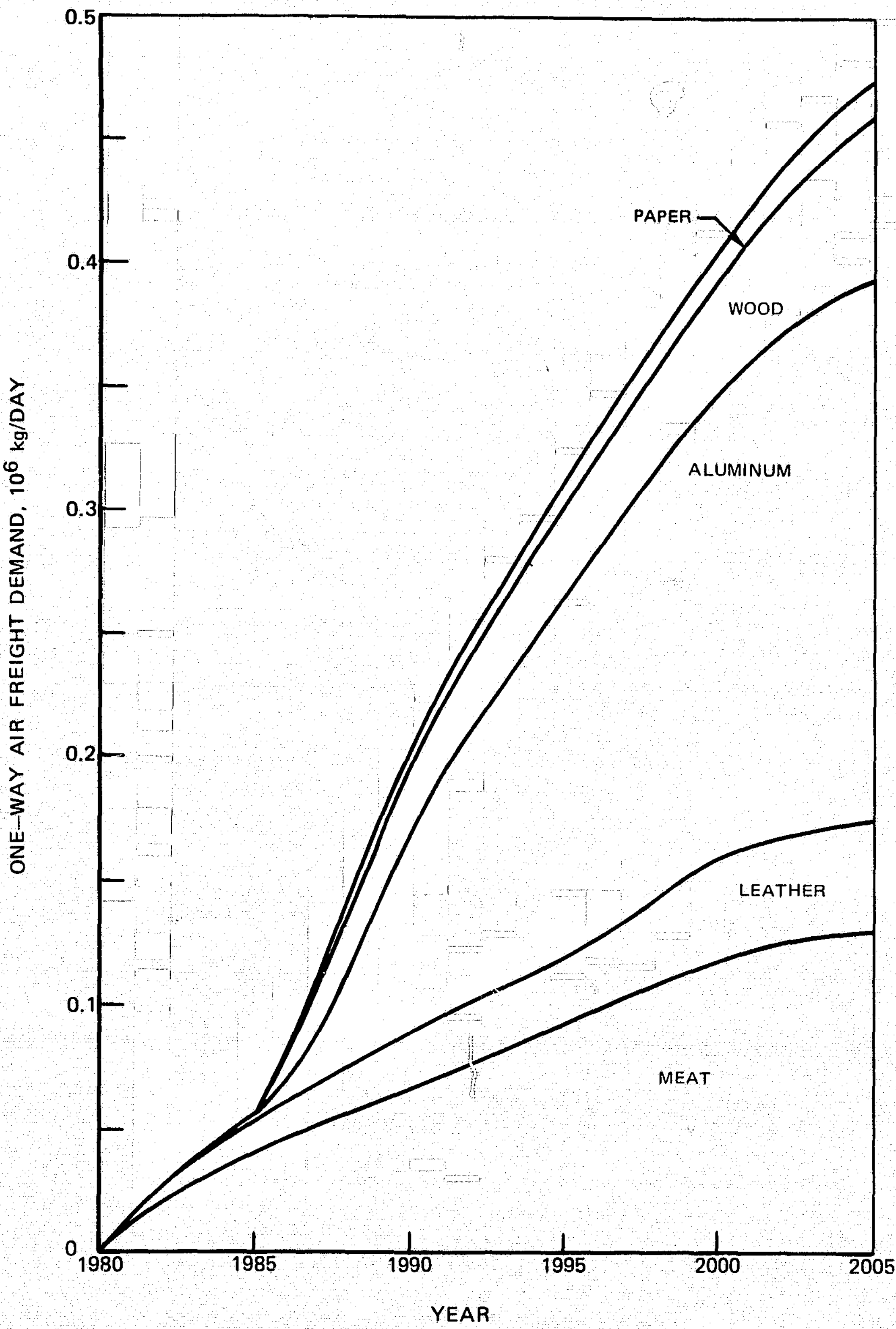
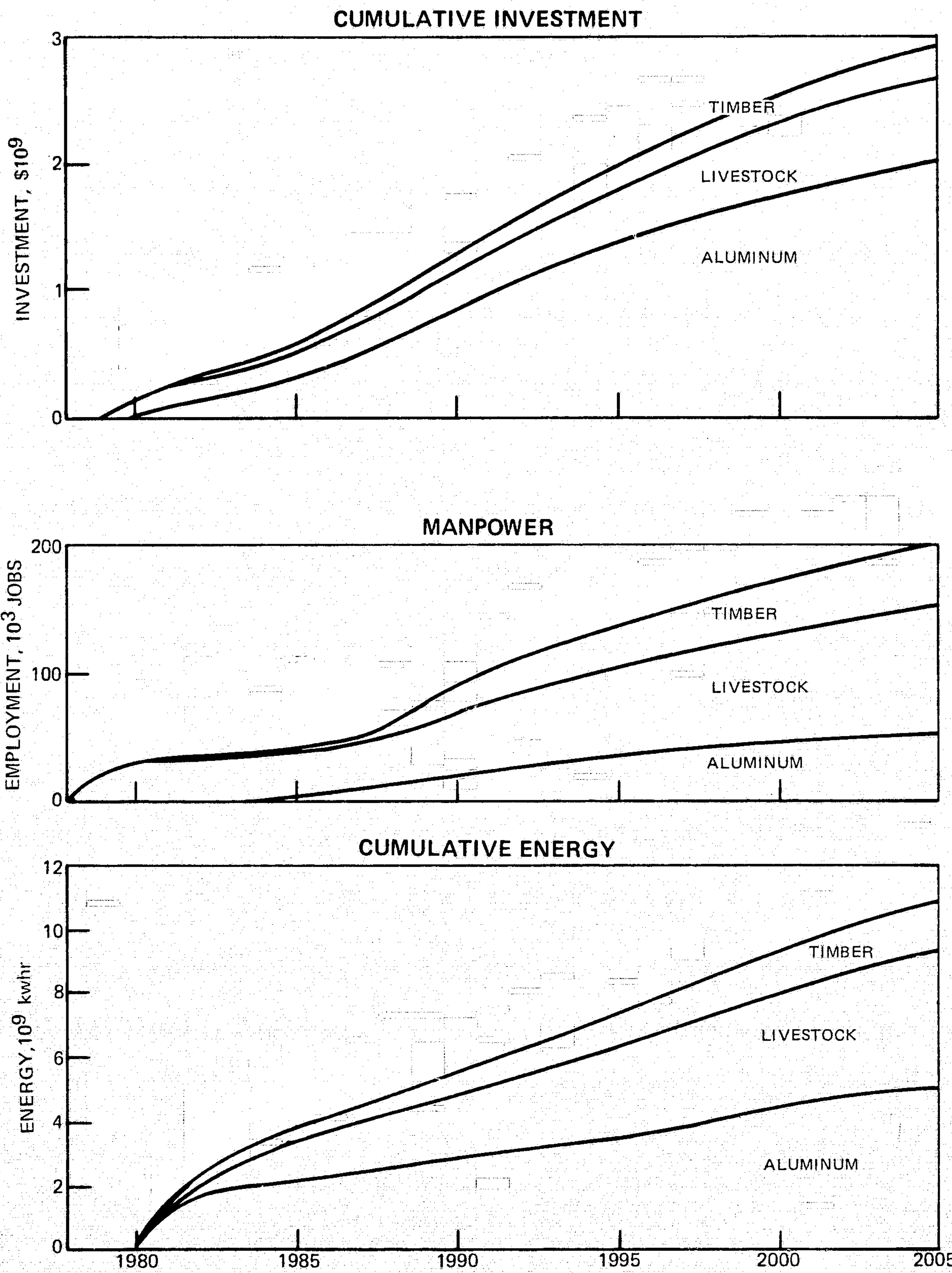


TABLE 37

CUMULATIVE INPUTS

Industry	Phase of Development	Avg. Unit Value $/kg	Energy, 10^9 kWh	Labor 10^3 workers	Capital Investment, $\$10^6$
Aluminum	1. Primary Manufacturing	0.46	1.7	0.789	135.5
	2. Intermediate Products	1.10	2.22	3.323	278.8
	3. Final Products	4.40	3.46	33.532	1315.9
Livestock	1. Ranching	0.40	0	29.37	112.70
	2. Meatpacking, Hides	0.90	1.205	33.66	201.77
	3. Meat & Leather Products	1.37	2.006	47.57	304.46
Timber	1. Logging	0.07	0.2434	1.455	15.876
	2. Sawmill/Pulpmill	0.24	0.3983	2.925	65.089
	3. Finished Wood & Paper Products	0.72	0.7258	22.940	122.323

FIG. 53



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shown in Fig. 53 by input and by industry to the year 2005. Putting these inputs in perspective with national figures, the following observations describe the expected scale of the Santarem A/I city by the year 2005.

1. The present rate of capital formation in Brazil is approximately 23 percent of GNP, up from 17 percent in 1960 (Ref. 7). Assuming the present percentage continues, and using the Brazil GNP projection presented earlier, the cumulative investment by the year 2005 will have been 0.14 percent of cumulative GNP over the same period.

2. At present, 31.7 percent of Brazil's population is economically active (Ref. 7). Assuming this percentage continues, and using the population projection presented earlier, the predicted employment at the Santarem A/I city would be 0.27 percent of the total Brazilian labor force in 2005.

3. Electric energy consumption in Brazil is presently 70.5 x 10^6 kw-hr/yr and has been growing at a rate of 9.5 percent per year (Ref. 7). Projecting future energy consumption at a more conservative 7 percent rate to reflect the worldwide conservation trends, cumulative energy consumption by the year 2005 will have been 0.16 percent of cumulative GNP over the same period.

These figures indicate that factor inputs at Santarem would have a relatively minor impact on the national economy of Brazil, although the regional impact would be very large, and very favorable. The Fig. 53 projections are, therefore, an important element of the Sociopolitical analysis which follows later in this section.

LARGE CARGO AIRCRAFT

In this section, a projection of the general-commodity air cargo requirements are made for both Brazil and Indonesia. The projection of Brazilian A/I city requirements derived in the preceding section are integrated with the general-commodity requirements for Brazil, and the numbers of all-cargo aircraft needed to satisfy the transport requirements in each of these markets, and their combined needs, are addressed.

General-Commodity Air Cargo Forecast

Forecasts were made of Brazilian and Indonesian air cargo traffic and fleets, both domestic and international, for the year 2005. These were baseline forecasts representing the evolutionary growth in general-commodity air cargo brought about by GDP and foreign trade growth, reduced air freight rates (in real terms), improved service, etc. Additional growth may occur due to development of markets specifically oriented toward utilization of air cargo, such as the A/I city market described earlier. Unless indicated otherwise, all data refer specifically to Brazilian and Indonesian carriers only, and exclude the contributions of foreign carriers. Therefore, additional cargo capacity is assumed to be present on international routes in the same ratio (foreign to national carriers) as is currently the case.

All Brazilian and Indonesian air cargo service was tabulated from the April 1976 issue of the Air Cargo Guide (Ref. 81). Brazil was found to have extensive international air cargo service, including daily B-707 freighter service between Rio de Janeiro and New York; weekly service via Manaus from Miami and Los Angeles; four flights/week from Europe; and a weekly flight from Buenos Aires. All of these flights serve Rio de Janeiro; most also serve Sao Paulo. In addition, B-707 aircraft are operated in a mixed passenger/main deck cargo mode from Tokyo via Los Angeles and Lima (2 flights/week) and from Santiago (1 flight/week). Domestic cargo service consists of 27 daily flights by B-727-100 and B-737-200 all-cargo aircraft, and B-727-100 aircraft in mixed passenger/main deck cargo configuration.

Brazil's cargo capacity is summarized in Table 38, which includes the belly capacity of passenger flights as well as all-cargo flights. (Projections of passenger flights appear in a later section.) The capacity for each type of aircraft was either taken direectly from Ref. 73 or calculated by the method used in Ref. 73. These are realistic volume-based capacities: cargo volume, less 0.13 m^3 (4.5 ft^3) per seat for passenger baggage, multiplied by an appropriate density of 163 kg/m^3 (10.2 lbs/ft^3) for main deck and containerized cargo or 115 kg/m^3 (7.2 lbs/ft^3) for loose belly cargo. Comparison between total cargo capacity and the most recent available revenue cargo data revealed load factors of about 50 percent, thereby indicating good utilization of capacity. (This comparison served as a verification of the capacity calculations.)

TABLE 38

1977 BRAZILIAN CARGO CAPACITY

Type		Capacity/ Flight 10^3 kg	Daily Flight Segments	Average Stage Length, km	Available Capacity,** 10^9 kg-km/yr	(% of total)
International:	B-707-320C, C*	40.5	8.9	3702	483.3	(63.4%)
	B-707-320C, M*	17.7	2.9	4239	78.0	(10.2%)
	DC-10-30, P*	11.4	7.4	3498	107.8	(14.1%)
	B-707-320C, P	3.4	26.7	2630	86.9	(11.4%)
	B-727-100, P	1.5	8.0	1133	4.9	(0.65%)
	B-737-200, P	1.6	4.3	714	1.8	(0.25%)
Total or Average		11.9	58.1	2636	762.7	(100.0%)
Revenue Cargo (1976)					329	
Load Factor					43%	
Domestic:	B-727-100, C	16.8	11.1	1140	77.7	(26.2%)
	B-737-200, C	13.6	6.3	1061	33.0	(11.1%)
	B-727-100, M	9.1	9.7	1211	39.0	(13.2%)
	B-727-100, P	1.5	94.0	861	44.1	(14.9%)
	B-737-200, P	1.6	228.9	685	91.3	(30.8%)
	BAC-111, P	0.9	45.1	524	7.7	(2.6%)
	Electra, P	0.5	54.6	355	3.5	(1.2%)
	YS-11, P	0.1	11.4	270	0.1	(0)
	Others, P	0	61.7	285	0	(0)
Total or Average		2.5	522.9	693	296.6	(100.0%)
Revenue Cargo (1976)					155	
Load Factor					52%	

Sources: Refs. 73, 81, 95.

*C - All cargo; M - Mixed passenger/main deck cargo; P - Passenger (belly cargo only)
** - Two-way capacity.

TABLE 39

1977 INDONESIAN CARGO CAPACITY

Type		Capacity/ Flight 10^3 kg	Daily Flights	Average Stage Length, km	Available Capacity 10^9 kg-km/yr	(% of total)
International:	DC-10-30, P[1]	11.4	6.3	2983	77.8	(72.8%)
	DC-8-50, P	2.6	7.1	2998	20.3	(19.0%)
	DC-9-30, P	1.6	16.9	880	8.6	(8.1%)
	Others, P	0.4	4.0	358	0.2	(0.2%)
Total or Average		5.2	34.3	1646	106.9	(100.0%)
Revenue Cargo (1976)					32	
Load Factor					30% (35%)[2]	
Domestic:	F-27, C[1]	5.7	3.4	826	5.9	(14.3%)
	DC-9-30, P	1.6	54.3	875	27.7	(67.4%)
	F-28, P	0.3	98.3	274	2.9	(7.1%)
	HS-748, P	0.4	16.9	533	1.3	(3.2%)
	Others, P	0.4	39.4	641	3.3	(8.0%)
Total or Average		1.0	212.3	525	41.1	(100.0%)
Revenue Cargo (1976)					20	
Load Factor					49%	

Sources: Refs. 73, 81, 95

1p - passenger (belly cargo only); C - all cargo
2 excludes US service (not operating in 1976)

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TABLE 40

AIR CARGO FORECASTS - WORLD AND UNITED STATES

Source	Reference	Date	Market	Average Annual Growth Rate Actual	Average Annual Growth Rate Forecast
World					
Boeing	82	7/76	World	13.5% (1960-74)	11.0% (1975-85)
NASA-Ames	83	8/75	World, except U.S. domestic	-	12.2% (1975-85)
UCLA	84	2/75	World	-	10.3% (1973-2000)
Lockheed	85	12/74	World domestic (except U.S.)	11.1% (1960-73)	8.1% (1974-85)
Lockheed	85	12/74	World international	19.8% (1960-73)	10.9% (1974-85)
SRI	86	11/74	World	16.7% (1960-73)	9.8% (1973-85)
UTRC	-	10/77	World international	16.2% (1960-75)	9.0% (1975-2005)
U.S.					
P&WA	81	6/77	U.S. Carriers - dom. & int'l.	3.3% (1967-76)	9.7% (1976-87)
FAA	87	2/77	U.S. domestic	-	6.1% (1974-2000)
FAA	88	1/77	U.S. domestic	8.2% (1965-74)	6.3% (1975-90)
FAA	88	1/77	U.S. Carriers - int'l.	18.3% (1965-74)	8.8% (1975-90)
NASA-Ames	83	8/75	U.S. domestic	-	8.5% (1975-85)
Lockheed	85	12/74	U.S. domestic	14.5% (1960-73)	8.9% (1974-85)
Lockheed	85	12/74	N.America-Europe/Asia/L.America	14.9% (1970-73)	11.1% (1974-85)
UTRC	-	10/77	U.S. domestic	12.4% (1960-75)	7.0% (1975-2005)
UTRC	-	10/77	U.S. Carriers - int'l.	13.2% (1960-75)	8.5% (1975-2005)

Indonesia was found to have very limited cargo service. There are no international cargo flights and only 3.4 daily domestic cargo flights, using F-27 aircraft. Present air cargo capacity for Indonesia is summarized in Table 39; excess capacity exists in the international market as a result of the recent introduction of wide-body aircraft.

Table 40 shows the results of a literature survey of air cargo forecasts (Refs 82-88). As with the passenger forecasts described later on, the cargo forecasts generally cover less than half of the defined 30-year period, are somewhat inconsistent, and are often not directly comparable since they apply to different markets. Nevertheless, there is unanimous agreement that growth in the next ten to fifteen years, although high, will be less than past growth, thereby reflecting a maturing trend in national economies and the air cargo industry. Growth beyond the forecasts should be at even lower rates; therefore, UTRC consensus forecasts for 1975 through 2005 were 9.0 percent for world international air cargo, 8.5 percent for US international, and 7.0 percent for US domestic.

Table 41 shows recent trends in gross domestic product and air cargo for the developed and less-developed countries. Also shown is the relationship between air cargo and GDP. In the case of international air cargo, the LDCs experienced a higher growth rate from 1960 to 1975 than the developed countries. In fact, a more detailed examination of the data shows that both groups of countries experienced similar growth during the 1960s, but since 1970 the LDCs' international air cargo has grown at more than double the rate of the developed countries. Surprisingly, the LDCs have more international air cargo per $1000 GDP than the developed countries. One explanation for this apparent emphasis on air cargo is the LDC tendency to operate international flag airlines, thereby creating more air cargo capacity than would normally be required. Another explanation is the nature of many LDC economies, i.e., dominance by a small segment of the population, producing high-labor-content goods for export, and sufficiently affluent to purchase imported manufactured goods. The bulk of the population, however, is too poor to contribute significantly to the national economy. Thus, foreign trade is more significant relative to total GDP than in developed countries. This explanation is supported by Table 42 which shows the portion of foreign trade most likely to be carried by air (manufactured goods, excluding machinery and transportation equipment) relative to GDP for the most recent year in which data were available. Although the developed and less-developed countries have similar foreign trade/GDP ratios, much of the developed-countries' trade is entirely within Europe, where short distances and well-developed surface modes make air transportion less competitive. When intra-European trade is excluded, the LDCs dependence on air/transportable foreign trade becomes apparent. As LDC economies mature and become more broadly based, their dependence on exports and imports will decline and the relationship between international air cargo and GDP will move closer to that of the developed countries.

Referring back to Table 41, application of GDP growth rates of 3.5 percent for the US, 4.5 percent for other developed countries, and 6.0 percent for the LDC group gave the 2005 GDP forecasts shown. The 9.0 percent and 8.5 percent international air cargo growth rates for the world and US,

TABLE 41

WORLD AIR CARGO TRENDS AND FORECASTS

	GDP (10^9 1970 $)			Scheduled Air Cargo (10^9 kg-km): International			Scheduled Air Cargo (10^9 kg-km): Domestic			Scheduled Air Cargo/GDP (10^3 kg-km/$1000): International			Scheduled Air Cargo/GDP (10^3 kg-km/$1000): Domestic		
	1960	1975	2005	1960	1975	2005	1960	1975	2005	1960	1975	2005	1960	1975	2005
World	1528.7	2914.9	11,110.9	1320	12,594	167,093	1460	7032	—	0.86	4.32	15.0	0.96	2.41	—
	—	4.4%	4.6%	—	16.2%	9.0%	—	11.0%	—						
United States	658.7	1086.4	3049.3	470	3017	34,872	984	5567	43,139	0.71	2.78	11.4	1.49	5.22	14.1
	—	3.4%	3.5%	—	13.2%	8.5%	—	12.4%	7.0%						
Other Developed Countries	602.4	1221.3	4574.2	655	6331	73,175	228	817	—	1.09	5.18	16.0	0.38	0.67	—
	—	4.8%	4.5%	—	16.3%	8.5%	—	8.9%	—						
All Developed Countries	1261.1	2307.7	7623.5	1125	9348	108,047	1212	6484	—	0.89	4.05	14.2	0.96	2.81	—
	—	4.1%	4.1%	—	15.2%	8.5%	—	11.8%	—						
Less Developed Countries	267.6	607.2	3487.4	195	3246	59,046	248	548	—	0.73	5.35	16.9	0.93	0.90	—
	—	5.6%	6.0%	—	20.6%	10.2%	—	5.4%	—						
Brazil	25.7	71.7	487.5	16.9	340	7313	72.8	134	3413	0.66	4.74	15.0	2.83	1.87	7.0
	—	7.1%	6.6%	—	22.2%	10.8%	—	4.2%	11.4%						
Indonesia	6.5	13.5	117.9	0.4	28	1993	5.1	19	825	0.06	2.07	16.9	0.78	1.41	7.0
	—	5.0%	7.5%	—	32.7%	15.3%	—	9.2%	13.4%						

NOTE: Excludes Communist countries.
Developed countries include: U.S., Canada, Japan, Austria, Belgium, Denmark, Finland, France, Italy, Luxembourg, Netherlands, Norway, Sweden, Switzerland, United Kingdom, West Germany, Australia, New Zealand, and South Africa.

TABLE 42

AIR-TRANSPORTABLE FOREIGN TRADE AND
GROSS DOMESTIC PRODUCT - 1972

	GPD, 10^9\$	Imports and Exports[1]	
		10^9\$	% of GDP
United States	1040.9	25.7	2.5%
All Developed Countries	2686.1	178.1 (86.3)[2]	6.6% (3.2%)[2]
Less-Developed Countries	467.0	31.6	6.8%

1 Manufactured goods less machinery and transportation equipment.

2 Excluding intra-Europe trade.

respectively, are consensus values from Table 40. Assuming 8.5 percent growth for the other developed countires as well, a 10.2 percent LDC international air cargo growth rate is implied. Finally, combining the 2005 forecasts of GDP and international air cargo for the developed countries and LDCs gave the air cargo/GDP ratios shown; these ratios are much higher than current values, indicating further capture of surface traffic by air cargo. Furthermore, the value for the LDC group has moved closer to the developed-countries' ratio (19 percent higher vs 32 percent higher in 1975), as postulated above.

Forecasts of the GDP growth rates for Brazil and Indonesia were presented earlier in the report. (They are higher than the overall LDC growth rate because these two countries possess extensive exploitable resources.) Brazil is already one of the more advanced LDCs and, by 2005, will just about meet the postulated $3000/yr GDP/capita requirement for developed-country status. Therefore, its ratio of international air cargo to GDP will be close to that of the developed countries, as shown in Table 41. (It is already midway between the LDC and developed-country averages.)

The international air cargo growth rate of 10.8 percent was derived from this ratio. Indonesia currently has very little international air cargo; its air cargo/GDP ratio is below the LDC average. However, Indonesia's petroleum and mineral reserves will support rapid economic growth and, by 2005, its level of international air cargo should be equivalent to other LDCs. This implies an average annual growth rate of 15.3 percent.

In examining the domestic air cargo data in Table 41, it is apparent that the United States dominates this area with 79 percent of the world total. Other countries with significant domestic totals are Canada (4 percent), Brazil (2 percent), Japan (2 percent), France (2 percent), and Australia (2 percent). All of these countries (except Japan) have relatively large areas, an obvious prerequisite for an extensive domestic air cargo system. Japan, although small in area, is about 2000 km in length. The US domestic air cargo growth rate of 7 percent derived from Table 40 gave 14,100 kg-km/$1000 GDP in 2005. Brazil, a very large country geographically, was expected to achieve a value somewhat higher than the present US value, implying a domestic air cargo growth rate of 11.4 percent. Indonesia, with inter-island distances of up to 5000 km, is already at about one-quarter of the US value. Rapid economic growth will push this ratio to about the same status as Brazil by 2005, giving a domestic air cargo growth rate of 13.4 percent.

The resulting Brazilian and Indonesian air cargo forecasts are shown in Fig. 54, with 1960-1976 growth indicated, and in Table 43 with forecasts from other sources (Refs. 84, 86, 88-90). These other forecasts do not extend to 2005 and are generally for markets in which Brazilian and Indonesian carriers participate but do not dominate. The forecasts from Refs. 89 and 90 include unscheduled as well as scheduled flights and are thus heavily influenced by recent and projected large airlifts connected with oil and mineral development. Because of these qualifications, the literature survey forecasts could not be used directly; nevertheless, they offered some support to the UTRC values.

BRAZILIAN AND INDONESIAN AIR CARGO

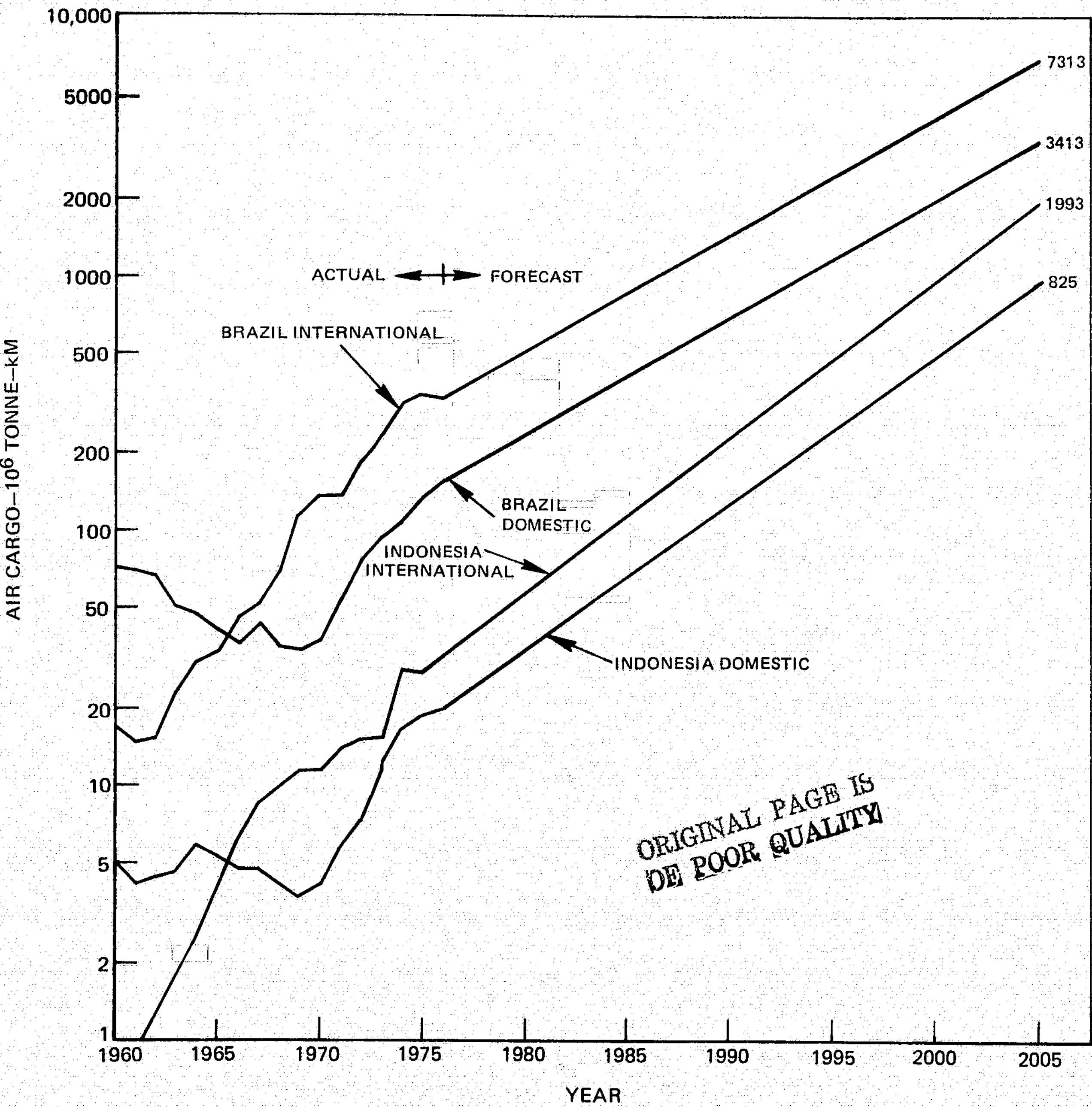

TABLE 43

AIR CARGO FORECASTS - BRAZIL AND INDONESIA

Source	Reference	Date	Market	Average Annual Growth Rate Actual	Average Annual Growth Rate Forecast
Brazil					
FAA	86	1/77	U.S.-S.America, non-U.S. Carriers	14.8% (1965-74)	9.2% (1975-90)
Lockheed	84	12/74	N. America - Latin America	16.7% (1970-73)	12.4% (1974-85)
UTRC	-	10/77	Brazilian Carriers - domestic	4.2% (1960-75)	11.4% (1975-2005)
UTRC	-	10/77	Brazilian Carriers - international	22.2% (1960-75)	10.8% (1975-2005)
Indonesia					
ATW	88	2/77	Garuda, S & NS[1]	49.8% (1971-75)	27.4% (1976-80)
FAA	86	1/77	U.S. - Asia, non-U.S. Carriers	33.1% (1965-74)	11.2% (1975-90)
Lockheed	84	12/74	N. America - Asia/Oceania	35.3% (1970-73)	12.6% (1974-85)
Lockheed	84	12/74	Europe - Asia/Oceania	27.2% (1970-73)	9.3% (1974-85)
Lockheed	84	12/74	Intra-Asia/Oceania	34.7% (1970-73)	8.4% (1974-85)
Repelita II	89	4/74	Indonesian Carriers - domestic, S & NS[1]	80.0% (1969-74)	14.0% (1975-79)
Repelita II	89	4/74	Indonesian Carriers - international S&NS[1]	75.0% (1969-74)	45.0% (1975-79)
Booz-Allen	90	10/73	Western and Trans-Pacific	-	25.0% (1971-85)
UTRC	-	10/77	Indonesia Carriers - domestic	9.2% (1960-75)	13.4% (1975-2005)
UTRC	-	10/77	Indonesia Carriers - international	32.7% (1960-75)	15.3% (1975-2005)

[1] Most data in this table refers to scheduled cargo only; those entries labeled "S & NS" refer to both scheduled and non-scheduled.

It can be seen that more than an order-of-magnitude growth is forecast on each of the lines in Fig. 54. While such growth may appear astonishing, it is important to recognize that the 30-year period is unusually long for forecasting, and that any significant growth rate would result in a large increase over the base year. Since relatively low growth rates were used (compared to the 15-year historical base in Fig. 54), the results may even be conservative. Although the use of declining growth rates might be appropriate in a developed country environment, the use of constant rates is more appropriate here because the air transport industries in Brazil and Indonesia are still in the early stages of development. The type of maturing trend which would be typified by a gradually declining growth rate over time was therefore not selected.

Tables 44 and 45 illustrate the computation of belly cargo capacity available in 2005 in the forecasted passenger fleets; the same methods were used as for the 1977 computations in Tables 38 and 39. Passenger fleet cargo capacity will increase rapidly, particularly in the domestic markets, where wide-body aircraft will be introduced.

In Table 46, the forecasted revenue cargo is allocated between passenger and all-cargo aircraft. In making this allocation, cargo load factors (i.e., cargo carried ÷ available cargo capacity) of 30 percent for narrow-body passenger aircraft, 50 percent for wide-body passenger aircraft, and 60 percent for all-cargo aircraft were used. These values were based on a study of 1976 CAB data for US carriers which showed cargo load factors of 19 percent for narrow-body domestic passenger aircraft, 35 percent for wide-body domestic and all-international passenger aircraft, and 60 percent for all-cargo aircraft. The low cargo load factors on passenger aircraft were a result of schedules which reflect time and route preferences of passengers rather than shippers. Nevertheless, as air cargo demand grows relative to passenger travel, more of this excess capacity will be utilized, thereby justifying the higher load factors used in this study. The all-cargo aircraft revenue cargo shown in annual kg-km in Table 46 was converted to aircraft capacity (10^6 kg/day) by dividing by 0.6 x 365 x the average stage lengths shown, which are typical of current all-cargo and/or passenger flights.

TABLE 44

2005 BRAZILIAN CARGO CAPACITY - PASSENGER FLEET

	Aircraft Seats	Capacity /Flight Tonnes	Daily Flights	Average Stage Length, km	Available Capacity 10^6 tonne - km/yr
International:	100	1.6	69	987	40
	130	2.7	69	987	67
	200	5.5	35	987	69
	280	11.4	96	3001	1199
	400	12.6	49	3001	676
	530	19.6	49	3001	1052
Total or Average	260	9.2	367	2519	3103
Total, 1977					201
Avg. Annual Growth					10.3%
Domestic:	15	0	727	275	0
	50	0.1	726	275	7
	100	1.6	1172	783	536
	130	2.7	1171	783	904
	200	5.5	658	706	933
	280	10.9	658	706	1848
Total or Average	122	3.2	5112	719	4228
Total, 1977					147
Avg. Annual Growth					12.7%

TABLE 45

2005 INDONESIAN CARGO CAPACITY - PASSENGER FLEET

	Aircraft Seats	Capacity /Flight Tonnes	Daily Flights	Average Stage Length, km	Available Capacity, 10^6 tonne - km/yr
International:	100	1.6	51	831	25
	130	2.4	51	831	37
	200	5.5	25	831	42
	280	11.4	50	2988	622
	400	12.6	26	2988	357
	530	19.6	26	2988	556
Total or Average	240	8.4	229	2328	1639
Total, 1977					107
Avg. Annual Growth					10.2%
Domestic:	15	0	607	345	0
	50	0.1	606	345	8
	100	1.6	856	607	303
	130	2.4	1100	661	637
	200	5.5	314	809	510
Total or Average	95	1.8	3483	638	1458
Total, 1977					35
Avg. Annual Growth					14.2%

TABLE 46

2005 CARGO CAPACITY REQUIREMENTS*

	Brazil		Indonesia	
	Domestic	International	Domestic	International
2005 Revenue Cargo, 10^9 kg-km:				
Total	3413	7313	825	1993
Passenger Aircraft	1825 (53%)	1530 (21%)	539 (65%)	807 (40%)
All-cargo Aircraft	1588 (47%)	5783 (79%)	286 (35%)	1186 (60%)
Average Route Length, km	1137	8426	1189	5481
All-cargo Aircraft Capacity, 10^3 kg/day	6378	3134	1098	988

* Two-Way Capacity

Cargo Load Factors: 30% - narrow body passenger aircraft
50% - wide body passenger aircraft
60% - all-cargo aircraft

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Analysis of Future Air Cargo Fleet Requirements

In the previous two sections, forecasts were made of the air cargo capacity requirements of a Santarem Airport/Industrial City and for the general-commodity air cargo markets of both Brazil and Indonesia. With these forecasts, it was possible to estimate air cargo fleet requirements in roughly ten-year increments (1985, 1995, and 2005) for both countries.

Brazil

For the baseline forecast (general-commodity market), the total all-cargo requirements were separated into international and domestic sectors because of the different aircraft performance requirements associated with these sectors. In the international sector, the total required cargo capacity for the three forecast years was estimated on the basis of growth rates derived in the previous section, as applied to present-day all-cargo traffic, and the breakdown of this cargo capacity among major international routes was postulated to be in the same proportions as present-day all-cargo traffic. The implicit assumption was that any new international routes initiated in the forecast period will have the route characteristics of at least one of the existing routes, thereby incurring no first-order effect on aircraft requirements*, and that those routes served by belly cargo, at present, will continue to be satisfied by belly cargo as passenger traffic grows, albeit at a slower rate than all-cargo. While the latter assumption was admittedly inaccurate, an attempt at closer definition of the future market was not justified by the information available. By use of cargo capacity, rather than actual air freight, requirements as the projected quantity, the assumption was made that all-cargo load factors will be constant at the projected level (i.e., 60%). No more definitive assumption was possible, and the sensitivity of the results to this assumption can be shown.

A similar approach was used to analyze the domestic cargo market, except that, whereas only all-cargo routes were considered in the international case, those routes served by mixed passenger/main deck cargo operations were also considered for the domestic sector. The rationale was that such service would grow into an all-cargo service because the cargo growth rate is higher than the passenger growth rate. All-cargo plus mixed passenger/cargo represent about half of the total cargo flow, a percentage which was tacitly assumed to persist throughout the forecast period.

With the above assumptions, the estimated all-cargo capacity, for each of the routes considered, and for each of the forecast years, is summarized in Table 47. These data were used to estimate the daily flights required of the aircraft assumed to be available, which are as follows:

---

*Of course, if projected cargo requirements were split up among more routes, the fleets would consist of more, but smaller, aircraft.

TABLE 47

FORECAST ALL-CARGO CAPACITY FOR BRAZIL

International	Route Distance (km)	One-Way Cargo Capacity (10^3 kg/day) 1977[4]	1985[5]	1995[5]	2005[5]
Rio[1] - New York	7730	37.5	86.5	246	700
- Miami	6840	5.8	13.4	38	108
- Los Angeles	10204	5.6	12.9	37	104
- Europe[2]	9405[2]	21.7	50.1	143	405
- Buenos Aires	2074	5.8	13.4	38	108
- Tokyo[3]	19,316[3]	5.1	11.7	33	95
- Santiago	2965	2.5	5.8	17	47
		84	193.8	552	1567
Domestic					
Rio - Sao Paulo	355	48.5	110.1	307	856
Manaus - Belem	1311	17.9	40.7	114	316
Rio - Brasilia	903	16.9	38.5	107	299
Brasilia - Belem	1619	14.3	32.5	91	253
Manaus - Rio	2827	6.5	14.8	41	115
Sao Paulo - Brasilia	870	11.8	26.9	75	209
Manaus - Sao Paulo	2720	10.8	24.5	68	191
Rio - Recife	1953	10.1	23.0	64	179
Salvador - Recife	707	10.1	23.0	64	179
Manaus - Brasilia	1953	8.5	19.2	54	149
Rio - Salvador	1285	4.1	9.3	26	73
Sao Paulo - Belo Hor.	1516	3.6	8.2	23	64
Sao Luiz - Belo Hor.	1940	3.6	8.2	23	64
Sao Luiz - Belem	475	3.6	8.2	23	64
Sao Paulo - Porto Ale.	1135	2.4	5.4	15	42
Manaus - Porto Velho	771	1.9	4.4	12	34
Sao Paulo - Campinas	80	1.9	4.4	12	34
Cuiaba - Campinas	1220	1.9	4.4	12	34
Cuiaba - Porto Velho	1144	1.9	4.4	12	34
		180.3	410.1	1143	3139

Notes: (1) From/to either Rio or Sao Paulo
(2) Via Lisbon; Rio-Lisbon leg is critical for payload capacity
(3) Via Los Angeles; L.A.-Tokyo leg is critical for payload capacity
(4) Based on daily flights with current equipment (Ref. 95)
(5) 1977 capacity x annual growth = 11.2% (Int'l.), 10.8% (Domestic)

TABLE 47

FORECAST ALL-CARGO CAPACITY FOR BRAZIL

International	Route Distance (km)	One-Way Cargo Capacity (10^3 kg/day) 1977(4)	1985(5)	1995(5)	2005(5)
Rio(1) - New York	7730	37.5	86.5	246	700
- Miami	6840	5.8	13.4	38	108
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- Europe(2)	9405(2)	21.7	50.1	143	405
- Buenos Aires	2074	5.8	13.4	38	108
- Tokyo(3)	19,316(3)	5.1	11.7	33	95
- Santiago	2965	2.5	5.8	17	47
		84	193.8	552	1567
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		180.3	410.1	1143	3139

Notes: (1) From/to either Rio or Sao Paulo
(2) Via Lisbon; Rio-Lisbon leg is critical for payload capacity
(3) Via Los Angeles; L.A.-Tokyo leg is critical for payload capacity
(4) Based on daily flights with current equipment (Ref. 95)
(5) 1977 capacity x annual growth = 11.2% (Int'l.), 10.8% (Domestic)

Generic Designation	Typical Aircraft	Payload Capacity (10^3 kg)	Years Available	Typical Block Speed (from OAG) (km/hr)	Typical Turnaround Time (In & Out) (hr)
2ENB	F27 Cargo	5.7	1985-2005	370	1
3ENB	727	16.8	"	750	1
4ENB	707-320C	40.5	"	800	1.5
3EWB	DC-10-30F	77	"	815	1.5
4EWB	747-200F	114.5	"	825	2
LCA	CLASS design	177	1995-2005*	825	2

Payload-range characteristics for those aircraft involved in long-range (international) service are shown in Fig. 55.

In making allocations of these aircraft, a simple rule was followed -- the largest available aircraft would be used first in meeting the demand for the given route. Where cargo requirements exceeded that for a whole number of daily flights, smaller aircraft would be used to carry the remainder. For example, the following numbers illustrate the process:

Cargo Capacity Requirement	Daily Flights Required
465,000 kg/day	2 LCA for 354,000 kg, 1 4EWB for 111,000 kg
190,000 kg/day	1 4EWB for 114,500 kg, 1 3EWB for 75,500 kg
38,000 kg/day	1 4ENB for 38,000 kg out of 40,500 available

This process provided an estimate of the daily flights by these aircraft, but not the number of aircraft required since, in some cases, the routes would be so short (some international routes and all domestic routes) that the same aircraft would be used for more than one daily flight. Where a single flight plus turnaround time would exceed the average daily utilization of the aircraft in the particular service (8.6 hrs international, 6.1 hrs domestic), say for long international flights, one flight per day was taken to represent one aircraft. Where the flight, plus turnaround time, was less than the average daily utilization, a fractional number of aircraft (equal to block time-plus-turnaround time divided by utilization) would be needed for that flight. These fractions were summed for all such flights to compute the number of aircraft needed, and the fraction was then rounded to the next higher whole number only when summing all aircraft of a given type (international plus domestic) for the country being examined (in this case, Brazil).

The results of this exercise are given in Table 48 for all-cargo international operations by Brazilian carriers for the forecast years.

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* Calculations were also made assuming LCA not developed by 2005, thereby showing effect on requirements for other aircraft.

PAYLOAD–RANGE CHARACTERISTICS OF ALL–CARGO TRANSPORTS

(WEIGHT–LIMITED CAPACITY)

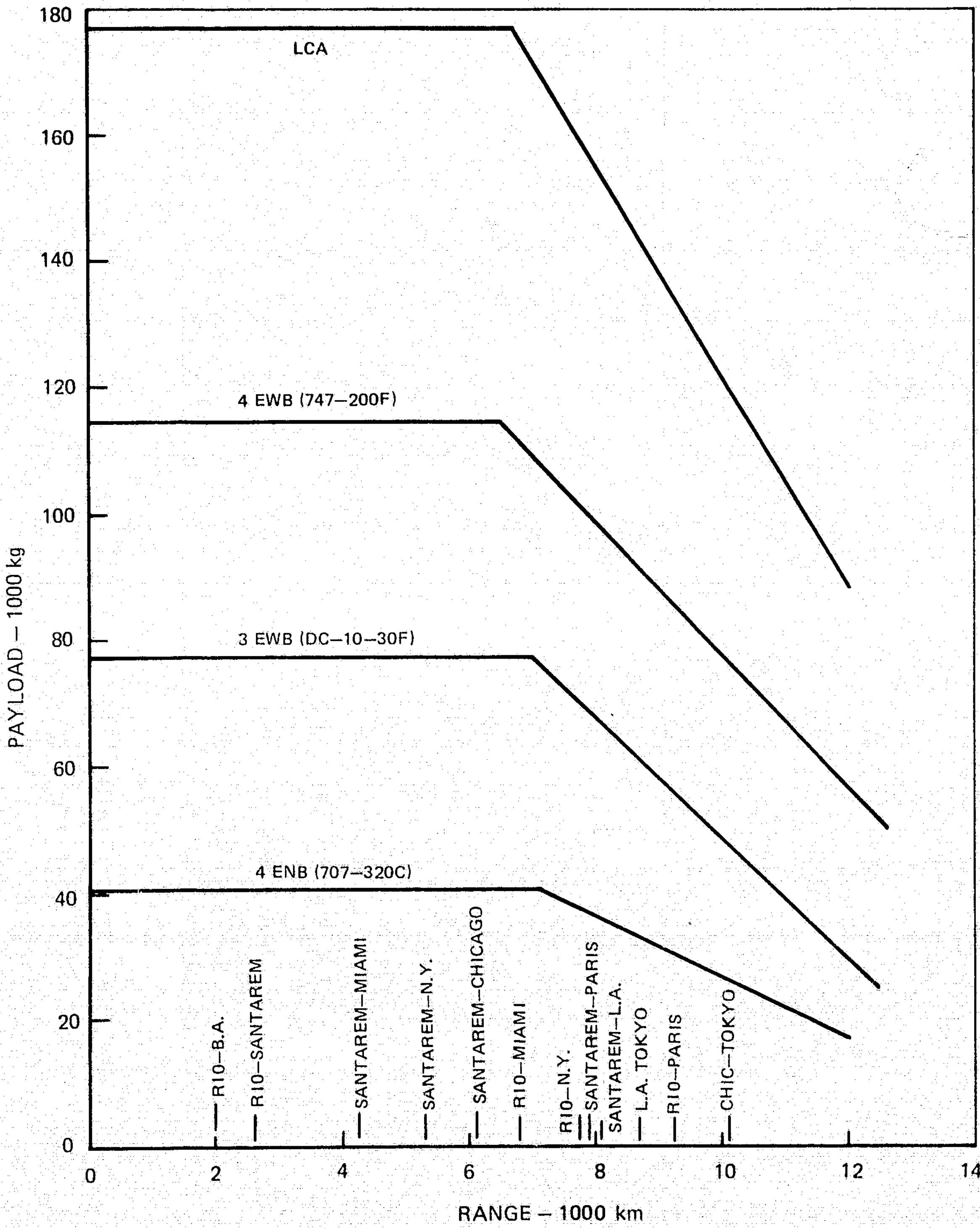

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TABLE 48

FLIGHTS AND AIRCRAFT NEEDED FOR
BRAZILIAN CARRIER ALL-CARGO INTERNATIONAL
OPERATIONS

Destination	Block Time (hr)	Total Time U	Round-Trip Flights per Day				Aircraft			
			4ENB	3EWB	4EWB	LCA	4ENB	3EWB	4EWB	LCA
2005										
New York	9.48	≅ 1.0	0	1	0	4	0	2	0	8
Miami	8.39	≅ 1.0	0	0	1	0	0	0	2	0
Los Angeles	9.14	≅ 1.0	0	0	1	0	0	0	2	0
Europe	9.43	≅ 1.0	0	0	1	2	0	0	2	4
Buenes Aires	2.43	.46/.51	0	0	1	0	0	0	1.02	0
Tokyo	10.67	≅ 1.0	0	0	0	1	0	0	0	2
Santiago	3.6	.60/.65	0	1	0	0	0	1.2	0	0
			0	2	4	7	0	3.2	7.02	14
1995										
New York	Same		0	0	1	1	0	0	2	2
Miami	as		1	0	0	0	2	0	0	0
Los Angeles	Above		1	0	0	0	2	0	0	0
Europe			0	0	0	1	0	0	0	2
Buenes Aires			1	0	0	0	.92	0	0	0
Tokyo			1	0	0	0	2	0	0	0
Santiago			3/7*	0	0	0	.52	0	0	0
			4 3/7	0	1	2	7.44	0	2	4
1985										
New York	Same		0	0	1	0*	0	0	2	0
Miami	as		3/7	0	0	0	.86	0	0	0
Los Angeles	Above		3/7	0	0	0	.86	0	0	0
Europe			0	1	0	0	0	2	0	0
Buenes Aires			3/7	0	0	0	.40	0	0	0
Tokyo			3/7	0	0	0	.86	0	0	0
Santiago			1/7	0	0	0	.18	0	0	0
			13/7	1	1	0	3.16	2	2	0

* 3/7 = Three flights per week
** LCA assumed not available in 1985

Similar tables were constructed for domestic operations and for special cases, as will be discussed below. Results for the baseline case are as follows:

Year	Sector	Brazilian Aircraft Requirements					
		2ENB	3END	4ENB	3EWB	4EWB	LCA
1985	International	--	--	3.16	2	2	--
	Domestic	4.4	1.6	6.5	0	0.8	
	Total*	5	2	10	2	3	0
1995	International	--	--	7.44	0	2	4
	Domestic	4.54	1.6	6.6	4.5	4.3	0.8
	Total*	5	2	14	5	7	5
2005	International	--	--	--	3.2	7.02	14
	Domestic	--	2.46	8.	4.82	6.22	11.66
	Total*	0	3	8	8	14	26

The objectives of this part of the study were to indicate the need for new large cargo airplanes (LCAs) as generated by the development of LDCs in the next 30 years. A perspective on the numbers forecasted, given in the above table, is to compare the fleets so indicated with what would be needed if LCAs were not developed, and if only existing aircraft were to serve throughout the forecast period. This comparison is given in the following table for Brazil (international plus domestic).

Year	LCAs Available in 1995						LCAs Not Developed by 2005				
	2ENB	3ENB	4ENB	3EWB	4EWB	LCA	2ENB	3ENB	4ENB	3EWB	4EWB
1985	5	2	10	2	3	--	5	2	10	2	3
1995	5	2	14	5	7	5	5	1	14	10	12
2005	--	3	8	8	14	26	--	--	9	10	53

It is clear that a very large number of 4EWB aircraft would be required in 2005, thereby resulting in possible congestion problems at key airports and a penalty in operating cost relative to the economies achievable with a new large aircraft suitable for the large quantities of cargo being generated.

Another objective of the study was to evaluate the effect, on fleets required, of the development of one or more A/I cities in Brazil. To accommodate this eventuality, some policy and operational assumptions were required:

- All air-transportable output of the A/I city was assumed to be destined for export. Since the Amazon region is remote, much of

* Rounded.

Santarem's output would be air-transported to other Brazilian cities or to international markets in any case, and the assumption that it would be exported rather than split up in some indeterminate fashion was not expected to influence the over-all air transport requirements to a significant degree. Further, it was believed that a major incentive for interior growth in the Amazon would be to expand Brazil's export trade.

- Since the primary interaction between Santarem and international points would primarily be the export of cargo, it was assumed that all-cargo aircraft would be used for all freight exported.

- Because there would be little, if any, international back-haul to Santarem, it could not be considered a primary origin in Brazil. It was, therefore, postulated that all-cargo flights would originate in the southern part of Brazil (Rio or Sao Paulo), pick up exports at Santarem, and go on to their international destinations. Back-haul would go to Rio or Sao Paulo. Thus, the product at Santarem would be added to that from the South, resulting in a requirement for more, or larger, aircraft, or higher load factors.

The air-transportable cargo available from Santarem was taken from the data presented in an earlier section of this report. To be conservative with respect to the contribution of Santarem, these values were not converted to air cargo capacity requirements, on the assumption that a greater load factor than the fleet average (60%) would be sought in flights out of Santarem. This assumption was equivalent to achievement of higher load factors on all flight segments out of Santarem. While conservative, the assumption was justified, at least in part, by the additional scheduling flexibility made possible by the Santarem stop.

When a comparison was made between exports generated by Santarem and those by the industrial South, the Santarem contribution was seen to be a significant fraction:

	10^3 kg/day			
	1977	1985	1995	2005
Santarem Req'ts	0	55	310	470
Total w/o Santarem	166	363	957	2528
Santarem %	0	15	32	19

It may appear surprising that Santarem grows at a faster rate than general cargo between 1985 and 1995, and then at a lower rate in the next ten years. This anomaly was a result of the limited, albeit large, resources in the Santarem region which would limit its growth once it had reached a relatively mature level.

Because of the route structure associated with the case in which Santarem was a pick-up stop on the way out of Brazil, the available payload capacities, as they vary with range according to Fig. 55, were different than in the baseline case described above. Interestingly, the capacities are greater because Santarem is located to the north, and closer to major world markets, so that the critical stage length of most international flights is shorter, thereby allowing somewhat greater payloads.

A comparison of total fleet requirements (including both domestic and international sectors), with and without an A/I city at Santarem, is given in the upper part of Table 49, which summarizes the cargo transport picture for Brazil. It is clear that, because of its significant air-transportable output, a single A/I city has a measurable impact on the over-all air transport reqirements of even a rapidly growing country such as Brazil. Furthermore, the stimulus to interior development provided by the A/I city concept could, if recognized, lead to parallel developments in other regions of Brazil, in which case the cumulative effect on air transport requirements could be very significant.

Indonesia

An analysis similar to the above was made for Indonesia. Because Indonesia is at an earlier stage of development than Brazil, somewhat different assumptions had to be made with respect to the all-cargo forecast. Since it has no international all-cargo service at present, it was necessary to assume that routes on which it now offers only belly cargo service would grow into all-cargo routes in the future. In addition, since its only domestic all-cargo service is by F-27s, it was assumed that the major domestic passenger routes, which presently offer limited belly cargo service, would become candidates for all-cargo service. However, it was assumed that all-cargo service would always amount to only a fraction of the total cargo demand, that fraction taken from Table 46, for 2005, and by interpolation between Tables 38 and 39 and Table 46, for intermediate forecast years. With these assumptions, the cargo capacity requirements were calculated as shown in Table 50 for both international and domestic sectors.

With these forecasts, the same procedure described above for Brazil was followed, resulting in the fleet requirements summarized in Table 49, which are presented along with those of Brazil, for comparison. It is clear that Indonesia's large-aircraft requirement is almost negligible by comparison with Brazil's. Nevertheless, while Indonesia's requirements may look small by comparison, they are not insignificant, and Indonesia's requirements, when added to other LDCs, both smaller and larger, represent a tremendous market when taken in conjunction with those of the developed countries.

TABLE 49

SUMMARY OF LDC CARRIERS' ALL-CARGO TRANSPORT NEEDS

BRAZIL

	Without A/I City at Santarem						With A/I City at Santarem					
Year	2ENB	3ENB	4ENB	3EWB	4EWB	LCA	2ENB	3ENB	4ENB	3EWB	4EWB	LCA
Assuming LCA fully operational in 1995 (not available in 1985)												
1985	5	2	10	2	3	-	5	2	10	2	3	-
1995	5	2	14	5	7	5	5	2	10	13	5	7
2005	0	3	8	8	14	26	0	3	8	8	7	35
Assuming LCA is not developed by 2005												
1985	5	2	10	2	3	-	5	2	10	2	3	-
1995	5	1	14	10	12	-	5	1	12	12	15	-
2005	0	0	9	10	53	-	0	0	14	12	56	-

INDONESIA

Year	2ENB	3ENB	4ENB	3EWB	4EWB	LCA
Assuming LCA fully operational in 1995 (not available in 1985)						
1985	4	1	0	0	0	-
1995	5	3	3	1	0	0
2005	2	5	4	12	0	2
Assuming LCA is not developed by 2005						
1985	4	1	0	0	0	-
1995	5	3	3	1	0	-
2005	1	5	4	11	3	-

TABLE 50

FORECAST ALL-CARGO CAPACITY FOR INDONESIA

International City Pair*	Route Distance (km)	One-way Cargo Capacity (10^3 kg/day) 1977	1985	1995	2005
Jakarta - Europe	13200	6.5**	-	40	127
- L.A.	13650	1.6**	-	-	32
- Hong Kong	3270	2.6**	-	-	51
- Singapore	900	11.2**	-	71	241
- Australia	4625	2.3**	-	-	43
		24.2**	-	111	494
Domestic*					
Jakarta - Surabaya	668	{ 3.3 / 16.0**	9.1	41	187
- Ujung Pandang	1411	{ 0.8 / 6.4**	3.4	15.4	70
- Denpasar	962	5.3**	2.5	11.2	51
- Jogyakarta	436	4.8**	2.3	10.2	46
- Medan	1411	4.8**	2.3	10.2	47
- Palembang	433	4.8**	2.3	10.3	47
- Balikpapan	1240	1.6	0.8	3.5	16
Surabaya - Banjarmasin	489	1.6	0.8	3.5	16
- Balikpapan	819	1.6	0.8	3.5	16
Jakarta - Pontianak	726	0.8	0.4	1.8	8.4
- Pedang	930	1.6**	0.8	3.4	15
Denpasar - Jogyakarta	533	1.6**	0.8	3.4	15
Menado - Ujung Pandang	946	1.6**	0.8	3.4	15
		9.7 / 46.9**	27.1	120.8	549.4
	Total	56.6			

* Omits some routes having very low cargo capacity
** Mixed passenger/cargo

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Sociopolitical Considerations

For the purpose of this application, the benefit/cost results are presented in two parts. The first part involves a comparison of the LCA with ocean transport. Specific siting of the large airport needed to accommodate the airplane was not a consideration in this comparison. The second evaluation concerns the A/I city as an alternative to the normal development process in a remote region. In this case, the comparison was between a centralized industrial center served by extensive domestic and international networks, and a diffuse system of smaller developments served primarily by road, river, and ocean transport.

The planning balance sheet for the LCA evaluation appears in Table 51. Rankings in this analysis were based on expected application of LCA service in Brazil, since the economic evaluation showed that Brazil might become an important user of the LCA within the forecast period, whereas Indonesia would not. The Table 51 comparison shows that ocean transport is superior in two major categories and air in three. Overall, the scores are very close, showing that noneconomic benefits and costs compensate in this case.

The rankings in Table 51 were affected by the fact that an air cargo system incorporating the LCA would not be an alternative to ocean shipping but, rather, an adjunct for special cargoes. For example, under resource utilization, an LCA would not provide access to primary materials to the same extent as ocean shipping because it could not compete in transporting bulk cargoes and other low-value goods. Nevertheless, a large volume of air-transportable cargo was projected in the economic analysis, and these projections are not affected by the noneconomic factors in Table 51 because they were based on historical precedents which already account for noneconomic objectives, and for economic growth which is affected only indirectly.

The A/I city evaluation in Table 52 compares an air-oriented development strategy with conventional development based on surface transport. As described earlier in this report, the A/I city was conceived so as to incorporate the air mode as an important element of the transport system, and to facilitate uniform, orderly growth of a rapidly expanding population center. The results of the economic evaluation showed that an A/I city in Brazil would foster industrial growth and stimulate significant transport requirements, particularly in the form of exportable products. The comparison in Table 52 further suggests that noneconomic factors also favor this type of development.

The air mode is shown to be superior in two major categories -- operational and political objectives -- and competitive with surface-dominated strategies in all other categories. Because of its centralized nature, the A/I city concept does not offer the high level of socio-economic benefits made possible by a wide-area road network. However, its operational, resource utilization and political advantages give the air mode a clear superiority in the overall comparison.

TABLE 51

SOCIOPOLITICAL COMPARISON

Large Cargo Airplane

OBJECTIVES	UNITS OF MEASUREMENT	WEIGHTS	Air		Ocean	
			Rank	Score	Rank	Score
IMPLEMENTATION						
Open Service Expeditiously	Months	4	5	20	1	4
Minimize Foreign Exchang Req'mts.	$	6	2	12	5	30
Min. Need for Expatriate Labor (Constr)	Person-Years	3	5	15	5	15
Avoid Instit. Delays at Inter'l Level	Prob. of Months	1	5	5	1	1
Secure High Salvage Value	$ or Equiv.	1	5	5	2	2
Subtotal		15		57		52
OPERATION						
Provide for Maximum Reliability	Prob. Days of Service Interr./yr	7	5	35	2	14
Provide for Maximum Safety	Anticip. Level of Damage Claims/yr	5	5	25	2	10
Min. Need for Expatriate Labor (Oper.)	Person - Years	3	1	3	5	15
Subtotal		15		63		39
SOCIO-ECONOMIC DEVELOPMENT						
Create Jobs for Available Work Force						
- In Construction	Person - Years	4	5	20	5	20
- In Operation/Maint.	No. of permanent jobs	7	1	7	5	35
Foster Upgrading of Tech. Skills	No. of skilled work trained/yr	5	2	10	5	25
Provide Reliable & Affordable Means of Mobility for General Pop.	No.Person-Km	5	--	--	--	--
Provide Fast & Comfortable Means of Mobility for General Population	Time Distance	5	--	--	--	--
Provide for Emergency Services	Time Distance	4	5	20	1	4
Encourage Establ. of Secondary Industries	Probability	3	5	15	2	6
Build-up of a Multipurpose Long-Range Infrastructure Network	Policy Judgment	2	5	10	3	6
Subtotal		35		82		96
RESOURCE UTILIZATION						
Conserve Energy, Part. Imported Fuel	Barrel Equiv/yr	7	2	14	5	35
Protect Physical Environment	Tons of Emiss./yr	5	5	25	5	25
Maximize Access to Primary Materials	Policy Judgment	8	2	16	5	40
Subtotal		20		55		100
POLITICAL						
Upgrade National Defense Capability	Policy Judgment	6	5	30	3	18
Promote Political Stability and National Unity	Policy Judgment	6	5	30	3	18
Generate National Pride	Policy Judgment	3	5	15	1	3
Subtotal		15		75		39
GRAND TOTAL		100		332		326

TABLE 52

SOCIOPOLITICAL COMPARISON

Airport/Industrial City

OBJECTIVES	UNITS OF MEASUREMENT	WEIGHTS	Air Rank	Air Score	Roads Rank	Roads Score	Water Rank	Water Score
IMPLEMENTATION								
Open Service Expeditiously	Months	4	5	20	1	4	4	16
Minimize Foreign Exchang Req'mts.	$	6	2	12	5	30	4	24
Min. Need for Expatriate Labor (Constr)	Person-Years	3	3	9	5	15	4	12
Avoid Instit. Delays at Inter'l Level	Prob. of Months	1	--	--	--	--	--	--
Secure High Salvage Value	$ or Equiv.	1	5	5	1	1	4	4
Subtotal		15		46		50		56
OPERATION								
Provide for Maximum Reliability	Prob. Days of Service Interr./yr	7	5	35	2	14	3	21
Provide for Maximum Safety	Anticip. Level of Damage Claims/yr	5	5	25	1	5	2	10
Min. Need for Expatriate Labor (Oper.)	Person - Years	3	1	3	5	15	3	9
Subtotal		15		63		34		40
SOCIO-ECONOMIC DEVELOPMENT								
Create Jobs for Available Work Force								
- In Construction	Person - Years	4	2	8	5	20	2	8
- In Operation/Maint.	No. of permanent jobs	7	2	14	5	35	3	21
Foster Upgrading of Tech. Skills	No. of skilled work trained/yr	5	5	25	3	15	1	5
Provide Reliable & Affordable Means of Mobility for General Pop.	No.Person-Km	5	2	10	5	25	3	15
Provide Fast & Comfortable Means of Mobility for General Population	Time Distance	5	5	25	3	15	1	5
Provide for Emergency Services	Time Distance	4	5	20	2	8	1	4
Encourage Establ. of Secondary Industries	Probability	3	2	6	5	15	3	9
Build-up of a Multipurpose Long-Range Infrastructure Network	Policy Judgment	2	4	8	5	10	2	4
Subtotal		35		116		143		71
RESOURCE UTILIZATION								
Conserve Energy, Part. Imported Fuel	Barrel Equiv/yr	7	2	14	3	21	5	35
Protect Physical Environment	Tons of Emiss./yr	5	4	20	1	5	5	25
Maximize Access to Primary Materials	Policy Judgment	8	4	32	3	24	5	40
Subtotal		20		66		50		100
POLITICAL								
Upgrade National Defense Capability	Policy Judgment	6	5	30	3	18	1	6
Promote Political Stability and National Unity	Policy Judgment	6	4	24	5	30	1	6
Generate National Pride	Policy Judgment	3	5	15	2	6	1	3
Subtotal		15		69		54		15
GRAND TOTAL		100		360		331		282

ADDITIONAL APPLICATIONS

The comprehensive list of airplane applications presented earlier in Table 2 was used as a basis for selecting the primary applications described in detail in the preceding paragraphs of this section. While these selections were made with the intent of focusing the results of the study toward the objectives enumerated in the INTRODUCTION, it was recognized that certain other applications ought not to be entirely excluded. Notable among these were passenger transport by the certificated carriers, and the general aviation sector. The former is a premier application of airplanes in Brazil and Indonesia, as well as in other LDCs, and accounts for a large percentage of the invested capital in air transportation. General aviation covers a multitude of uses, as shown in Table 2, and constitutes a large fraction of registered fleets. Therefore, these two important airplane applications were analyzed to determine potential future aircraft needs in Brazil and Indonesia even though, as stated earlier, the airplanes likely to be purchased for these applications need not be appreciably different, technologically, from those which will be required in the developed countries.

Passenger Transport

Scheduled passenger transport, both domestic and international, is a major LDC airplane use which will undoubtedly grow rapidly in parallel with LDC economic growth. In view of their rapid rates of growth, and present liberal use of air transport, Brazil and Indonesia will experience increasing needs for scheduled service. The forecasts presented here for domestic and international air transport in the two countries were based on extrapolative techniques commonly utilized in the forecasting of demand and supply in the air transport industry. However, because of the special characteristics of the two study countries and their dynamic states of development, these forecast are subject to greater error than similar predictions in the developed world.

Domestic Scheduled Passenger Transport

A conventional starting point in analyzing aircraft needs on a national scale is to determine the historic relationship between air travel and economic growth. Such a relationship is presented in Fig. 56 in terms of the portion of GNP devoted to domestic air travel plotted against real GNP per capita for the United States for the years 1951 to 1976 (Ref. 91). It appears that, as a country's wealth increases, it can devote a larger share of that wealth to air travel, since its basic needs (food, shelter, etc.) have been met. Also shown are forecasts through 2005 for the US, based on 1976-2005 average annual growth rates of 6 percent in air travel, 3.5 percent in real GNP, and 0.8 percent in population. Corresponding growth rates for 1951-1976 were 11.0 percent, 3.2 percent, and 1.3 percent, respectively. The gradual decline in the slope of the curve reflects the maturing of the air industry.

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DOMESTIC AIR TRAVEL VS ECONOMIC DEVELOPMENT

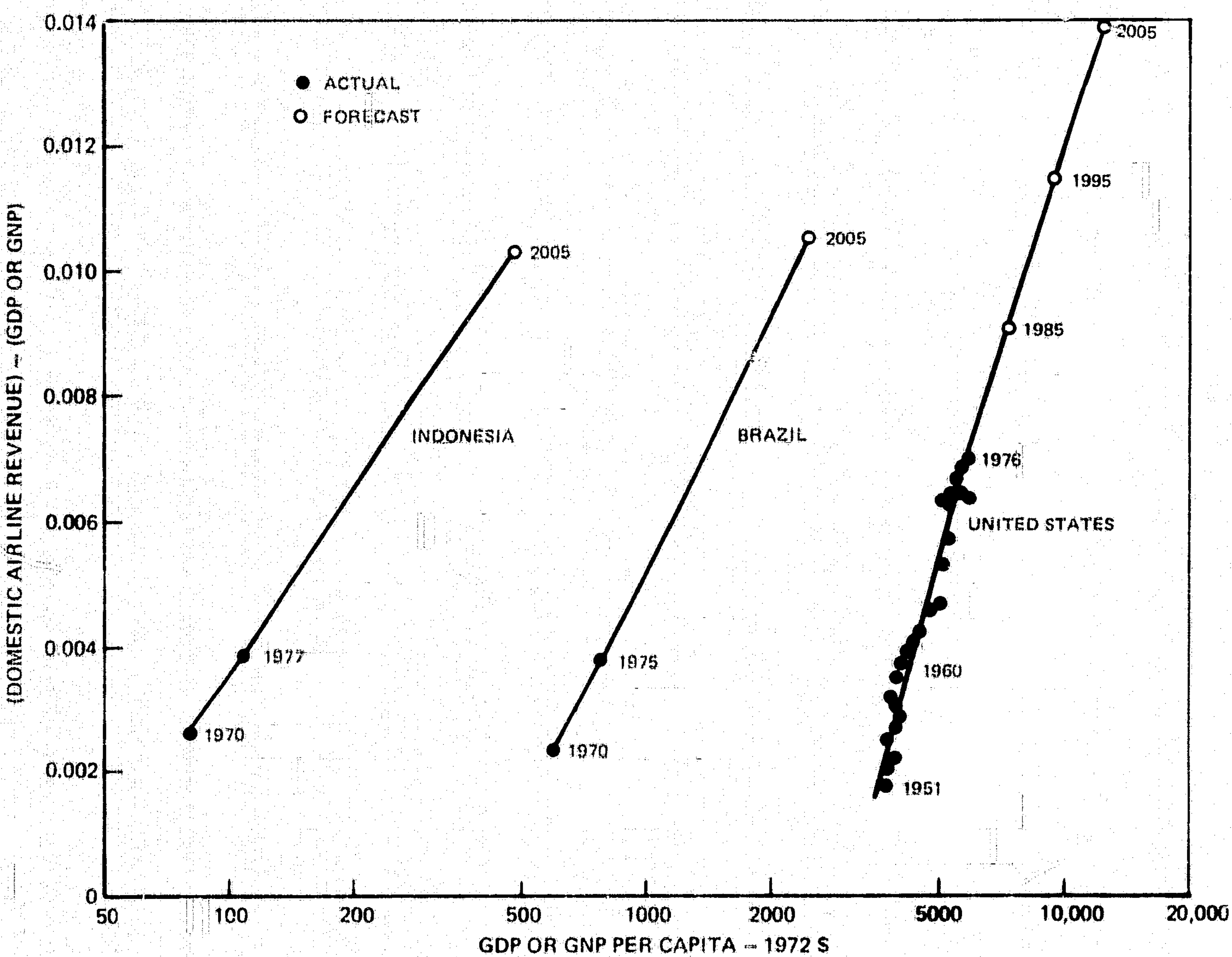

FIG. 56

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When Brazilian and Indonesian data for recent years (derived from Refs. 92, 93) are plotted, they hit far to the left of the US data. These countries have achieved a level of air travel spending relative to GDP comparable to the US level in the early 1960s, even though they are much poorer. This is probably a result of the fact that many air travelers in LDCs are foreigners or members of the wealthy elite whose incomes are far above average. Also, surface modes are less advanced than in developed countries, therefore offering less competition, and current air travel is more attractive than early US air travel in terms of cost, speed, and comfort.

The forecasts for Brazil and Indonesia were made by assuming continuation of the current 14-15 year lag in relative air travel spending between these countries and the US. While the high GDP growth rates of the LDCs could tend to shorten the lag, improvements in surface modes would have the opposite effect. Also, more equitable income distributions could slow the growth of air travel relative to the growth in average income, since even large increases in the incomes of the poor might still not permit them to afford air travel. In view of these offsetting trends, continuation of the present lag appears reasonable. Also, as shown in Fig. 56, the forecasts are consistent with recent trends, and indicate convergence to the US curve in the very distant future when the Brazilian and Indonesian economies have matured.

By combining the forecasts of the fraction of GDP spent on domestic air travel with forecasts of real GDP growth (6.6 percent/yr for Brazil, 7.5 percent/yr for Indonesia), and using constant real air fares, average annual air travel growth rates of 10.3 percent and 11.3 percent were obtained for Brazil and Indonesia, respectively. The GDP, air travel, and population trends in the two countries are summarized in Table 53. Note that while the forecasted air travel growth rates are high, they are modest compared to recent past history. These 30-year forecasted growth rates are also below the 13 percent average annual growth rate experienced in the last 30 years in the US. While the forecasts reflect maintenance of the 14-15 year lag relative to the US in the portion of GDP devoted to domestic air travel, the actual levels of air travel, both total and per capita, remain much further behind those of the US because of lower values of GDP and GDP/capita. In fact, both countries show slippage from current lags of 30-36 years to 40-50 years in 2005 because future air travel growth rates in Brazil and Indonseia will be lower than past US growth. The US experience was due not only to economic growth, but also to past improvements in the cost, speed, and comfort of air travel which are unlikely to be duplicated in the future.

Past and future trends in GDP and domestic air travel for Brazil and Indonesia are shown in Figs. 57 and 58, respectively. An interesting occurrence for both countries was the sluggish growth of GDP and air travel during their political problems of the 1960s, followed by rapid growth in the 1970s.

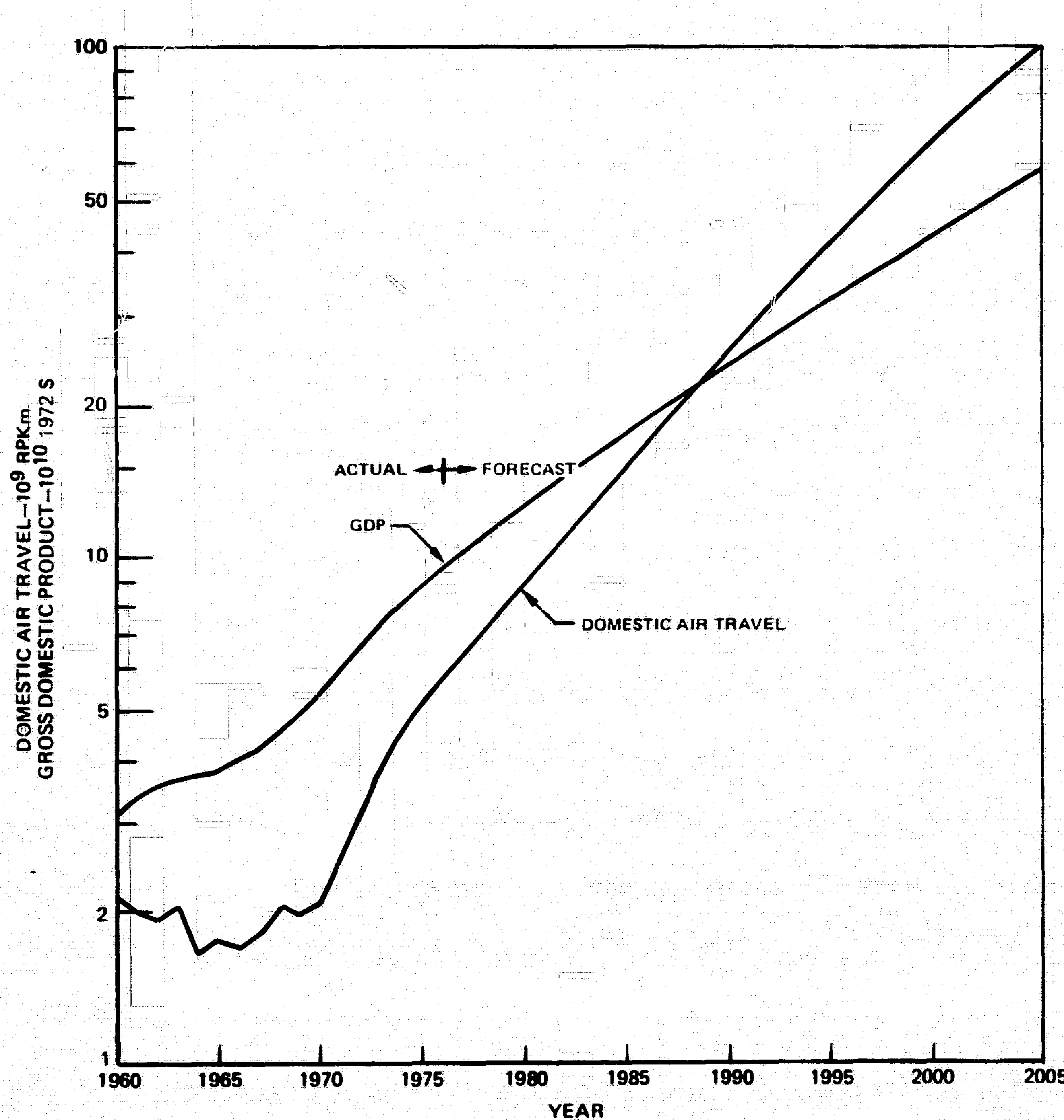
All scheduled domestic air services for Brazil and Indonesia were tabulated for 1970 and 1977 from the Official Airline Guide (Refs. 94,95). Brazilian service is summarized in Table 54, in which all routes have been categorized by range and density, and Table 55, which details the specific aircraft types in use. A striking feature was the rapid replacement of old,

TABLE 53

DEMOGRAPHIC AND DOMESTIC AIR TRAVEL DATA

	BRAZIL				INDONESIA			
	1960	1970	1975	2005	1960	1970	1977	2005
Population, 10^6	70.6	93.3	109.7	231.2	88.0	115.3	142.7	248.0
Growth Rate	-	2.8%	3.3%	2.5%	-	2.7%	3.1%	2.0%
Gross Dom. Prod. 10^9 1972 $	30.8	55.0	85.9	583.7	6.5	9.2	15.7	120.3
Growth Rate	-	6.0%	9.3%	6.6%	-	3.5%	13.4%	7.5%
GDP/Capita, 1972 $	436	589	783	2525	74	80	110	485
Growth Rate	-	3.1%	5.9%	4.0%	-	0.8%	4.7%	5.4%
Domestic Air Travel, 10^6 RPkm	2142	2107	5284	100,941	229	529	2245	44,986
Growth Rate	-	-0.2%	20.2%	10.3%	-	8.7%	22.9%	11.3%
Equivalent U.S. Year	1941	1941	1945	1966	1932	1935	1941	1959
RPkm/Capita	30	23	48	437	3	5	16	181
Equivalent U.S. Year	1944	1944	1945	1965	1934	1936	1941	1954
Domestic Air Rev./GDP	-	0.0023	0.0038	0.0106	-	0.0026	0.0039	0.0103
Equivalent U.S. Year	-	1953	1961	1991	-	1955	1962	1990

GDP AND DOMESTIC AIR TRAVEL – BRAZIL



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GDP AND DOMESTIC AIR TRAVEL – INDONESIA

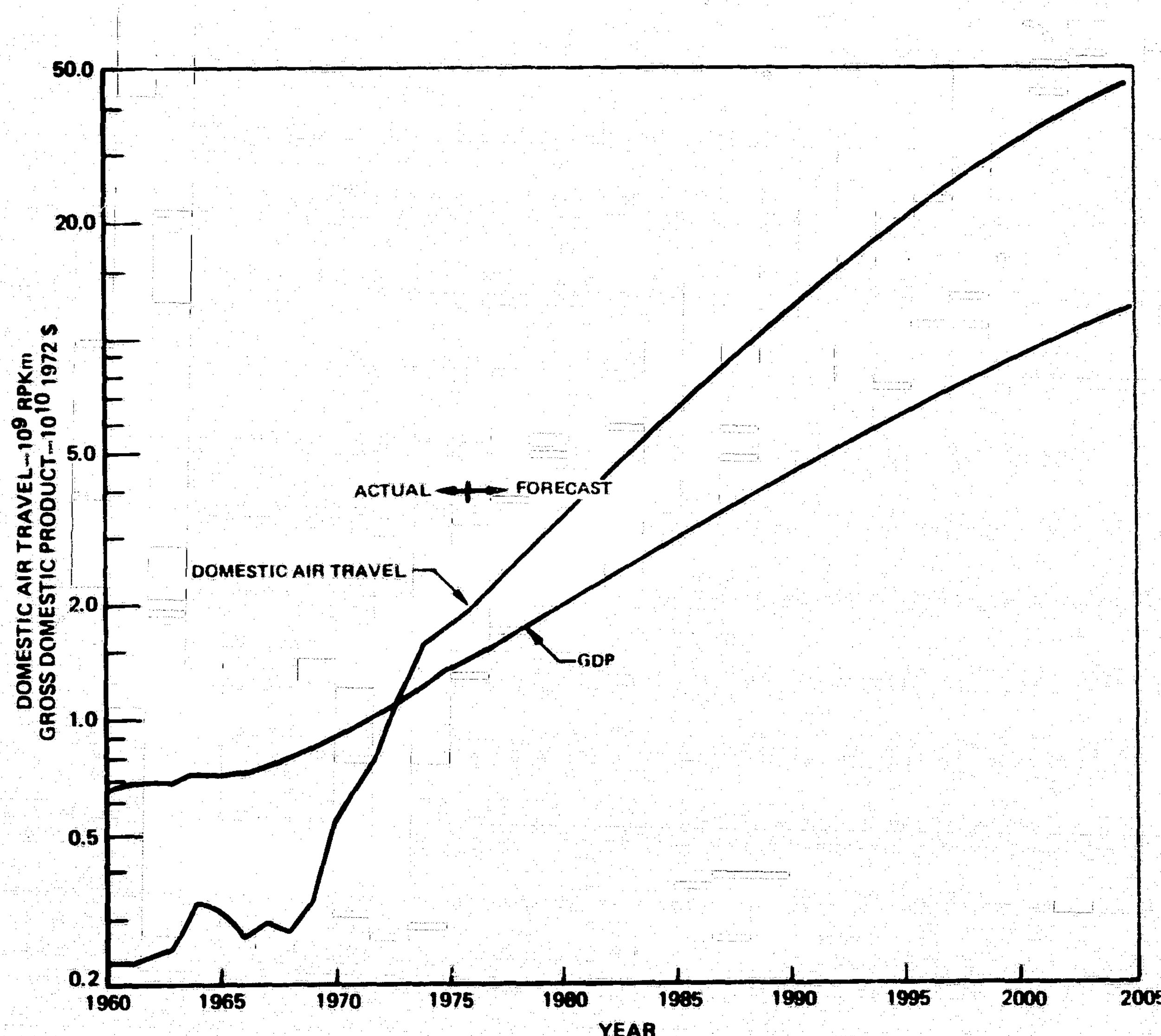

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TABLE 54

BRAZILIAN DOMESTIC AIR SERVICE

Route Density - seats/day:		1-100		100-400		400-2000		2000+	
		1970	1977	1970	1977	1970	1977	1970	1977
Distance 0-800 km	Routes	209	60	22	25	3	19	1**	1**
	Daily flights:								
	Piston*	103	0	13	0	0	0	19	0
	Small turboprop	0	57	0	5	0	0	0	0
	Large turboprop	37	2	65	10	15	0	47	55
	Jet	1	11	9	45	8	152	15	35
	Total	141	70	87	60	23	152	81	90
	Daily flights/route	0.7	1.2	3.9	2.4	7.8	8.0	81	90
	Avg. stage length, km	288	368	431	475	489	429	355	355
	Seats/flight	27	29	55	80	68	96	53	89
	Fraction of total seat-km	10.4%	2.6%	19.4%	7.9%	7.3%	21.8%	14.4%	9.9%
								TOTAL	
800 km+	Routes	9	12	9	9	4	12	257	138
	Daily flights:								
	Piston	2	0	0	0	0	0	137	0
	Small turboprop	0	0	0	0	0	0	0	62
	Large turboprop	4	0	11	0	11	0	189	66
	Jet	1	7	8	18	17	109	60	378
	Total	7	7	19	18	28	109	385	506
	Daily flights/route	0.7	0.6	2.1	2.0	7.1	9.1	1.5	3.7
	Avg. stage length, km	1012	1247	1350	1684	1258	1173	572	672
	Seats/flight	43	100	77	100	83	99	48	85
	Fraction of total seat-km	2.7%	3.1%	18.2%	10.5%	27.6%	44.2%	100.0%	100.0%

*See Table 56 for composition of aircraft categories

** Rio-Sao Paulo

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TABLE 55

BRAZILIAN DOMESTIC AIR SERVICE BY AIRCRAFT TYPE

Category	Aircraft Type	Seats	Daily Flights 1970	Daily Flights 1977
Piston	Avro Anson	8	76	0
	DC-3	24	61	0
	Total		137	0
Small Turboprop	Piper Navaho	6	0	5
	Embraer Bandeirante	15	0	57
	Total		0	62
Large Turboprop	FH-227	44	23	0
	Viscount	54	25	0
	YS-11	54	60	11
	Herald	55	38	0
	Electra	85	42	55
	Total		189	66
Jet	BAC-111	74	0	45
	Caravelle	75	31	0
	737-200	100	29	229
	727-100	100	0	104
	Total		60	378
TOTAL			385	506

small piston aircraft by new, small turboprops of Brazilian manufacture, and the replacement of larger turboprops by jets. (Most of the 1977 large turboprop flights were between Sao Paulo and Rio's downtown airport, from which jets are excluded.) Another significant occurrence was the rapid decline in the number of short, low-density* routes receiving scheduled service, from 209 in 1970 to 60 in 1977. Most of these routes received only one or two round-trips per week in 1970; they are probably served today by one of Brazil's many unscheduled air taxi operators (Ref. 92). (Although there is a possibility that the OAG did not list all scheduled service, there were approximately enough flights listed to fully utilize the fleets of the four scheduled carriers.)

To forecast the future domestic fleet requirements of Brazil, the seven route categories in Table 54 were regrouped into four categories, as shown in Table 56. The low-density category includes all routes served in 1977 by small turboprop aircraft only; medium density includes all other routes having a 1977 density of 400 seats/day or less; high-density routes are those between 400 and 2000 seats/day. The very dense Rio-Sao Paulo route forms its own category. Forecasts for 2005 for each category were made by applying the growth rates shown to the 1977 seat-km totals. (Since passenger flow data for individual routes were not available, route capacity was used instead. The assumption was future maintenance of today's 60 percent load factor.) These individual growth rates were set by judgment, with the requirement that total capacity will increase by 10.3 percent/yr, as previously forecasted. The underlying assumption was that the least dense routes will grow at the highest rates, since population growth and economic development are likely to be greatest in the small cities.

Dividing the total seat-km for each category by the 1977 average stage length gave total seats; dividing this value by the average seats/flight (based on the aircraft to be assigned to each category of routes as given in Table 57) gave the total flights required. The flights were sufficient to calculate the fleet sizes, but for completeness the number of routes served was also computed. For the low- and medium-density categories, the number of routes was found by dividing the total flights by the average daily flights/route. In the high-density category, the number of routes was held constant, giving the average flights/route shown. (Note that each category covers a wide spectrum of route densities, so that, in actuality, there is a continuum of service levels rather than the four discrete values shown.) From the totals shown for 2005, the Brazilian domestic network will obviously undergo a significant expansion.

Table 57 shows the fleets required to provide the service forecasted in Table 56. The number of aircraft of each type was found by dividing the total daily flights by the average number of flights flown by each aircraft.

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* The low-density scheduled serive analyzed in this section should not be confused with the low-density transport application described earlier. The latter application involved even lower-volume routes which are not presently served by scheduled flights.

TABLE 56

BRAZILIAN DOMESTIC AIR SERVICE FORECAST

Market:	Low Density	Medium Density	High Density	Rio-Sao Paulo	Total
1977					
Seat-km/Day, 10^6	0.20	6.72	18.99	2.84	28.75
Avg. Stage Length, km	275	783	745	355	672
Seats/Day, 10^3	0.7	8.6	25.5	8.0	42.8
Seats/Flight	14	84	97	89	85
Flights/Day	52	103	262	90	506
Daily Flights/Route	1.4	1.5	8.4	90.0	3.7
Routes	36	70	31	1	138
1977-2005 Average Annual Growth Rate, Seat-km	16.0%	13.1%	9.0%	5.0%	10.3%
2005					
Seat-km/Day, 10^6	12.8	211.0	212.1	11.1	447.0
Avg. Stage Length, km	275	783	745	355	719
Seats/Day, 10^3	46.5	269.5	284.7	31.3	622.0
Seats/Flight	32	115	240	240	122
Flights/Day	1453	2343	1186	130	5[illegible]2
Daily Flights/Route	3	5	38	130	5.2
Routes	484	469	31	1	985

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TABLE 57

BRAZILIAN DOMESTIC AIRCRAFT REQUIREMENTS - 2005

Market	Aircraft Seats	Avg. Stage Length, km	Flights/Day /Aircraft	Flights/Day Total	Aircraft Required
Low Density	15	275	7.4	727	98
	50	275	7.4	726	98
Medium Density	100	783	6.1	1172	192
	130	783	6.1	1171	192
High Density &	200	706	6.4	658	103
Rio-Sao Paulo	280	706	6.4	658	103
Total or Average	122	719	6.5	5112	786

These averages were derived from US CAB data (Ref. 91) for similar aircraft types operated by similar average stage lengths. Although Brazil is a large country in area, the longest domestic route is currently 2860 km and, since most of the population is concentrated along the coast, there will be little need for large, long-range, domestic aircraft, despite large-scale development of the interior. Nearly all of the likely long routes are within the capabilities of medium-range aircraft such as the B-727.

The largest numbers of required aircraft will be in the 100-seat category, such as the B-727-100 and B-737-100 (both of which are extensively used in Brazil today), and the larger 130-seat size (e.g., B-727-200 or DC-9-50); about 200 of each size will be needed for the medium-density routes. The high-density routes will require about 100 larger aircraft each in the 200-seat (e.g., B-7X7, DC-X-200, A-300B-10, etc.) and 280-seat (e.g., DC-10, L-1011, A-300B) sizes. The low-density routes will be served by about 100 15-seat turbopropos, such as the Brazilian-made EMB-110 Bandeirante, and 100 larger, 50-seat aircraft. This latter type might also be of Brazilian manufacture, as Embraer's scope is expanded in the future.

A completely analogous analysis was performed for Indonesia and is shown in Tables 58 to 61. Air service in Indonesia is less well developed than in Brazil, with fewer routes and flights. Although most of the service shown was by jet, it is not certain that all Indonesian scheduled service was listed in the 1977 OAG, since only three of six scheduled carriers - Garuda, Merpati, and Bouraq - were listed. There were no listed flights utilizing the latter two airlines' small aircraft (Twin Otters, Islanders, and Trislanders). However, the remaining other three carriers are very small (Ref. 93), and the small aircraft of Merpati and Bouraq might have been used exclusively for unscheduled service. At any rate, the number of missing routes was small and would be in the low-density category.

The forecast of Indonesian air service in 2005 is shown in Table 60. Here, the low-density market consists of all routes under 800 km having densities under 100 seats/day. The medium-density market includes all routes under 100 seats/day over 800 km, and all routes between 100 and 400 seats/day. The high-density market includes all routes above 400 seats/day except Jakarta-Surabaya, which forms its own category. The aircraft requirements are given in Table 61 and are similar to those of Brazil except that fewer large aircraft are needed. Although the islands of Indonesia stretch across 5000 km of ocean, the bulk of the population lives on Java, near the geographic center of the country. Since flights connecting the eastern and western ends of Indonesia are unlikely to overfly Java's large population centers, few long-range aircraft will be needed for domestic use.

The case-study LDCs presently rely primarily on the same US-built airplanes as are operating in our own system, and a continuation of this trend is likely. Shortages of foreign exchange will probably dictate purchase of used models (B-737, DC-9, B-727) from US carriers as re-equipment proceeds in this country and elsewhere in the developed world. Those airplanes which can be most easily adapted to special LDC conditions (hot weather, rainy seasons, occasional rough fields, rudimentary ground facilities) will be

TABLE 58

INDONESIAN DOMESTIC AIR SERVICE

Route Density - seats/day:		1-100		100-400		400-2000		2000+	
		1970	1977	1970	1977	1970	1977	1970	1977
Distance									
0-800 km	Routes	38	13	4	22	1**	4	0	1**
	Daily Flights:								
	DHC6/DC3*	16	4	2	0	0	0		0
	Large Turboprop	19	9	9	17	3	8		4
	Jet	0	2	0	54	3	32		20
	Total	35	15	11	71	6	40		24
	Daily flights/route	0.9	1.1	2.7	3.2	6.0	10.0		24.3
	Avg. stage length, km	367	344	565	399	668	488		668
	Seats/flight	35	43	47	62	73	71		98
	Fraction of total seat-km	20.4%	2.0%	13.1%	16.9%	13.5%	13.3%		15.2%
								TOTAL	
800 km +	Routes	8	5	3	8	0	4	54	57
	Daily flights:								
	DHC6/DC3	1	0	0	0		0	18	4
	Large Turboprop	7	1	1	9		4	40	53
	Jet	0	1	4	20		24	7	153
	Total	8	2	5	29		28	65	209
	Daily flights/route	1.0	0.5	1.8	3.6		7.0	1.2	3.7
	Avg. stage length, km	1062	1662	1403	1006		1231	711	697
	Seats/flight	45	80	104	63		97	47	72
	Fraction of total seat-km	16.8%	2.9%	36.2%	17.6%		32.1%	100.0%	100.0%

*See Table 60 for composition of aircraft categories.

** Jakarta-Surabaya

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TABLE 59

INDONESIAN DOMESTIC AIR SERVICE BY AIRCRAFT TYPE

Category	Aircraft Type	Seats	Daily Flights 1970	Daily Flights 1977
DHC6/DC3	DHC-6 Twin Otter	18	3	0
	DC-3	24	15	4
	Total		18	4
Large Turboprop	HS-748	44	0	17
	F27	44	36	6
	YS-11	54	0	13
	Viscount	60	0	10
	Electra	85	4	0
	Vanguard	100	0	7
	Total		40	53
Jet	F-28	65	0	98
	DC9-30	102	6	54
	DC8	133	1	0
	Total		7	153
TOTAL			65	209

TABLE 60

INDONESIAN DOMESTIC AIR SERVICE FORECAST

Market:	Low Density	Medium Density	High Density	Jakarta-Surabaya	Total
1977					
Seat-km/Day, 10^6	0.21	3.90	4.75	1.59	10.45
Avg. Stage Length, km	345	607	850	668	697
Seats/Day, 10^3	0.6	6.4	5.6	2.4	15.0
Seats/Flight	43	63	82	98	72
Flights/Day	15	102	68	24	209
Daily Flights/Route	1.1	2.9	8.5	24.3	3.7
Routes	13	35	8	1	57
1977-2005 Average Annual Growth Rate, Seat-km	16.0%	13.0%	10.0%	6.5%	11.3%
2005					
Seat-km/Day, 10^6	13.4	119.5	68.5	9.3	210.6
Avg. Stage Length, km	345	607	850	668	638
Seats/Day, 10^3	38.8	196.8	80.6	13.9	330.1
Seats/Flight	32	115	165	200	95
Flights/Day	1213	1712	488	70	3483
Daily Flights/Route	3	5	61	70	4.6
Routes	404	342	8	1	755

TABLE 61

INDONESIAN DOMESTIC AIRCRAFT REQUIREMENTS - 2005

Market	Aircraft Seats	Avg. Stage Length, km	Flights/Day /Aircraft	Flights/Day Total	Aircraft Required	
Low Density	15	345	5.9	607	103	
	50	345	5.9	606	103	
Medium Density	100	607	6.9	856	124	
	130	607	6.9	856	124	167
High Density	130	850	5.7	244	43	
	200	850	5.7	244	43	54
Jakarta - Surabaya	200	668	6.6	70	11	
Total or Average	95	638	6.3	3483	551	

most applicable, but the fact that the Brazilian and Indonesian carriers utilize existing airplanes successfully suggest that these conditions do not dominate. The conclusion is that the domestic passenger market does not justify a special R&D effort.

International Scheduled Passenger Transport

All international air service offered by the carriers of Brazil and Indonesia was tabulated from Ref. 95. The Brazilian carrier VARIG has a fairly extensive route network including a total of 15 weekly round trips to Rio de Janeiro from London, Paris, Zurich, Frankfort, and Rome; each of these flights also serves Lisbon or Madrid. There is daily nonstop service from New York, daily service from Miami with stops in Caracas or Belem, and four weekly flights from Los Angeles stopping in Lima or Manaus; three of the Los Angeles flights also serve Tokyo. Thirteen Latin American points are also served, with the most service provided to Buenos Aires. In addition there are two flights per week to Johannesburg. Nearly all of the international flights serving Rio also serve Sao Paulo. The intercontinental and longer South American routes are served by B707s and DC-10s; the shorter routes within South America are served by VARIG's B-737 equipment and Cruzeiro's B-727-100s and B-737s. Brazil's international air service is summarized in Table 62.

Indonesia's less extensive international air service is summarized in Table 63. Garuda, the state-owned carrier, operates four weekly round-trips between Jakarta and Amsterdam; each follows a different routing and makes three or four stops in Frankfurt, Paris, Rome, Jeddah, Bombay, Bangkok, or Singapore. A weekly round-trip by DC-10 to Los Angeles via Denpasar (Bali), Guam, and Honolulu was listed in the OAG but had not yet received government approval at the time of this analysis. The longer regional routes served by DC-8s include 10 weekly flights to Hong Kong from Jakarta and Denpasar, two of which continue to Tokyo, and six weekly flights to Sydney and Melbourne from Jakarta via Denpasar. There are also 98 DC-9 flights per week from Jakarta to Singapore, the principle connecting point in the region, and a few other short international flights, some operated by Merpati and Bouraq.

Table 64 summarizes a number of forecasts for the various markets in which the Brazilian international carriers operate. None of these forecasts specifically applies to Brazil alone, and none covers more than one-third of the thirty-year forecast period. Furthermore, there is some inconsistency among the various forecasts, such as the SRI and Douglas values for future South Atlantic annual growth (8.5 percent and 13.0 percent, respectively). Nevertheless, considering all of the forecasts shown--recent past growth of Brazilian international air travel and the previously forecasted domestic growth rate of 10.3 percent--an international growth rate of 9.0 percent appears reasonable. (International travel would be expected to grow more slowly than domestic since it includes more travel by residents of the developed countries, whose economies are growing more slowly.)

Forecasts applicable to Indonesian international air travel are summarized in Table 65. Here again, published forecasts are limited with

TABLE 62

1977 BRAZILIAN INTERNATIONAL SERVICE

Market:	Europe, S. Africa	North & Central America, Japan	S. America	Total
Daily Flight Segments:				
DC-10-30	5.1	2.3	0	7.4
B-707-320C	10.0	14.7	4.9	29.6
B-727-100	0	0	8.0	8.0
B-737-200	0	0	4.3	4.3
TOTAL	15.1	17.0	17.2	49.3
Avg. Stage Length, km	3101	3329	1123	2675
Seats/flight	187	165	114	154
Fraction of Total seat-km	43%	46%	11%	100%

Source: Ref. 95

TABLE 63

1977 INDONESIAN INTERNATIONAL SERVICE

Market:	Europe	U.S.[1]	Asia/Oceania	Total
Daily Flight Segments:				
DC-10-30	5.1	1.1	0	6.3
DC-8-50	0	0	7.1	7.1
DC-9-30	0	0	16.9	16.9
F-28	0	0	2.0	2.0
Others[2]	0	0	2.0	2.0
TOTAL	5.1	1.1	28.0	34.3
Avg. Stage Length, km	2887	3414	1542	2062
Seats/flight segment	260	260	103	132
Fraction of Total seat-km	41%	11%	48%	100%

[1] Subject to Government approval.

[2] F-27, YS-11, DC-3, Vanguard

Source: Ref. 95

TABLE 64

FORECASTS APPLICABLE TO BRAZILIAN INTERNATIONAL AIR TRAVEL

Source	Date	Ref.	Market	Average Annual Growth Rate	
				Actual	Forecast
IATA	1/77	1	South Atlantic N. America - S. America	-- --	11.0% (1975-81) 7.4% (1975-81)
P&WA	9/76	2	S. American Carriers	--	9.9% (1976-86)
SRI	4/76	3	South Atlantic N. America - S. America	-- --	8.5%[1] (1975-80) 8.0%[1] (1975-80)
SRI	12/75	4	U.S. - Latin America	11.4% (1960-74)	6.6% (1974-85)
Lockheed	12/74	5	Western Hemisphere International	12.8% (1960-73)	12.7% (1974-85)
SRI	11/74	6	Latin American International Carriers	14.6% (1960-73)	10.9% (1973-85)
Douglas	1/76	7	South Atlantic	16.7% (1968-74)	13.0% (1975-84)
			Brazilian International Carriers	{11.3% (1970-76) 13.9% (1960-76)}	9% (1976-2005)

[1]Average of high and low forecasts

TABLE 65

FORECASTS APPLICABLE TO INDONESIAN INTERNATIONAL AIR TRAVEL

Source	Date	Ref.	Market	Average Annual Growth Rate	
				Actual	Forecast
Douglas	1/77	8	Indonesian International Carriers	25.0% (1968-75)	19.0% (1976-81)
IATA	1/77	1	Europe - Far East/ Australia	--	9.3% (1975-81)
			North/Mid Pacific	--	6.6% (1975-81)
P&WA	9/76	2	Far East Carriers	--	9.4% (1976-86)
SRI	12/75	4	U.S. - Asia/Oceania	16.7% (1960-74)	9.2% (1974-85)
Lockheed	12/74	5	Europe - Asia/Oceania	14.3% (1960-73)	11.1% (1974-85)
			N. America - Asia Oceania	17.1% (1960-73)	12.1% (1974-85)
			Intra-Asia/Oceania	14.0% (1960-73)	12.9% (1974-85)
SRI	11/74	6	Asian & Pacific International Carriers	120.3% (1960-73)	13.3% (1973-85)
Douglas	2/75	9	S.E. Asia[1] - other W. Pacific	29.3% (1968-73)	13.4% (1974-83)
Douglas	2/74	10	Europe/Mid-East - S.E. Asia[1]	21.6% (1968-72)	13.9% (1973-80)
Douglas	2/73	11	North Pacific	18.8% (1966-71)	15.8% (1972-80)
			Indonesian International Carriers	17.2% (1970-76) 124.9% (1960-76)	12% (1976-2005)

[1]S.E. Asia: Malaysia, Singapore, Indonesia

respect to both the forecast period and direct applicability to Indonesia. However, based on the high growth rates forecasted for Asian air travel and the relatively undeveloped level of Indonesian international service, particularly to large potential markets such as the United States, Japan, Taiwan, and China (PRC), a forecasted growth rate of 12 percent was chosen. Table 66 and Fig. 59 show past and forecasted levels of domestic and international air travel for both Brazil and Indonesia. In both countries, international air travel, starting from very low levels, increased rapidly during the 1960s and 1970s, while domestic air travel grew very little from 1960 until the rapid growth of the 1970s. The forecasted growth rates for all four markets are modest in comparison to recent past growth, thereby reflecting a long-term maturing trend.

The first step in forecasting the future aircraft requirements for Brazilian international air travel was to restate the current service in terms of short/medium-distance aircraft (B-272 and B-737) and long-distance aircraft (DC-10 and B-707), as shown in Table 67. The total capacity (seat-km) for 2005 was based on the passenger forecast in Table 66 and a 60 percent load factor, resulting in 9.2 percent annual capacity growth from 1977. In assigning a higher growth rate to the short/medium-distance markets (11.0 percent vs 9.1 percent) consideration was given to the relatively low levels of current intra-South American service compared to intercontinental service, as well as the higher anticipated growth of travel between Brazil and other LDCs as opposed to travel between Brazil and developed countries. As with the domestic forecasts reported earlier, seat-km were converted to flights by applying current average stage lengths and projected average seats/flights based on the aircraft assigned.

The computation of aircraft requirements is shown in Table 68; the average number of daily flights per aircraft was based on US CAB data for similar aircraft sizes and stage lengths. Brazil's short/medium-distance international requirements in 2005 can be met with a total of 33 aircraft divided among the 100-seat (e.g., B-727-100, B-737-200, DC-9-30), 130 seat (e.g., B-727-200, DC-9-50), and 200-seat (e.g., B-7X7, DC-X-200, A300B-10) sizes. Long-distance routes will require 88 aircraft in the 280 (e.g., DC-10, L-1011, A-300B), 400 (e.g., B-747-200) and 530 (e.g., B-747 stretch derivative) seat sizes. For both route categories, emphasis was placed on the smaller sizes, reflecting the relatively low route densities.

The computation of Indonesia's international aircraft requirements is shown in Tables 69 and 70. Applying a 60 percent load factor to the forecasted 2005 air travel resulted in the total capacity shown in Table 69. This total represents only 9.8 percent annual capacity growth from 1977, compared to 12.0 percent travel growth. The disparity is due to low current load factors and inclusion of US service in 1977 capacity, for which there were no passengers in the 1976 traffic base year. For Indonesia, the only significant destination in the short/medium-distance category is Singapore, accounting for 90 percent of the capacity in this category. Since Singapore is the major connecting point in East Asia, and since direct international service to Indonesia is expected to grow rapidly, the growth rates assigned to the two distance categories reflect this trend. As shown in Table 70,

TABLE 66

BRAZILIAN AND INDONESIAN AIR TRAVEL

(10^9 RPKm and Average Annual Growth Rates)

	Brazil				Indonesia			
	Domestic		International		Domestic		International	
1960	2.142		0.537		0.229		0.030	
1970	2.107	(-0.2%)	2.278	(15.5%)	0.529	(8.7%)	0.397	(129.5%)
1976	5.880	(18.7%)	4.320	(11.3%)	1.952	(24.3%)	1.046	(17.5%)
2005	100.941	(10.3%)	52.584	(9.0%)	44.986	(11.4%)	27.980	(12.0%)

BRAZILIAN AND INDONESIAN AIR TRAVEL

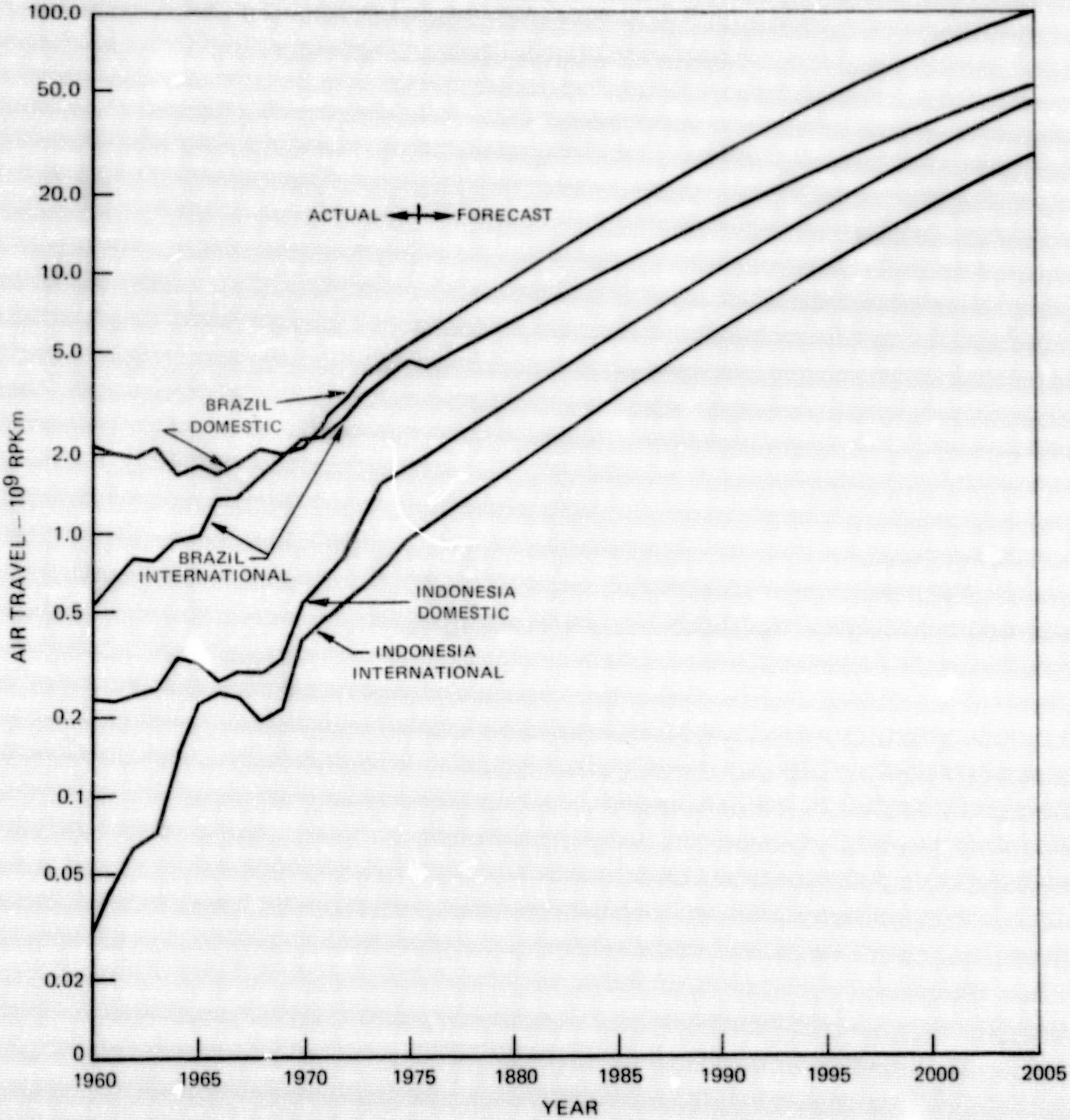

TABLE 67

BRAZILIAN INTERNATIONAL AIR SERVICE FORECAST

	Short/Medium Distance	Long Distance	Total
1977			
Seat-km/day, 10^6	1.212	19.109	20.322
Avg. stage length, km	987	3001	2675
Seats/day	1229	6367	7596
Seats/flight	100	172	154
Flights/day	12.3	37.0	49.3
1977-2005 Average Annual Growth Rate, seat-km	11.0%	9.1%	9.2%
2005			
Seat-km/day, 10^6	22.52	217.59	240.11
Avg. stage length, km	987	3001	2519
Seats/day	22815	72506	95321
Seats/flight	132	373	260
Flights/day	173	194	367

TABLE 68

BRAZILIAN INTERNATIONAL AIRCRAFT REQUIREMENTS - 2005

Market	Aircraft Seats	Avg. Stage Length, km	Flights/Day Aircraft	Flights/Day Total	Required Aircraft
Short/Medium Distance	100	987	5.2	69	13
	130	987	5.2	69	13
	200	987	5.2	35	7
Long Distance	280	3001	2.2	96	44
	400	3001	2.2	49	22
	530	3001	2.2	49	22
Total or Average	260	2519	3.0	367	121

TABLE 69

INDONESIAN INTERNATIONAL AIR SERVICE FORECAST

	Short/Medium Distance	Long Distance	Total
1977			
Seat-km/day, 10^6	1.617	7.723	9.339
Avg. stage length, km	831	2988	2062
Seats/day	1945	2584	4529
Seats/flight	93	192	132
Flights/day	20.9	13.4	34.3
1977-2005 Average Annual Growth Rate, seat-km	8.0%	10.1%	9.8%
2005			
Seat-km/day, 10^6	13.95	113.81	127.76
Avg. stage length, km	831	2988	2328
Seats/day	16787	38089	54876
Seats/flight	132	373	240
Flights/day	127	102	229

TABLE 70

INDONESIAN INTERNATIONAL AIRCRAFT REQUIREMENTS - 2005

Market	Aircraft Seats	Avg. Stage Length, km	Flights/Day Aircraft	Flights/Day Total	Required Aircraft
Short/Medium Distance	100	831	5.8	51	9
	130	831	5.8	51	9
	200	831	5.8	25	4
Long Distance	280	2988	2.2	50	23
	400	2988	2.2	26	12
	530	2988	2.2	26	12
Total or Average	240	2328	3.3	229	69

Indonesia's international requirements in 2005 can be met with 22 short/medium-distance and 47 long-distance aircraft, with the same size mix as used for Brazil.

General Aviation

In analyzing the general aviation markets in Brazil and Indonesia, a survey was made of the most recent data on registered aircraft uses, by category (e.g., Refs. 89, 96, 97), typical results of which are presented in Table 71. As shown, the categories employed by the Brazilian and Indonesian governments to characterize their fleets were adapted to US practice. Reducing these data to percentages resulted in the presentation given in Fig. 60. This presentation is useful because it illustrates the effect of the stage of LDC development on aircraft uses. Indonesia, for example, being at an early stage in its economic development, uses its fleet almost equally in the Commercial, Scheduled Carrier, Business, and Instruction categories, with almost no Personal use. In the US, more than half of the fleet is in the personal-use category, and other categories have substantially lower percentages than Indonesia. Brazil, although an in-between case, is clearly more similar to the US than to Indonesia.

A generalization and extrapolative forecast of just the general aviation segments of these fleets was made (Fig. 61) for the two countries using per-capita GNP as the basic parameter. The solid symbols represent historical fleet data for recent years (since 1969) and the open symbols are the 2005 forecasts based on per-capita GNP projections presented earlier in the report. As shown, the market for general aviation airplanes in Brazil is large, numbering some 40,000 additional aircraft in the 30-year forecast period, while the Indonesian market is considerably smaller, totaling about 5000 airplanes.

The category corresponding to unscheduled, low-density transport analyzed previously as a primary application is included in Table 71 under Air Taxi. Fractions of the respective general aviation fleets devoted to this type of use are inversely related to development: US - 4.3 percent, Brazil - 10.5 percent and Indonesia - 32.4 percent. It appears, then, that the low-density sector of the market grows rapidly during the period when remote areas are undergoing exploration and development, but eventually declines as low-density routes advance to scheduled service and surface transport infrastructure extends into a comprehensive network. During the 30-year forecast period it would be expected that the percentages of general aviation airplanes serving this market would not change radically in Brazil and Indonesia because of the very large undeveloped areas in these countries. If the same percentages are adopted for 2005, there will be a need for 4000 additional airplanes to serve low-density routes in Brazil during the 30-year period, and 1600 airplanes in Indonesia.

In spite of the impressive requirements shown in Fig. 61, it is expected that countries like Brazil, and perhaps Indonesia in the future, will depend on domestic manufacture of light airplanes to the maximum possible extent.

TABLE 71

AIRCRAFT USES

U.S. Categories	U.S. Fleet 1969	Brazilian Categories	Brazilian Fleet 1972	Brazilian Fleet 1976	Indonesian Categories	Indonesian Fleet 1970
Personal	70500	Recreation	157	123	Pers. Flying	1
		Private Trans.	1454	2641	——	
Business	24388	Ind. & Comm. Service	265	712	Exec. Flying	53
		Government	168	192	——	
Commercial	11832		351	864		68
Air Taxi (1)	5642	Air Taxi Oper.	270	515	Transport (1)	56
		Indiv. Air Taxi	25	22	——	
Agriculture	5788	——			Aerial Applic.	12
Ind./Spec.	402	Spec. Services	81	327	——	
Instructional	15655	Training	658	758	Instruc. Flying	51
Air Carrier	2690	Scheduled	151	197	Scheduled	64
Other	8431	Other	0	104	Other	0
TOTAL	133496		3229	5591		237
Gen. Aviation	130806		3078	5394		173
Air Carrier	2690		151	197		64

(1) Nonscheduled

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USES OF AIRCRAFT FLEETS

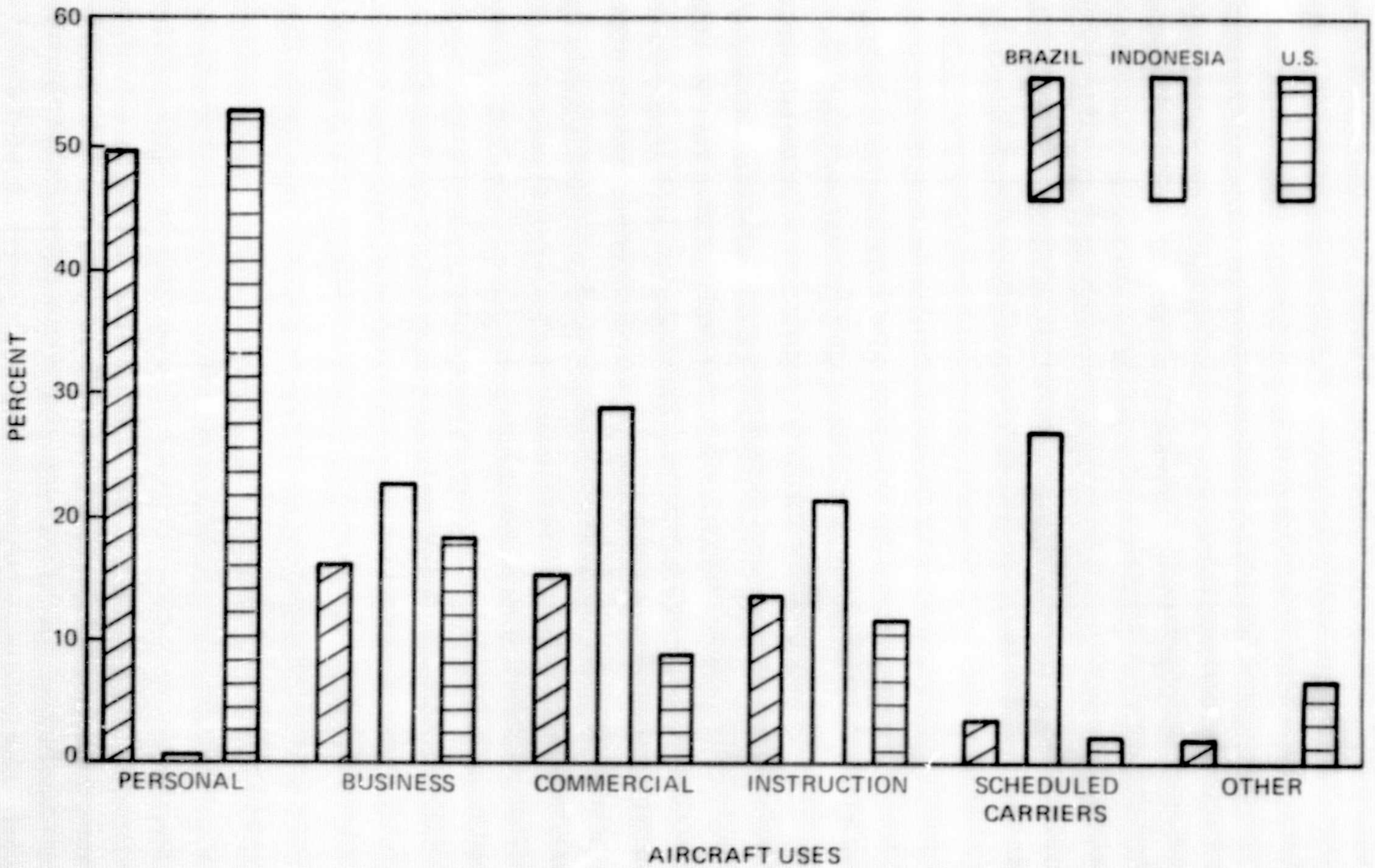

FIG. 60

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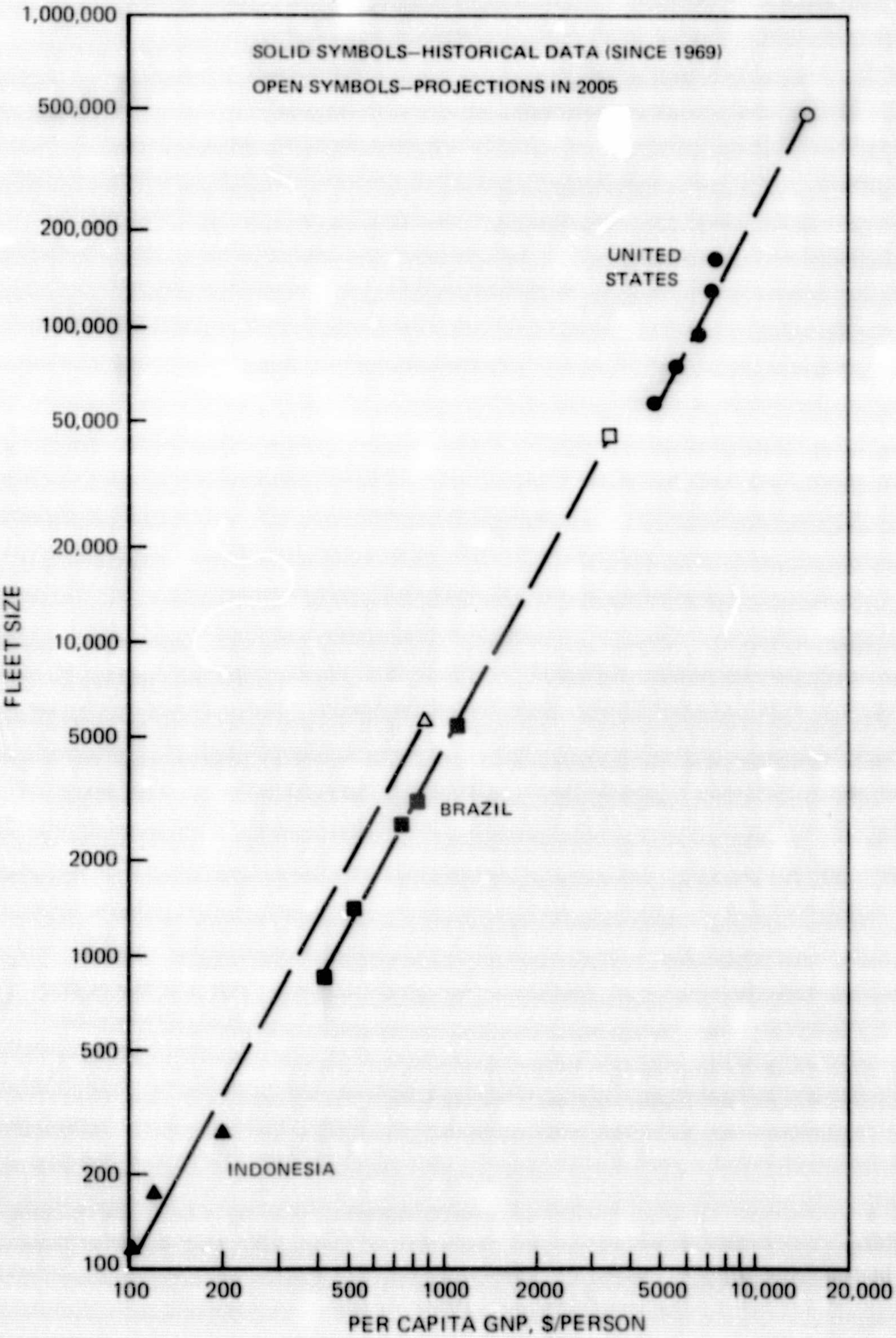
GENERAL AVIATION FLEET PROJECTION

1977 DOLLARS



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Therefore, these markets may not be open to US manufacturers on other than a licensed-manufacture basis.

One additional type of data obtained in this registered-aircraft survey were airport characteristics. The table below lists some basic information concerning the numbers of airports in each country and their stages of development. It is interesting to note in this table that Indonesian airports are more heavily devoted to regular service than in Brazil or the US, again reflecting the greater percentage of air carrier uses. In terms of numbers of airports, however, Indonesia is far behind Brazil, which is, in turn, far behind the US. Since both Brazil and Indonesia have ambitious plans to upgrade existing airports and add new ones, the disparities are likely to decrease considerably during the forecast period.

Airport Data
(Refs. 59, 89, 92, 95-97)

	Indonesia		Brazil		United States	
Total Airports	67		1453		13,770	
Airports with Paved Runways (%)	14	(21)	120	(8)	5,109	(37)
Airports with Regular Service (%)	21	(31)	103	(7)	631	(5)
Airports with Jet Service (%)	15	(22)	35	(2)	284	(2)

LDC Competition in Aircraft Manufacturing

It appears that aircraft manufacturing has become an important initial step in advancing the technological status of developing nations. The process begins with assembly of foreign-made components, progresses to manufacture of components under license for domestic assembly, advances to complete manufacture and assembly, and finally reaches the stage of domestic design and manufacture. The tendency of LDCs toward state ownership of such ventures can lead to tariff protection, which effectively legislates purchase of domestically made airplanes by national carriers. Furthermore, Government subsidization can result in prices competitive with high-volume US- and European-made models. This, in turn, creates an export market, particularly to neighboring LDCs. Brazil's EMBRAER Is presently in this position with the EMB-110, which is aggressively marketing for export in Latin America and Africa, and EMBRAER may even attempt to obtain sales in the US and Europe.

Airplane production gives LDCs several important benefits. First, it employs manpower in an industry which upgrades technological skills. Secondly, it conserves foreign exchange which would be expended to purchase foreign-made airplanes, and thirdly, it can ultimately become a source of foreign exchange if domestically manufactured airplanes can be sold abroad. Thus, the inducement to enter the aircraft manufacturing field is a powerful one, although only the most advanced nations of the LDC group have thus far made the necessary committment of resources. A survey of current LDC aircraft manufacturing, based on Ref. 98, appears in Appendix G.

Realistically, there are technical limits to the scope of such ventures in LDCs. The aircraft programs which they can undertake at present are confined to relatively small models, and the highest-technology components (engines and avionics) must be imported from the developed world. These restrictions may change in the future, but the changes will be gradual. Transport aircraft up to about 50-passenger size should be feasible for LDCs like Brazil, but competing in the larger-aircraft market requires an enormous technical infrastructure and a commitment of capital that few LDCs could contemplate in the foreseeable future. Also, the development and manufacture of aircraft engines is likely to be many years in the future for all but the most technologically advanced LDCs.

Relating these arguments to the airplane applications presented earlier in Table 2, it appears that at least the requirements of the utility applications (emergency relief, exploration and mapping, technical assistance) and the low-density passenger transport market are likely to be fulfilled by LDC manufacturers. Not all LDCs will compete in this market, but the ones that do (Brazil, Spain, India, etc.) would be the major markets for US manufacturers attempting to penetrate the LDC market for such aircraft. Therefore, it appears that this light aircraft market is a risky one for direct competition with LDCs (except for engines and avionics) unless licensing agreements for LDC production are accepted as the standard. In any case, it should be the US manufacturers of small aircraft, engines and other components who would be the benefactors of R&D efforts in this area.

Military requirements in LDCs include trainers, fighters, and airlift transports. There is evidence that LDCs can produce their own trainers. (EMBRAER has been producing the Macchi trainer under license but is presently developing its own design.) The LDC market potential for advanced fighters and logistic transports will remain favorable for US manufacturers, but it is not likely that LDC needs will set technology requirements. Therefore, the LDC military market is not important from the R&D standpoint.

STUDY IMPLICATIONS

The results documented in the previous section showed that good prospects exist for some applications of advanced-technology transport aircraft in developing countries. Remote mining was found to offer a unique opportunity not only in the sense of a clear and present need for air support, but also with respect to the potential aircraft needs in Brazil and Indonesia for applications of this type. Low-density transport and tropical forestry appear to offer less certain opportunities, although technology improvements related to the special requirements of these applications could improve their potential. A substantial LCA market was projected for Brazil in the long term, but not for Indonesia, indicating that only those nations of the LDC group which have a large present commitment to air cargo will be a factor in the LCA picture. Finally, the markets for scheduled airliners of the types which will be introduced in the developed world, and many types of general aviation aircraft, will remain strong in Brazil and Indonesia, and probably in other LDCs as well, depending on future growth.

An important objective of this study was to identify research and development items associated with future LDC aircraft needs. Although NASA's present R&D program in aeronautics is broadly based, its orientation is appropriately in the technologies which will find applications in the US. Therefore, a premise of the study was that, LDC aircraft uses not being identical to US uses, some unique R&D needs might emerge from LDC requirements. By providing the US aeronautics industry with the benefit of such research, sales of US manufacturers in LDCs would thus be promoted.

A review of the present NASA program (Ref. 100) was the starting point in the R&D task. With a knowledge of this program as background, it was possible to determine which of the technology areas identified as important to LDC needs were already incorporated in NASA-sponsored research, and which were not. In the former case, additional support could be offered for existing programs, and in the latter case, recommendations for new research areas could be made.

RESEARCH AND DEVELOPMENT NEEDS

To initiate the process of isolating R&D opportunities to guide the NASA's program, some general specifications were outlined for each of the four primary aircraft applications. These specifications, which appear in Table 72, reflect the results obtained in the analyses of the last section of the report. Although expressed in general terms, they serve to quantify the design requirements of each application.

TABLE 72

GENERAL AIRCRAFT SPECIFICATIONS

Application	Year Needed	Payload kg	Design Range km	Cruise Mach	Field Length m	Propulsion Type*	Propulsion Number	Special Features
Remote Mining Transport	1980	30,000 to 40,000	1000	0.65 to 0.75	< 750	TF or PF	2 to 4	Short, rough, high field
Low-Density Route Transport	1980	< 5,000	500	0.65 to 0.75	1200	TF or PF	2	Pass./Cargo adaptability Remote area operation
Tropical Forestry Airship	1985	30,000	1000	0.10	Hover	TP	$\geq$ 2	External loads Remote area operation
Large Cargo Aircraft	1995	177,000	7500	0.85	4200	TF or TP	$\geq$ 4	Low noise

* TF = Turbofan
TP = Turboprop
PF = Prop-fan

Remote mining constitutes an immediate need for a VTOL or STOL airplane with a payload capacity which accommodates earth-moving machinery, and with the capability to operate reliably in the rough conditions of a mountainous and/or jungle environment.* This applicaton has moderate speed and range requirements, and candidate aircraft should be adaptable to both passenger and cargo uses.

The Low-Density Route application is seen to provide an immediate need for a small- to medium-size, twin-engine airplane with a relatively low cruise speed and design range, moderate field length, ready adaptability for passenger /cargo use, and the capability to operate in remote areas (i.e., independent of facilities and maintenance skills commonly available in an industrial environment).

In the Tropical Forestry application, requirements for hovering and very low-speed cruise wth a large external payload make a lighter-than-air solution attractive. Other VTOL designs might fulfill these requirements, but remote-area operation in the mid-1980s precludes advanced VTOLs, such as tilt-wing or tilt-rotor configurations, and conventional helicopters are too restricted in range for the particular application identified. As is well known, helicopters have found application in short-distance transport of logs, particularly high value species. While such applications will also occur in LDCs, deep penetration into remote areas will place a premium on longer range.

The data specifications for the Large Cargo Aircraft (LCA) in Table 72 are descriptive of a large airplane of conventional design (i.e., not a spanloader configuration). Since this airplane will be primarily for international service, it must be compatible with major world airports as regards field length and noise. A lower speed than that indicated in Table 72 might be acceptable based on the characteristics of the important Rio - New York and Rio - Los Angeles - Tokyo routes, for which departure and arrival time-of-day considerations could permit some cruise speed flexibility (slightly lower speed) which might favor high bypass turbofan or prop-fan propulsion. However, since the LCA will be designed to the needs of other world cargo routes, speeds lower than current practice may not be tolerable.

The next step in working toward R&D recommendations was to identify technology impact areas for each of the four applications, as in Table 73. Here, the general specifications in Table 72 have been translated into technology impact groups with weightings assigned to indicate the relative importance of each item. The objective was to select, for each application, a prioritized list of technology impact areas as a preliminary to isolating R&D items. Thus, the reordering of these items, as in Table 74, indicated the nature of the requirements for each application. This listing was useful in two ways. First, it indicated the essential and important features which should dictate R&D emphasis in each case; and second, it indicated which items could be traded to achieve these objectives.

---

* In many respects, the remote mining application resembles a military operation, and technology requirements would be expected to reflect the similarity.

TABLE 73

TECHNOLOGY IMPACT AREAS

+++ = Essential
++ = Important
+ = Useful
0 = Unnecessary

Air Transport Application	Performance			Cost		Maintenance		Airfield				Adaptability		
	High Speed	Long Range	Good Controllability	Low Capital Cost	Low Operating Cost	Independent of Maintenance Skills and Facilities	Ruggedness for Rough Operating Environment	Reduced Field or Hovering Capability	Low Noise	Rough Field Capability	High Altitude Field Capability	Cargo Handling	Adaptability	All-Weather Capability
Remote Mining Transport	+	+	+++	+	+	++	+++	+++	+	+++	+++	+++	++	+++
Low-Density Route Transport	+	+	+	++	+++	++	++	++	+	++	+	+	+++	++
Tropical Forestry Airship	+	+	++	++	+++	++	+++	+++	+	0	0	+++	0	+
LCA	++	+++	0	+	+++	+	0	0	+++	0	0	+++	0	+

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TABLE 74

NATURE OF REQUIREMENTS

Essential (+++)	Important (++)	Useful (+)	Unnecessary (0)
Remote Mining Transport			
Outsize Loads Short/Hi-Alt. Field Rough Field Controllability All-Weather Capability Ruggedness	Pass./Cargo Adapt. Maintainability*	High Speed Long Range Low Cap. Cost Low Oper. Cost Low Noise	
Low-Density Transport			
Low Oper. Cost Pass./Cargo Adapt.	Low Capital Cost Maintainability* Ruggedness Reduced Field Rough Field All-Weather	High Speed Long Range Controllability Hi-Alt. Field Low Noise Cargo Handling	
Tropical Forestry Airship			
Reduced Field (hover) Outsize Loads Low Oper. Cost Ruggedness	Controllability Low Cap. Cost Maintainability*	Long Range High Speed All-Weather Low Noise	Rough Field Hi-Alt. Field Pass./Cargo Adapt.
Large Cargo Aircraft			
Long Range Low Oper. Cost Cargo Handling Low Noise	High Speed Mil./Civil Adapt.	Low Cap. Cost Maintainability* All-Weather	Controllability Ruggedness Reduced Field Rough Field Hi-Alt. Field Pass./Cargo Adapt.

*Maintainability refers to the independence of maintenance skills and facilities

Remote Mining

Expanding on the items in the "Essential" and "Important" headings in Table 74, for Remote Mining, a prioritized list of technology items is presented in Table 75 for this application. This list provides an elaboration of each requirement (e.g., Carry Outsize Loads) in order to identify the primary technological means of achieving the requirement. Moreover, under each feature, the items are listed in the probable order of emphasis desired to achieve the requirement.

The capability to carry appropriate outsize loads in fixed-wing aircraft requires a cargo hold with a minimum width of 3.5 m and height of 3.0 m, based on the dimensions of a D-7 bulldozer (weight approximately 18,000 kg). Many other types of earth-moving and construction vehicles such as graders and pipe layers also fit within this box, and transport of even larger bulldozers (e.g., D-8) would be beneficial, but not essential. Helicopters have the attractive feature of carrying loads externally*, which relaxes restrictions on dimensions but not on payload. To carry very large payloads, helicopters can be used in tandem (twin lift), a capability which would permit even larger earth movers (e.g., D-8 bulldozers) to be transported for short distances. The technologies required for this type of operation are of high priority since helicopters may be essential for projects where terrain impediments preclude runways of any length. One alternative is the HLA, which showed up well in the economic comparison, but is an entirely unproven concept. Another alternative is airdrop and retrieval, which must be done with great precison and safety. The military technique of low-speed, low-altitude flyover with dynamic load alleviation is one method. A circling technique in which a long cable is extended to describe a helical trajectory with the low end stationary (Ref. 99) is another. The development of such methods would also be of value in serving remote areas, particularly in disaster relief and other emergency situations. Remaining items in this category are self-explanatory, and most are common with the LCA, to be considered below.

As was shown earlier in Fig. 13, achieving a reduced-field capability at high altitude presents both aerodynamic and propulsive requirements. Based on these peculiar high-altitude requirements, an internally blown-flap system (e.g., augmentor wing) is of interest here because a supplementary engine might be carried inside the airplane to augment normal air flow in the flap system or to unload the main propulsion engines. This solution is attractive because it requires no permanent compromise to the basic aircraft in other applications (the duct system would already be part of the airplane), whereas augmenting a mechanical or externally blown-flap design requires installation of an engine (or other thrust augmentor such as JATO) outside the airplane. Although the total need has been estimated to be significant (on the order of 100 airplanes for remote mining projects in Brazil and

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* Advanced VTOL concepts such as tilt-wing, tilt-rotor, and vectored thrust are probably ruled out because of their inability to carry external loads, as well as performance, cost, and complexity problems.

TABLE 75

TECHNOLOGY PRIORITIES FOR REMOTE MINING

Cargo Handling - Outsize Loads

Wide Doors: Door actuation - hydraulics, seating & locking
Seals - materials, design
Large cutouts - adv. struct. anal. techniques
Load Management: Cargo load distribution - C.G. management
Self-contained loading mechanism
Roll on/roll off
Tie down
Helicopter and HLA operations -
External load } Stabilization, engagement, release
Tandem lift }
Airdrop & Retrieval: Dynamic, static

Reduced (Short)/High-Altitude Field

Takeoff: Thrust augmentation - JATO, APU
Blown flap - aero., materials, config.
Landing: Blown flap -
Wing } aerodynamics, design
Rotor } materials, manufacture
Braking -
Thrust reversal - hydraulics, mat'ls., design
Brake technol. - dynamics, config., mat'ls.
Stopping Syst. - electronics, sensors, integration
Precision unflared approach - flight controls

Rough Field

Landing Gear: Braking - anti-skid features
Load alleviation - gear configuration
Tire technology - materials, design
Crosswind - side loads
Air cushion - deployment & retracting, mat'ls.
Foreign Obj. Dam. Tol.: Engine ingestion } design, mat'ls.
Windshield }
Towing & Jacking Compatibility: Design

Controllability

Precision Landing & Hovering }
Stability Augmentation }
Gust Alleviation } Design, aerodynamics
Airdrop & Retrieval }
Dynamic Rotor Response }
In-Flight Thrust Reversal }
Crosswind Landing

All-Weather Capability

Weather Diagnostics - Systems analysis
Turbulence & Wind Shear Effects - Design
Heavy Rain: Engine flameout, pilot visibility - design
Automatic Landing: Design

Ruggedness

Damage-Tolerant Structure: Airframe, engine - design
Structure: Materials, fastenings

Passenger/Cargo Adaptability

Multi-Use Pallets: Seating, containers, vehicles, mobile fuel depot, maintenance shop, etc.
Dual Certification: Passenger, cargo
Fuel Compatibility: Diesel fuel for gas turbines

Independent of Maintenance Skills & Facilities

Maintenance Monitoring Systems }
Modular Design } Design
Self-Jacking Capability }

Indonesia by the year 2005), any compromise built into an airplane specifically for the remote mining application would constitute a drawback in other applications, and would reduce the potential production volume.

Most of the technology areas indicated in the rest of Table 75 need little elaboration. They include a number of technologies which are part of the NASA's R&D program (Ref. 100), in which case additional justification and/or emphasis is implied, and some which are unique to the remote mining application. However, the last two items under the Adaptability category may require additional explanation.

It was learned in researching the Ertsberg venture (Indonesia) that an important aircraft use involved ferrying men and supplies between Irian Jaya, where the project was going on, and the islands of Bali and Java. High speed is a basic element of this requirement, which offers an excellent opportunity to further utilize a fixed-wing airplane, perhaps at reduced payload, to extend range. However, the airplane would have to be certified for passenger as well as cargo service; otherwise, the operator would not be able to insure it. This dual certification requirement presents design problems concerning egress from the main cabin in an emergency. If means can be found to offer the required features, the added capability will be of great value in the remote mining application.

The last item in this category, Fuel Compatiblity, refers to the possibility of utilizing the same fuel in the airplane engines as in the diesel engines of the earth-moving machinery. Since diesel engines are probably less restrictive of fuel characteristics, use of jet fuel ought to be possible; running aircraft gas turbines on diesel fuel is less certain. However, a common fuel offers the intriguing possibility of ferrying fuel in the airplanes' main tank and pumping it into remote fuel dumps for surface-vehicle use. Since fuel transport was a significant fraction of total air transport in the Ertsberg project (about one-third), this capability might be a time- and cost-saving feature which could be quite valuable.

Low-Density Transport

The Low-Density Transport application involves a significantly different emphasis of technology areas when compared with Remote Mining. As indicated in Table 76 the highest priority is to minimize operating cost (including capital cost which is not singled out as a special priority in Table 76). Even for those requirements which are common, e.g., Adaptability, the objectives are dissimilar for the two applications.

As explained earlier, low-density routes appear to offer opportunities for airplanes ranging in size from light US general aviation aircraft up to small commercial sizes. The upper size is bounded at a payload of about 4000 kg, or 45 passengers. At present, low-density LDC routes are served by US general aviation models, many older aircraft (e.g., DC-3) and small foreign airplanes, especially the British Islander series and the Canadian

TABLE 76

TECHNOLOGY PRIORITIES FOR LOW-DENSITY ROUTE TRANSPORT

Requirement	Technology Priority
Low Operating Cost	Reduce structure weight: materials, analytical methods Improve fuel efficiency: engine components, materials Design simplifications: standardized structural elements, simple shapes Improved manufacturing processes: casting, winding Design for commonality: "family of airplanes" Improved maintenance practice: diagnostics Extended component lifetimes: flutter and fatigue analysis
Adaptability	Wide doors: large cutouts Develop retractable or readily removable seats Provide for carry-on baggage
Independence of Maintenance Skills and Facilities	Modularization Tamper-proof components Rugged construction
Reduced Field (RTOL)	Provide low-speed thrust augmentation Design for low-wing loading
Rough Field Capability	Improve landing gear for anti-skid braking and dynamic load alleviation Design for engine ingestion protection Design for rugged construction
All-Weather Capability	Improve reliability in heavy rain Improve onboard (independent) navigation Improve onboard (independent) meteorology prediction

Twin Otter. These airplanes are of relatively low technology content, but they are inexpensive to operate, adaptable to the demands of a remote environment (as regards cargo variability), and compatible with small, unimproved airstrips.

Although an airplane with a higher technology content might compete for this low-density market, it can do so only if costs are kept from escalating with the improving technology. As indicated in Table 76, weight reductions provide the most powerful means of attaining higher technology content while holding the line on cost. Materials, manufacturing processes and engine efficiency R&D should be stressed to achieve this objective. In particular, the introduction of advanced technology in the general aviation sector should be promoted because it is this sector of the US aircraft manufacturing industry which will be most affected by low-density LDC route growth. However, the stiff competition of indigenous LDC airplanes (see Appendix G), including the possibility of tariff barriers erected to promote their use, is a factor to be reckoned with. Technology is clearly the most likely offering of US manufacturers in this market, but nontechnology factors render the market an uncertain one.

Tropical Forestry Airship

The technology priorities of the Tropical Forestry application, for which the economic evaluation specified LTA as the preferred air mode, are summarized in Table 77. The ability to hover while carrying a heavy external load was shown to be essential for this application. Therefore, the technology items concerned with achieving these objectives receive highest priority. A number of additional technologies contribute to reducing operating cost, another essential objective if the airship is to show a clear economic advantage over conventional, surface-based methods. Although the Heavy Lift Airship (HLA) concept described in NASA-sponsored studies did not compare favorably in the economic evaluation because of its high capital cost, it should be noted that cost reductions achieved by implementing advanced-technology improvements would help to bring that configuration into the competitive range. However, in view of its dependence on helicopter assist, HLA cost reductions are likely to be more contingent on reducing the capital cost of advanced helicopters than on the technology of the LTA. As in the remote mining application, heavy lift helicopter technology items which improve performance are important priorities. But, in the tropical forestry case, reduced cost is of at least equal value.

Large Cargo Airplane

Since the CLASS studies are nearing completion, LCA technology recommendations soon to be published will supersede those which appear here. Therefore, Table 78 is included only to complete the R&D analysis of the present study. These technology items are not only less detailed than what can be expected from the CLASS study (Refs. 73, 101) results, but they are based on a conventional airplane and not a Spanloader design. The decision to incorporate only a conventional design in this study was, perhaps, a conserva-

TABLE 77

TECHNOLOGY PRIORITIES FOR TROPICAL FORESTRY AIRSHIP

Requirement	Technology Priority
Reduced Field (Hover)	Precision hover and terminal area control: zero speed controls, gust alleviation, fly-by-wire Buoyancy control: rapid ballast exchange, automatic valving Ground handling: mooring systems, mobile masts, constant-tension winches
Cargo Handling	On-board cargo handling: independent of terminal facilities, unitized pallets for quick turnaround Concentrated loads distribution to structure Buoyancy control: rapid ballast exchange
Low Operating Cost	First cost: design-to-cost, structural techniques and materials, long-life engines and control systems Maintenance cost: repairable in field (fabric and outer shell materials), modular design, maintenance monitoring systems Productivity: cargo handling (rapid turnaround), precision hovering, all-weather capability (avionics, digital electronics) Fuel consumption: Propulsive efficiency - propeller and rotor technology Alternate fuels - diesel, gas turbine Aerodynamic efficiency - control surfaces, protuberances, propulsion system integration Crew: automatic pilot, avionics and digital electronics
Ruggedness	Damage-tolerant structure: repairable in field Structural design: materials, fastenings, mfr. methods
Controllability	Same technologies as above (Reduced Field)
Low Capital Cost	Same technologies as above (Low Oper. Cost: First Cost)
Maintainability	Same technologies as above (Low Oper. Cost: maintenance, Ruggedness)

TABLE 78

TECHNOLOGY PRIORITIES FOR INTERNATIONAL
LARGE CARGO AIRPLANE

Requirement	Technology Priority
Long Range	Improved Fuel Efficiency: Engine - component weights & efficiencies, prop-fans, alternative fuels Aerodynamic - airfoil technology (low speed & high speed), high A.R. - laminar flow control, pliant skin Structure - composite materials (secondary & primary structure) - flight control techniques to improve fatigue life - stability analysis technology to optimize structural elements Operations - digital electronics for optimum fuel management
Low Operating Cost	First Cost: Design-to-cost, structural techniques & materials, long-life engines & control systems, military/civil commonality Fuel Cost: See above under Improved Fuel Efficiency Maintenance Cost: Maintenance monitoring systems, diagnostics Productivity: Cargo handling system (rapid turnaround) Crew: Avionics & digital electronics to reduce workload
Cargo Handling	Intermodal Cargo Handling: Containerization, terminal facilities military/civil commonality
Low Noise	Source Noise: Engine - low-noise cycle selection, nacelle treatment Aerodynamic - design for threshold below engine noise Operational: Steep climb angle, steep approach
High Speed	Design for speeds equal to current aircraft: Engine - high thrust-to-weight ratio, prop-fan technology Airframe - low structure weight (composite structure) - improved aerodynamics (supercritical wing)
Adaptability	Military/Civil Commonality: Systems Analysis to identify military/commercial requirements Design to achieve optimum compromise between military & civil req'ts (range, speed, size)

tive assumption considering the predicted future volume of Brazilian cargo. However, Indonesian cargo volumes will be much smaller, making the need for even a conventional LCA design uncertain.

Regardless of design configuration, long range is a basic requirement for an LCA, since it will be used predominantly on international routes, and reductions in structure weight and fuel consumpton are the primary technology areas which bear on this requirement. In this respect, many of the technologies noted in Table 78 offer additional support for ongoing NASA research programs.

As noted earlier, in the context of the LCA, high speed is intended to represent a need to achieve speeds competitive with present long-distance aircraft, which are in the range $0.72 \leq M \leq 0.85$. Both turbofan and prop-fan propulsion are candidates in this speed range, the turbofan competing best in the upper part of this speed range and the prop-fan offering competition in the lower part. Low external noise for compatibility with the world's major airports, particularly in view of nighttime cargo movements, and the need for high fuel efficiency, present special demands on the propulsion system which will require a heavy R&D emphasis in this area.

IMPLEMENTATION

In the course of this study, numerous personal contacts were made with individuals expert in their knowledge of the LDC environment and the special problems of transport which exist in the developing world. Almost without exception, there was recognition by these experts that this study was a worthwhile endeavor and that air transport would play an important role in LDCs in the future. However, the role of advanced technology was regarded with skepticism by some, the needs for low cost and simplicity often being viewed as paramount, and in conflict with advanced technology.

The view that advances in technology are necessarily accompanied by escalations in cost and complexity is surely not supported by experience, but there is a body of opinion that presumes this connection. It is also common to encounter the presumption of a methodical transition of transport development through technological stages, as was the case in the histories of the developed countries. Thus, the assumption of surface transport, particularly roads, as an essential percursor to development, is frequently made. Nevertheless, the unique benefits of airplanes are generally recognized, and numerous examples of unusual applications appear in the literature.

To promote the cause of aviation in LDCs, it is essential that convincing arguments be addressed to those who are in positions of leadership and influence. In the case of LDCs, Government planners at an authoritative level play an important role in the decison-making process. But international lending institutions are equally important because LDCs frequently rely on these sources to obtain funding for internal development. The support of money lenders in promoting air transport in LDCs should be sought to prevent recurrence of instances reported in the literature where there have been duplications of surface transport facilities. Highway and rail projects have been implemented side by side, involving large capital expenditures funded, in part, by the international financial community. There is a growing awareness that more control must be exercised over large, capital-intensive projects in LDCs. In the case of the World Bank, for example, it was found that the evaluation of LDC project alternatives (in which transport is almost always a factor) is conducted by a staff of experts who are generally receptive to progressive ideas.

If changes are to be effected in the attitudes of decision-makers regarding their presumptions about air technology, the benefits of new and wider uses of aircraft must be made in terms they will find convincing. The attributes of low risk in uncertain markets, rapid implementation of service without large capital expenditures, and extended access to valuable resources in remote areas have been stressed in the applications analyzed in this study. The concept of opportunity cost of capital has been emphasized in order to quantify the economic advantages implicit in speed and flexibility, factors always favoring the air mode. Although these arguments have been raised in a study specifically oriented toward air transport opportunities, they are nevertheless compelling. Objective analyses conducted in this study have shown that greater reliance on air transport can be beneficial to the future development of LDCs.

CONDENSATION OF STUDY RESULTS

In the INTRODUCTION to this report were listed a number of premises and objectives upon which the study was conceived. This section reconsiders these premises and objectives in order to relate them to specific results which have appeared in the text, and to determine the success of the study in achieving the goals set forth at its inception. The initial discussion concerns the premises, and the remainder of the section deals with the objectives in terms of aircraft applications, fleet projections and technololgy requirements.

PREMISES

1. Lack of surface transport infrastructure in a developing country may make it desirable to implement an air system in the early development phase, either as a precursor to a surface network or as a permanent alternative.

There seems to be little doubt that air transport is an effective way to initiate and support the early stages of remote area development. In the low-density transport application it was shown that an interim air system is a sensible alternative to expensive surface roads. However, as passenger and cargo volume grow, the surface system will eventually displace the air mode for routine transport. Once the major road segments are in place extensions would be added to create a network to support area development.

However, there are special situations where opening an area to settlement is not the primary objective. In these cases, typified in this study by remote mining and tropical forestry, the transport system is not intended to be permanent, but only a means of resource utilization. Choice of the air mode to fulfill these transport requirements takes advantage of the speed flexibility and low system capital cost features which are the primary attributes of airplanes.

2. Specialized aircraft, different from types which will be developed to satisfy US needs, may be required to meet the specialized transport needs of LDCs.

Most of the aircraft required to meet LDC needs could be of the types developed for US and other developed-country markets. Scheduled passenger service, military, and many general aviation categories have similar requirements because, to a large extent, they are directed toward the needs of the developed sectors of LDCs. However, two of the primary aircraft applications identified in the study, remote mining and tropical forestry, are indeed unique to LDC environments, and the low density transport application involves a type of airplane (e.g., Twin Otter) which may realize a larger market in LDCs than in developed countries.

3. <u>The LDC group may be a large future market for aircraft of US manufacture.</u>

A fairly large aircraft market already exists in LDCs, and projections of rapid economic growth promise an even larger market for the future. There has been a trend of used airplane purchases by LDCs, and this trend can be expected to continue, particularly for those LDCs which remain short of capital. However, the used market may not be sufficient to meet future requirements. And, even if it is, retirement of these airplanes from developed country fleets will stimulate sales of new models, in which case US manufacturers are sure to benefit.

PROMISING APPLICATIONS

Remote Mining

1. Return on equity is the parameter which would prompt a mining company to emphasize air transport in remote mining. If return on <u>total</u> invested capital is above a minimum acceptable value (assumed to be 10% in this report) there would be an incentive for a mining company to choose aircraft in order to leverage the return on its <u>own</u> invested capital (equity). Although this equity capital would generally be only 15% of the total investment, it would be advanced close to project inception; therefore, the airplane's advantage in shortening the construction period would enhance the return on this portion of the investment.

2. Future rich mineral finds will be in increasingly remote and inaccessible places characterized by jungle and mountain terrain over long inland distances. Airplanes will play an important role in exploiting these resources. Fixed wing aircraft permit development of deep inland sites (375 km was the calculated value) from the closest access point. Range/payload limitations restrict sites to somewhat shorter inland distances for advanced helicopters.

3. Good estimates of field length available for fixed-wing operations and elevation of remote mine sites could not be made in this study. It seems certain, however, that short field performance and heavy load carrying capability are essential. At least some sites, and perhaps the majority in mountainous countries like Indonesia, require a VTOL capability which is best met by advanced helicopters.

4. Noneconomic factors favor road over air, but not by a convincing margin. Therefore, it may be concluded that the economic advantage of air transport to a mining company would be the dominant factor in mode choice.

Low-Density Transport

1. The basic economic tradeoff in the low-density transport application is the low capital cost and high operating cost of airplanes vs. the high capital cost and low vehicle operating cost of roads. The comparison is affected by route volume and its rate of growth over an assumed amortization period for the road investment. Although uncertainties in road cost make it difficult to generalize, it appears that an air system is preferable for route volumes of 5×10^6 kg/yr, regardless of anticipated growth rate within the 6%/yr to 14%/yr range investigated.

2. The most competitive airplane in the application is strongly influenced by the growth rate of route volume and the cost of roads in a particular case. A high growth favors smaller airplanes, which range in size from the DHC-6 (or even smaller) up to the F-27 as route volume increases. Beyond some upper volume limit, a dirt road is a more economical alternative than an air system, but that limit is very dependent on knowledge of the physical characteristics of the region (as they affect road cost) and the ability to forecast future demand in a highly uncertain environment.

Tropical Forestry

1. The stump-to-site transport of logs usually requires a network of logging roads, but the delicate ecology of tropical forests renders this practice questionable on environmental grounds. Moreover, low-yield forestry (high-grading), which may be necessary to prevent permanent deforestation, requires an even more extensive road network to achieve a given volume of production. The high road costs associated with this type of selective cutting make an innovative air transport system based on lighter-than-air (LTA) vehicles economically competitive with roads.

2. As tropical forests continue to be developed in response to growing world demand for wood and paper products, transport costs will increase. But higher costs will be acceptable as temperate forest production falls short of demand and better uses are found for tropical hardwoods. Therefore, the output of a remote tropical forest, developed by LTA craft in a high-grading operation, could be competitively priced in world markets.

Large Cargo Airplane

1. In the long-term forecasts of this study (to 2005), the advanced nations in the LDC group, e.g., Brazil, could be potential users of a LCA of conventional design. Because of a significant present volume of air cargo in Brazil, and an expected high rate of future growth, justification for LCAs can be made for at least the densest international routes, and probably for other international and domestic routes.

The analysis for Brazil showed that the major potential for an LCA derived from rapid expansion of the present all-cargo demand, which is already sizeable. Penetration into somewhat lower value commodities can be expected as a result of the LCA's economies of scale, but the primary factors leading to an eventual need for the LCA in Brazil are national objectives. The two most significant objectives which impact the LCA are: 1. priority to achieve self sufficiency in basic resources (e.g., aluminum) and to develop a large export trade which will earn foreign exchange, and 2. priority to process resources into higher value products in order to increase their export value, promote industrial development and stimulate employment.

2. A scenario involving an airport/industrial city (A/I city) in the Amazon region of Brazil was found to stimulate significant additional demand for a LCA. The A/I city fits well into the stated plan for development of the Amazon region because it is predicated on the industrial processing of the vast resources of this region into products suitable for export. Because of their high value relative to the raw materials, a portion of these products would be air transportable to international markets, thereby earning valuable foreign exchange. At the same time the centralized industries would employ large numbers of people and promote the orderly growth of the region without unfavorable environmental impacts.

AIRCRAFT NEEDS

Airplane fleet requirements for Brazil and Indonesia were projected to the year 2005 for each sector of civil aviation.* The results for each sector were generated in different sections of the report, and are restated here to present a complete picture of the potential markets for various types of airplanes in these two countries.

Civil Airplane Fleets

	Brazil			Indonesia		
Aviation Sector	Present	2005	Avg. Growth Rate %/yr	Present	2005	Avg. Growth Rate %/yr
Domestic Passenger	172	786	5.4	97	551	6.2
Int'l. Passenger	18	121	6.8	14	69	5.7
Domestic All-Cargo	3	30	8.3	1	9	7.9
Int'l. All-Cargo	4	45	8.7	0	24	---
General Aviation	5394	46,000	7.7	270	5600	11.0
TOTAL	5591	46,982	7.6	382	6253	10.1

These figures refer to Brazilian and Indonesia carriers only. In the international aviation sectors additional airplanes serving these countries would be operated by US and other foreign carriers.

* Excludes military

It is apparent that fleets in all sectors are expected to grow at high rates during the 30-year forecast period, presenting an enormous potential market for new (and used) aircraft of all types, from small general aviation airplanes up to LCAs. To estimate the number of airplane sales which will be made to reach the fleets shown for 2005, it was necessary to make an assumption regarding retirements. Using a 15-year life for all aircraft, regardless of type, the following required fleet additions (unit sales) were calculated.*

	Fleet Additions	
Aviation Sector	Brazil	Indonesia
Domestic Passenger	1390	904
Int'l. Passenger	190	119
Domestic All-Cargo	42	13
Int'l. All-Cargo	61	32
General Aviation	67,100	6490
TOTAL	68,782	7548

The growing dominance of the general aviation sectors is readily seen in the totals. However, in terms of dollar volume, scheduled-carrier fleet additions would comprise a much greater share of the total in each country. Some indication of this is shown in the following list which gives fleet additions by airplane type for the scheduled-carrier fleets, i.e., excluding general aviation.

	Fleet Additions	
Airplane Type	Brazil	Indonesia
2 & 4 Eng. Turboprops**	471	369
2 Eng Narrow Body	385	250
3 Eng " "	320	250
4 Eng " "	32	19
2 Eng Wide Body	178	82
3 Eng " "	170	33
4 Eng " "	80	48
LCA	47	7
TOTAL	1683	1058

* Note that the significant figures carried in these calculated data do not imply accuracy to the nearest airplane. Although the use of a 15-year average aircraft life may appear low based on recent trends in commercial airline usage, the high percentage of used airplane purchases anticipated in the fleet projections does not justify a longer life expectancy for the fleets of Brazil and Indonesia.

** This category does not include the low-density transport application which was included within the general aviation category.

Although the largest single category of fleet additions is in the small two- and four-engine turboprop size, significant numbers of larger aircraft will also be required. The used aircraft market will accommodate some of these sales, but many will be new purchases. Note also that the fleet additions projected here are for Brazilian and Indonesian carriers only, and that other LDC purchases will augment these projections by a considerable amount. It was projected earlier that a total fleet addition figure for the entire LDC group would be 16,000 airplanes in the 30-year forecast period. The predicted additions for the study countries account for less than 20% of that total.

TECHNOLOGY RECOMMENDATIONS

A general conclusion which emerged from the R&D task was that numerous R&D items (in Tables 75-78) are presently incorporated in some fashion within the present NASA program (Ref. 100). Additional emphasis, relative to LDC needs, could be placed in the following areas:

1. Programs which give a direct expectation of cost reductions in both manufacture and operation of general aviation aircraft through advances in technology not likely to be within the capabilities of LDC aircraft manufacturers

2. Programs which minimize dependence on petroleum fuels, including improved fuel efficiency and derivation of aviation fuels from nonpetroleum sources

3. Programs which improve aircraft handling and controllability and reduce deterioration of aircraft subsystems in tropical weather environments, such as heavy rain and blowing sand

The genesis of each of these recommendations was developed in describing the nature of LDC transport problems and in the analyses of primary aircraft applications:

1. Low-density transport and utility aircraft markets will be important to US general aviation manufacturers if a superior technology base permits them to compete with subsidized aircraft programs in the more advanced LDCs.

2. Most LDCs are not rich in petroleum reserves (Indonesia is an exception), and the escalating cost of imported petroleum imposes a foreign exchange burden that stresses LDC economies even more than our own.

3. The LDC group is heavily concentrated in the tropics, where monsoon or desert conditions are common.

In addition to programs already in progress, several new R&D opportunities were identified as possibilities for inclusion in the NASA program:

1. Heavy-load external lift by helicopters, either by a single vehicle, by vehicles operating in tandem or in a hybrid configuration such as the HLA

2 Precision airdrop and retrieval techniques for pickup and delivery of heavy payloads

3. Internally blown-flap STOL airplane with lift augmentation by an internally stowed engine

4. Compatibility of aircraft gas turbine and diesel engines for operation with a common fuel

The requirements for these recommendations all derive from the remote mining application. However, the first is also related to the heavy lift airship (HLA) concept under study by the NASA (Ref. 70). The dynamics and control of helicopters acting in concert is, therefore, a research area of potentially great impact. Items 2 and 3 are directed toward the unique high-altitude field requirement of the remote mining application, and the last item is one which could be of interest for military as well as the proposed civil application.

CONCLUSIONS

1. Air transport is an effective way to initiate and support the early stages of remote-area development in developing countries. However, it can rarely, if ever, eliminate the need for surface transporation once significant development has occurred. An exception may be in low-yield forestry where ecological consideration is a driving factor.

2. Most of the aircraft required by developing countries could be of types used by the US and other developed countries. Exceptions are as follows:

   - Low-yield forestry, in which highly efficient VTOL aircraft (possibly lighter-than-air vehicles) can be used effectively

   - Remote mining applications in which advanced STOL aircraft could achieve a high payoff.

3. A low-density transport application, typical of developing countries, requires a type of airplane (e.g., Twin Otter) which may realize a larger market in LDCs than in developed countries.

4. While the needs of developing countries for large cargo aircraft are expected to be small compared with the developed-country market, this sector may represent an important supplementary market which could expand the production base.

5. Ongoing NASA technology programs identified as particularly pertinent to the needs of developing countries are as follows:

   - Cost reductions in manufacturing and operation of general aviation aircraft

   - Programs which minimize dependence on petroleum fuel

   - Improvements in aircraft handling and controllability

   - Subsystem design to reduce deterioration in tropical weather environments, such as heavy rain and blowing sand.

6. In addition to programs already in progress, several new R&D opportunities were identified as possibilities for inclusion in the NASA program:

   - Heavy-load external lift by helicopters, either by a single vehicle, by vehicles operating in tandem, or in a hybrid configuration such as HLA

CONCLUSIONS (Cont'd)

- Precision airdrop and retrieval techniques for pickup and delivery of heavy payloads
- Internally blown-flap STOL airplane with lift augmentation by an internally stowed engine
- Compatibility of aircraft gas turbine and diesel engines for operation with a common fuel

REFERENCES

1. Brown, M. and M. Usui: Choice and Adaptation of Technology in Developing Countries - An Overview of Major Policy Issues. Part One, Review of Discussion Development Centre of the OECD, Paris, 1974.

2. Fromm, Gary, ed.: Transport Investment and Economic Development, Brookings Institution, Washington, D. C., 1965.

3. Gill, R. T.: Economic Development: Past and Present. Prentice-Hall, Inc., Englewood Cliffs, N. J. 1967.

4. Haefele, E. T., ed.: Transport and National Goals. Brookings Institution, Washington, D. C., 1969.

5. Owen, W.: Strategy for Mobility. The Brookings Institution, Washington, D. C., 1964.

6. World Bank: Annual Report 1976.

7. United Nations: 1975 Statistical Yearbook, Department of Economic and Social Affairs, New York, 1976, Publication ST/ESA/STAT/Ser. S/3, Sales No. E/F.76, XVII.1.

8. Keating, R. B. and J. T. Howell: A Transport Reconnaissance of The Northeast Congo Region. Agency for International Development, Washington, D. C., PB210420, December 1970.

9. United Nations: Economic Communication for Asia and the Far East, Introduction to Transport Planning, 1967. UN Sales No. 67.II.F.13, Report E/CN, 11/746.

10. Prest, A. R.: Transport Economics in Developing Countries, Frederick A. Praeger, New York, 1969.

11. de Neufville, R., U. Ayala, J. Acevedo, and L. Mira: Role of Air Transportation in Sparsely Developed Areas. Massachusetts Inst. of Tech., Cambridge. Dept of Civil Engineering. (220 010, PB-219 293, January 1973.

12. Department of Transportation: Preparation and Appraisal of Transport Projects. Washington, D. C., PB-207 862, June 1968.

13. African Studies Association: Air Transport Patterns and Prospects in Africa: the Role of Aviation in the Context of National Development. Manhasset, N. Y., R. Dixon Speas Assoc., 1974.

REFERENCES (Cont'd)

14. Dwemoh, E. R. K.: The Importance of Air Transport in the Economies of Developing Countries. Arab Wings, January/February 1975.

15. Ausrotas, R. A.: Low Density Air Transportation in Developing Countries. Transportation Research Forum - 15th Annual Meeting, Vol. XV, No. 1, 1974.

16. Agency for International Development: Arid Lands of Sub-Saharan Africa. National Academy of Sciences, Washington, D. C., Office of Science and Technology. PB245 595, 1975.

17. Agricultural Aviation in Brazil and India: A Sharp Contrast. Interavia, December 1976.

18. Roberts, P.: Choice of Transport Technology Under Varying Factor Endowments in Less Developed Countries. Charles River Associates, Inc., Cambridge, MA., PB/195 291, June 1970.

19. Straszheim, M. R.: Air Passenger Technology and Public Policy in The Developing Countries. Transportation Research Forum - 9th Annual Meeting, September 4,5,6, 1968, Kansas City, Missouri.

20. van der Tak, H. G. and A. Ray: The Economic Benefits of Road Transport Projects. International Bank for Reconstruction and Development, Johns Hopkins Press, Washington, D. C., 1971.

21. Hall, E. N.: Presentation to the Conference on the Influence of Technological Innovation on the Future of Connecticut. University of Connecticut, October 1968.

22. Hesse, J. E.: Research Concept of an Airport/Industrial City. UARL Report J-970822-2, Prepared under Research Support Award No. 69-11 from the Connecticut Research Commission, April 1970.

23. Wilson, G. W.: The Impact of Highway Investment on Development, Brookings Institution, Washington, D. C. 1966.

24. Cheaney, E. S., R. D. Leis, and D. M. Landreman: Transportation Technology for Development. Volume I. Battelle Memorial Inst., Columbus, Ohio. Columbus Labs. PB 210 592, February 1965.

25. Sletmo, G. K.: International Air Transport and National Interests. Arkiv For Luftrett (Archives for Air Law), Vol. 3, University of Oslo, Oslo, Norway, 1967.

REFERENCES (Cont'd)

26. Cartaino, T. F.: Technological Aspects of Contemporary and Future Civil Aircraft for the World's Less-Developed Areas. RAND Corporation, Santa Monica, Calif., Memorandum RM-3060-RC, 1962.

27. World Airliner Census. Flight Magazine Issues of: October 26, 1967; December 11, 1969; October 21, 1971; November 29, 1973; December 5, 1974; December 4, 1975; December 11, 1976.

28. U.S. and International Commercial Jet Transport Fleets. Pratt & Whitney Aircraft Group, Effective Dates February 15, 1972 and January 1, 1977.

29. Aircraft Types and Prices. Lloyd's Aviation Dept., 1976.

30. Turnham, D.: The Employment Problem in Less Developed Countries. A Review of Evidence. Development Centre of the OECD, Employment Series No. 1, Paris, 1971.

31. Golden Press: The Odyssey World Atlas. Universal Edition, New York, 1967.

32. Plano Nacional de Desenvolvimento, Brazil's Second National Development Plan (1975/79). Approved by the Brazilian Congress, November 1974.

33. Repelita II, Indonesia Develops -- Second Five Year Development Plan (1974/5 - 1978/79). Department of Information, Republic of Indonesia.

34. Commodity Review. Jakarta A-118, June 19, 1974.

35. Amazonia. Brazilian Embassy, No. 10, London, February 1976.

36. Ministerio das Minas e Energia. Departmento Nacional da Producao Mineral. Projeto Radambrasil, Vols. 5, 7, 8, 9, 10, 11.

37. OECD: Investing in Developing Countries. Third revised edition, Paris, 1973.

38. Govett, G. J..S. and M. H.. Govett, Eds.: World Mineral Supplies - Assessment and Perspective. Elsevier Scientific Publishing Company, Amsterdam, 1976.

39. Schreck, A. E.: Minerals Yearbook, 1973. Volume III. Area Reports: International. Bureau of Mines, Washington, D. C. PB 254 165.

REFERENCES (Cont'd)

40. Minerals in Brazil. U.S. Department of Commerce NTIS DIB 76-01-011, May 1975.

41. Bosson, R. and B. Varon: The Mining Industry and the Developing Countries. Published for the World Bank. Oxford University Press, 1977.

42. A Report on the LIPI-NAS Workshop on National Resources. Vol. 1, Overall Findings and Recommendations - Working Group Reports. Prepared for AID by the National Academy of Science, PB/217 293, 1972.

43. A Survey of Business Opportunities in Indonesia.

44. Engineering and Mining Journal, November 1975.

45. Indonesia: Business Opportunities in a Resource-Rich Economy. Business International Asia/Pacific Ltd., Asian House, One Hennessey Road, Hong Kong, October 1975.

46. United Nations: The Application of Modern Transport Technology to Mineral Development in Developing Countries. Dept. of Economic and Social Affairs, ST/ESA/43, Sales No. E.76.VIII.1, 1976.

47. New Action Areas Dot Latin America. The Oil and Gas Journal, February 18, 1977.

48. Japan's Brazilian Venture. Financial Times of London, October 22, 1976.

49. There's An Awful Lot of Iron in Brazil. Iron Age, March 4, 1974.

50. Brazil: A Mining Venture Goes International. Business Week, February 3, 1975.

51. Amazon Has Enough Iron Ore to Last Centuries. New York Times, August 10, 1975.

52. Brazil Is on The Verge of a Boom in Minerals. New York Times, May 28, 1977.

53. The Ertsberg Project. Mining Magazine, Vol. 129, No. 4, October 1973.

54. Ertsberg (Gunung Bijih): The West Irian Copper Project, Milestone in The Economic Progress of the Republic of Indonesia. Freeport Indonesia, Inc., Jakarta.

REFERENCES (Cont'd)

55. Called "Mission Impossible", Freeport's Ertsberg Cu Project Convinces Skeptics. Mining Engineering, January 1973.

56. Freeport Indonesia Marks Production Capacity at Ertsberg Mine. Skillings Mining Review, Vol. 63, No. 40, October 5, 1974.

57. How the Birds Conquered the Mountains. Engineering and Mining Journal, August 1972.

58. Sour Notes in A Siren Song of Riches. Indonesia/Cover Story, Time Magazine, May 16, 1977.

59. Transportation in Indonesia. Department of Transport, Communications and Tourism, Draft Text, January 7, 1974. (Confidential).

60. Ausrotas, R. A.: Air Transportation in Developing Countries. Flight Transportation Laboratory, MIT Dept. of Aeronautics and Astronautics, FTL Technical Memorandum 73-12, July 1973.

61. V/Stolport Site Search and Feasibility Study, Northern New Jersey and New York Metropolitan Area. Technical Report prepared for State of New Jersey Transportation Dept. by Parsons, Brinckerhoff, Quade and Douglas, Inc., August 1975.

62. Bineck, A.: Forest Products in Terms of Metric Units. 1973.

63. FAO: El Transporte de la Madera en Paises de America Latina. Seminaria FAO/SIDA/Mexico. Oaxtepec, Mexico, 23 Febrero-21 Marzo 1975. Rome, 1975.

64. Goodland, R. J. A., and H..S. Irwin: Amazon Jungle: Green Hell to Red Desert. New York, Elsevier Scientific Publishing Company, 1975.

65. Frumkin, G.: Effects of Transportation Economics on U. S. Markets. Conference on Transportation of Tropical Wood Products. State University of New York, Syracuse, N. Y., November 16-18, 1971.

66. FAO: Logging and Log Transport in Tropical High Forest. A Manual on Production and Costs. Rome, 1974.

67. Performance, Weights and Dimensions of the S-58T Helicopter. Sikorsky Sales Data. SE 58-103-7, February 25, 1972.

68. Performance, Weights and Dimensions of the S-64F Helicopter. Sikorsky Sales Data. SE-64-19, January 11, 1973.

REFERENCES (Cont'd)

69. Huang, C. J. and C. Dalton: Cargo Transportation by Airships: A Systems Study. NASA CR-2636, May 1976.

70. Feasibility Study of Modern Airships, Phase II, Volume I - Heavy Lift Airship Vehicle, Book I - Overall Study Results. Goodyear Aerospace Corp., NASA CR-151917, September 1976.

71. Kay, J. A. and E. M. Burgess: The Crane Helicopter in Overseas Oil Rig Operations. AIAA Paper No. 69-192, AIAA/AHS VTOL Research, Design and Operations Meeting. February 17-19, 1969.

72. U.S. General Imports, World Area by Commodity Groupings. U.S. Department of Commerce FT 155/Annual 1975.

73. Cargo Logistics Airlift Systems Study (CLASS). Monthly Progress Report for Period 1 July to 31 July 1977. McDonnell Douglas Corporation. Prepared under Contract NAS1-14948.

74. Census of Manufactures, U.S. Dept. of Commerce, 1972.

75. United Nations Commodity and Trade Statistics. Statistical Papers, Series D, Vol. XXIV, No. 1-42, 1974.

76. Yearbook of Industrial Statistics. Dept. of Economic and Social Affairs, Statistical Office of the United Nations, New York, 1977.

77. Annual Survey of Manufactures, Value of Produce Shipments. U.S. Dept. of Commerce M75(AS)-2, 1975.

78. U.S. General Imports, Schedule A - Commodity by Country. U.S. Dept. of Commerce FT 135, December 1975.

79. Input-Output Structure of the U.S. Economy. U.S. Dept. of Commerce, Office of Business Economics, 1963.

80. Statistical Abstract of the United States, U.S.. Dept. of Commerce, Bureau of the Census, 1976.

81. Air Cargo Guide, Reuben H. Donnelley Corp., April 1976.

82. Olason, M. L. and A. D. Reynolds: A View of Air Freight Developments in the Next Decade. Aeronautical Journal, July 1976.

83. Williams, L. J. and A. Wilson: Survey of Projected Growth and Problems Facing Air Transportation, 1975-1985, NASA TMX-62, 476, August 1975.

REFERENCES (Cont'd)

84. English, J. M. and G. L. Kernan: The Prediction of Air Travel and Aircraft Technology to the Year 2000 Using the Delphi Method. Transportation Research, February 1976.

85. Lockheed-California Company: World Air Traffic Forecast, December 1974.

86. Stanford Research Institute: World Commercial Airline Industry, November 1974.

87. FAA: Aviation Futures to the Year 2000 (AVP-110), February 1977.

88. Maio, D. J., G. H. Wang, N. Meltzer: Forecasting Models for Air Freight Demand and Projection of Cargo Activity at U. S. Air Hubs. FAA-AVP-77-2, January 1977.

89. U.S. Dept. of Commerce: A Survey of Business Opportunities in Indonesia, 1976. (Quoting from REPELITA II - Indonesian Second Five-Year Plan).

90. Booz-Allen Applied Research Inc.: Forecasts of Transpacific Air Travel, October 1973. (NTIS-AD-775315).

91. Handbook of Airline Statistics, Civil Aeronautics Board, 1975.

92. Brazilian Embassy, London, Transport and Telecommunications in Brazil, June 1976.

93. Douglas Aircraft Company, The Airlines of Indonesia, January 1977.

94. Official Airline Guide, Worldwide Edition, Reuben H. Donnelley Corp., May 1976.

95. Official Airline Guide, Worldwide Edition, Reuben H. Donnelley Corp., May 1977.

96. Avionics and Aviation Support Equipment - Brazil. U.S. Dept. of Commerce, CMS 75-030, February 1975.

97. Registro Aeronautico Brasileiro. Republica Federativo do Brasil Ministerio da Aeronautica, December 31, 1976.

98. Jane's All the World's Aircraft, 1977-1978. John W. R. Taylor, Editor, Library of Congress Cat. No. 75-15174.

99. Moore, D. D., W. Vigrass and K. P. Rahbany: Transportation and Communications for Remote Exploitable Areas. Ekistics, February 1969.

REFERENCES (Cont'd)

100. Research and Technology Objectives and Phase Summary (RTOPS). NASA, Fiscal Year 1977 Research and Technology Program (available from NTIS).

101. Cargo Logistics Airlift Systems Study (CLASS). Mid-Term Oral Review Brochure, Lockheed Georgia Co., October 17, 1977.

102. Agency for International Development. An Economic Evaluation of the Utility of ERTS Data for Developing Countries. Environmental Research Institute of Michigan, August 1974. NTIS PB 236 600 (Vol. 1), NTIS PB 236 601 (Vol. 2).

103. Resede, E.: Highways and Brazil's Development. Seventh World Meeting of the International Road Federation, Munich, October 1973.

104. Push for Land is Following Route of New Highway into Amazon Region. New York Times, October 19, 1975.

105. Conquering the Amazon Jungle. Wall Street Journal, April 5, 1977.

106. Opening up the Back Garden of Brazil. Financial Times of London. December 16, 23, 30, 1976 (in three parts).

107. Commercial Aircraft of the World. Flight International Magazine, Series of Annual Articles, most recent of which is in the issue of October 9, 1976.

108. Foley, J. S.: Comparative Study of V/STOL Aircraft for Short-Haul Intercity Transportation. United Aircraft Research Laboratories Report J-170808-1, August 1970.

109. Intercity Passenger Comparison Data: Energy Comparisons. The Boeing Commercial Airplane Company, D6-41814, November 1974.

110. Cost/Benefit Trade-offs for Reducing Energy Consumption of the Commercial Air Transportation System. Final Report, Volume 1: Technical Analysis, NASA CR-137923, Douglas Aircraft Company, June 1976.

111. Guide to Feederliner Aircraft. Flight International Magazine, Series of Annual Articles.

112. Company Helicopters. Flight International Magazine, October 30, 1975, pp. 659-663.

113. Sikorsky Sales Data Brochures.

REFERENCES (Cont'd)

114. The New Executive Light-Twin Helicopters. Business and Commercial Aviation. January 1976, pp. 86-91.

115. Ashley, T. S.: Helicopter Roundup. Flight Operations, January 1977, pp. 46-47.

116. Field, H.: Which Company Helicopter? Flight International Survey, November 13, 1976, pp. 1419-1424.

117. Study of Quiet Turbofan STOL Aircraft for Short-Haul Transportation. Final Report, NASA CR-2353, Douglas Aircraft Company, February 1974.

118. Sweet, H. S., J. H. Renshaw and M. K. Bowden: Evaluation of Advanced Lift Concepts and Potential Fuel Conservation for Short-Haul Aircraft. NASA CR-2502, Lockheed Aircraft Corporation, February 1975.

119. Professional Pilot. February 1977.

120. Gallagher, F. O.: Transport Reseach and the Operation of Regular Air Services to Isolated Areas. Austrailian Transport Research Forum, Forum Papers, 2nd Annual Meeting, 1976. Adelaide, So. Australia Dept. of Transportation, pp. 55-100.

121. Civil Aeronautics Board, Aircraft Operating Cost and Performance Report. Bureau of Accounts and Statistics, Washington, D. C., July 1976.

122. Soberman, R. M.: Transport Technology for Developing Regions. A Study of Road Transportation in Venezuela. Cambridge, Mass., The MIT Press, 1966.

123. United Nations, Dept. of Economic and Social Affairs, Statistical Office, Statistical Yearbook, 1975.

APPENDICES

APPENDIX A

SELECTION PROCESS FOR CASE-STUDY COUNTRIES

The objective of this task was to select, from amongst the 125 Less-Developed Countries (LDCs) in Table 1, two countries for detailed case studies. As stated in the contract, one country was to be from Latin America and one from another continent. The approach was to reduce the list in successive phases. In the first phase, five study participants from UTRC and PBQ&D were given the tabulation of data in Table 1 and instructed to recommend 30 countries for retention. Although all five analysts began with the same data base, each was free to devise his own criteria by which to evaluate the countries. Individual parameters could be disregarded, combined into groups, or weighted according to a judgment of relative importance. Furthermore, intangibles such as political stability were factored in by those who had specific knowledge of countries where these considerations were judged to be relevant.

The results of the first elimination are shown in Table A-1. In all, 52 countries were named, and 14 of these were unanimously chosen by all five participants. The Island Groups were most popular, all but one receiving at least a single vote. Only one European country was chosen, primarily because the European group was dominated by Communist bloc countries which are not attractive for the purposes of this study. Central America also received only a single vote, Mexico, the basic drawback to other Central American countries being their small size. The representation of each group is indicated at the bottom of the table (e.g., seven of eight island groups (88 percent) received at least one vote).

In the second phase, each participant was apprised of the preliminary screening and then asked to reduce the list to ten. As would be expected, these selections came primarily from the top of the list in Table A-1. Additional data were provided in the second phase, but the size of the list still precluded much more detailed quantitative analysis. The primary difference between the first and second stages of the selection process was the improvement in ability to analyze the data based on the experience of the initial screening.

Table A-2 gives the results of the second elimination. In most respects, the results, in terms of selection agreement is depicted in Fig. A-1, are very similar to those in the first round. This plot shows how percent agreement among the participants varied with cumulative number of countries in each horizontal grouping in Tables A-1 and A-2. Thus, 100 percent agreement was achieved for 14 out of 52 countries (27 percent) in the first round and 5 out of 23 (22 percent) in the second round. At least 80 percent agreement was reached for 18 out of 52 or (35 percent) in the first round, etc. It can be seen that the results are quite consistent between the two rounds.

TABLE A-1

Results of First Phase of Selection Process

% Agreement	Island Groups	Central America	South America	South Asia	S.E. Asia	Europe	Mid East	Far East	Africa
Unanimous Selections, 100%	Indonesia Malaysia Philippines	Mexico	Argentina Brazil Peru		Thailand		Iran Saudi Arabia Turkey		Algeria Morocco Nigeria
80%			Bolivia Columbia						Sudan Tanzania
60%	Gr. Antilles			Afghanistan	Burma	Spain	Iraq		Egypt Ivory Coast Kenya Zaire Zambia
40%	Ind. Ocean		Chile Ecuador Venezuela	India Pakistan					Angola Ethopia Gabon Libya So. Rhodesia Tunisia
20%	Melanesia Micronesia		Guyana Paraguay					China, P.R. So. Korea	Botswana Cameroon Cen. Afr. Rep. Congo Ghana Namibia
TOTALS 52	7	1	10	3	2	1	4	2	22
Representation by Group, % 42	88	13	77	38	40	7	25	29	48

TABLE A-2

Results of Second Phase of Selection Process

% Agreement	Island Groups	Central America	South America	South Asia	S.E. Asia	Europe	Mid East	Far East	Africa
Unanimous Selections, 100%	Indonesia		Brazil				Iran Turkey		
80%			Peru						Nigeria
60%		Mexico	Bolivia		Thailand				Morocco
40%	Malaysia Philippines		Chile Colombia	Pakistan			Saudi Arabia		Sudan
20%			Argentina Venezuela						Algeria Egypt Kenya Zambia
TOTALS 23	3	1	7	1	1	0	3	0	7
Representation by Group, % 18	38	13	54	13	20	0	19	0	15

RESULTS OF SELECTION PROCESS

PHASE 1: REDUCTION TO 30: 52 COUNTRIES NAMED
PHASE 2: REDUCTION TO 10: 23 COUNTRIES NAMED

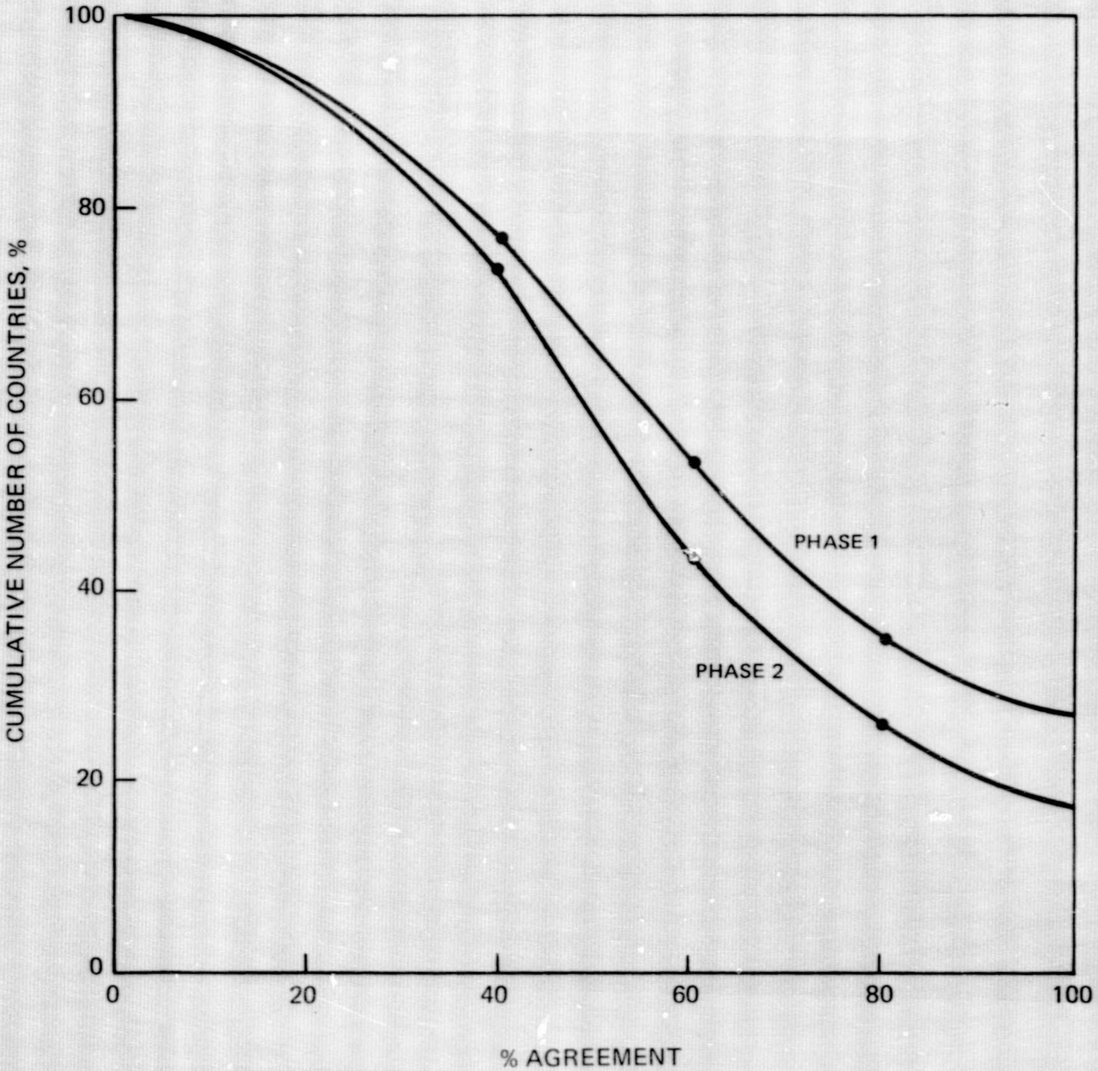

FIG. A–1

and 5 out of 23 (22 percent) in the second round. At least 80 percent agreement was reached for 18 out of 52 or (35 percent) in the first round, etc. It can be seen that the results are quite consistent between the two rounds.

Of the nine LDC categories, the Island Groups and South America retained the highest percentages through this stage, and each had one unanimous selection, while the European and Far Eastern country groups were eliminated entirely. African countries are well represented numerically, but four of the seven received only one vote apiece. Two Middle Eastern LDCs, Iran and Turkey, were unanimous selections. Since the objective of the second elimination was to reduce the list of candidate countries to ten, the highest-ranked countries in Table A-2 were carried forward. The top ten LDCs are: Bolivia, Brazil, Indonesia, Iran, Mexico, Morocco, Nigeria, Peru, Thailand, and Turkey. Each of these countries received at least three out of five votes in the second round.

A change in format was adopted for the final stage of the selection process. All participants were assembled in a conference to discuss the pros and cons of each candidate country, and to consider the possibility of altering the study ground rules to accommodate either more than two case studies, or to aggregate countries into regional groups. Moreover, with the list reduced to ten, it was possible to improve and enlarge the base of data comparisons and to provide descriptive narratives summarizing the features of each country.* The expanded data comparisons are shown in Table A-3.

The data in Table A-3 are presented for the ten case-study candidates as well as for the average of the 125-nation LDC group, the world, and for six selected developed nations, for comparison purposes. Four categories of information are presented: social factors, economic factors, resources, and air transport factors. Each of these categories has some bearing on the evaluation of the candidates. For example, air transport factors, such as terrain, route length, and present emphasis on aviation, should be favorable in order to maximize the occurrence of potential air opportunities. However, if economic growth does not permit exploitation of these opportunities, positive results will not be obtained. This may come about because expenditures on capital equipment are not sufficient, or because social problems with feeding, housing, and providing health care to a burgeoning population drain the available capital away from market exploitation.

In the conference at which final selections were made, no attempt was made to formalize the data in Table A-3 into a quantitative evaluation scheme. Rather, each country was considered individually by the assembled group, and the positive and negative factors of each were discussed at length. At the midway point in this one-day conference, a vote was taken to reduce the list. Five countries were chosen for continued evaluation:

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* The narrative descriptions for Brazil and Indonesia appear in Appendix B.

TABLE A-3 - Characteristics of Candidate Countries

	Bolivia	Brazil	Indonesia	Iran	Mexico	Morocco	Nigeria	Peru	Thailand	Turkey	$LDC_{avg.}$	World	United States	Canada	USSR	Japan	United Kingdom	Australia
SOCIAL FACTORS																		
Population																		
Total, 10^6 (1974)	5.5	104.2	128.2	32.1	58.1	16.9	61.3	15.4	41.0	38.3	23.7	3890	211.9	22.5	252.1	109.7	56.0	13.3
Growth, %/yr	2.6	2.8	2.1	2.9	3.4	2.4	2.7	3.2	3.2	2.4	2.2	1.9	0.8	1.3	0.9	1.3	0.2	1.6
Density, per km^2	5	12	86	20	29	38	66	12	80	49	36	29	23	2	11	295	229	2
Agriculture																		
Food Prod, kg/pers./yr	212	410	207	267	265	193	58	440	398	560	286	538	1404	1793	1402	335	696	1735
Livestock, Head per cap	2.0	1.4	0.1	1.3	0.8	1.2	0.3	1.6	0.2	1.4	0.6	0.7	1.0	0.9	1.3	0.1	0.9	13.4
Machines, per 1000	0.2	1.8	0.1	0.8	2.3	1.3	0.1	0.8	0.4	5.5	0.7	4.4	23.9	34.9	11.7	5.1	9.4	30.2
Investment, % GDP	15	12	40	12	10	27	35	16	31	26	-	-	4	5	18	5	3	7
Health																		
Life Expectancy, yrs	50	59	48	50	62	51	37	54	56	54	-	-	71	73	70	73	71	71
Hospital Beds per 1000	1.9	3.8	0.7	1.4	1.3	1.4	0.7	2.0	1.3	2.1	-	-	6.9	9.4	11.6	12.8	9.5	12.3
Physicians per 1000	0.47	0.49	0.05	0.33	0.72	0.08	0.04	0.56	-	0.50	-	-	1.61	1.63	2.76	1.15	1.33	1.39
ECONOMIC FACTORS																		
GNP																		
per cap (1974)	280	920	170	1250	1090	430	290	740	310	750	335	1220	6600	6460	2100	4130	3370	5880
Growth, 1960-73, %/yr	2.5	3.6	2.4	6.4	3.3	1.6	3.6	2.1	4.8	3.9	3.0	3.5	3.1	3.7	3.6	9.4	2.4	3.1
%/yr 1965-73	2.2	6.0	4.5	7.4	2.8	2.5	8.3	1.8	4.5	4.4	3.4	3.5	2.5	3.5	3.5	9.6	2.3	3.0
Economic Activity																		
Capital Formation	11	23	18	19	21	14	20	16	20	18	-	-	18	23	-	34	20	24
Industry	31	21	18	53	28	25	30	31	20	23	-	-	29	27	53	37	31	28
Transport	8	4	4	3	3	-	3	5	6	8	-	-	6	7	6	7	8	7
Exports	27	8	18	26	9	27	26	16	22	7	-	-	7	26	-	14	24	15
Imports	30	9	19	27	10	26	18	21	23	11	-	-	7	26	-	15	27	15

TABLE A-3 (Cont'd)

Characteristics of Candidate Countries (Cont'd)

	Bolivia	Brazil	Indonesia	Iran	Mexico	Morocco	Nigeria	Peru	Thailand	Turkey	LDC $_{avg.}$	World	United States	Canada	USSR	Japan	United Kingdom	Australia
RESOURCES																		
Mineral Production																		
% World Min. Prod. / % World Population	10.5	0.8	0.3	1.2	1.5	1.3	0.3	3.3	0.8	0.9		1.0	2.9	15.3	2.5	0.2	0.3	10.4
Major Minerals (% World Production	Antim. (17.2) Tin (16.2)	Asbes. (15.4) Mang. (12.1) Iron (8.1)	Tin (14.2) Oil (2.4)	Oil (10.8)	Sulph. (13.0) Silver (12.7) Merc. (9.7)	Phos. (16.9)	Oil (4.0)	Silver (13.8) Zinc (7.2) Lead (5.6)	Tin (11.3) Antim. (6.1)	Chrom. (8.2) Antim. (8.2)			17 (Number of Minerals > 5% of World Prod)	15	26			9
Education																		
Students per 1000	92	162	124	174	240	117	85	265	184	184	105	136	327	284	245	210	179	238
Teachers per 1000	7.7	6.9	4.7	6.0	5.0	3.5	2.6	8.4	6.2	5.9	3.4	5.7	-	-	14.5	10.5	-	11.4
Investment, % GDP	-	2.9	2.7	3.1	3.0	5.2	3.9	4.3	3.0	5.6	-	-	6.7	8.1	7.5	4.3	-	5.0
AIR TRANSPORT FACTORS																		
Size																		
Area, 10^6 km^2	1.1	8.5	6.0	1.7	2.0	0.5	0.9	1.3	0.5	0.8	0.6	135.8	9.4	10.0	24.4	0.4	-.2	7.7
Long Route, km	1000	3450	3600	1250	2350	700	800	1450	700	1000	-	-	4600	3700	6300	1250	900	3350
Terrain, % by type																		
Mountain	35	4	5	0	30	30	0	40	18	50	-	-	16	15	20	30	0	10
Water	1	1	70	0	0	0	1	2	2	2	-	-	2	25	2	30	10	3
Forest	35	60	23	0	5	0	19	50	80	10	-	-	48	35	38	25	10	7
Desert (or semi-)	4	5	0	95	50	30	0	8	0	8	-	-	6	0	10	0	0	70
Grassland	25	30	2	0	15	0	80	0	0	0	-	-	25	5	5	0	0	5
Mediterranean	0	0	0	5	0	40	0	0	0	30	-	-	3	0	5	15	80	5
Domestic Aviation																		
Pass-km per cap	20	45	11	19	57	2	2	27	3	15	8	78	1024	597	410	153	46	568
Growth, %/Yr	11.6	18.6	28.5	15.3	17.9	32.3	21.2	35.6	2.3	14.5	12.6	6.4	5.1	12.2	7.1	17.6	4.3	8.0
10^6 Frt. Ton-km/GNP	1100	1080	665	75	555	14	23	675	39	140	370	1240	3400	1495	3605	270	133	1365
Growth	14.2	28.2	42.0	19.8	12.0	-2.3	-7.9	1.8	-10.9	14.7	4.7	2.6	3.9	2.3	-	7.2	3.3	11.3

Brazil, Indonesia, Iran, Peru, and Nigeria. It was also decided at this point that the original ground rule of selecting two countries be adhered to, and that no attempt be made to aggregate countries into regional groups. Any of the five countries would have been a good choice. However, it was the consensus of the participants that the countries be selected so as to provide the best representation of potential market opportunities for aircraft applications. On this basis, Brazil and Indonesia were judged to be the best choices; Brazil because of its size and diversity of terrain and resource variables, and Indonesia because it is an island group with transport needs potentially different from Brazil and any other continental country. Therefore, the final selections of Brazil and Indonesia were made and submitted for NASA approval.

APPENDIX B

BACKGROUND ON BRAZIL AND INDONESIA

A wealth of qualitative and quantitative information was gathered in the course of the study to document the important characteristics of Brazil and Indonesia, the case study countries. The purpose of this Appendix is to summarize that information in a concise form as reference material to support the analyses described in the main body of this report.

Descriptions of Selected Countries

Brazil

Brazil is a remarkable country which has vast resources and potential for development. There are six major areas which can be considered. The North contains the world's largest tropical rain forest whose agricultural potential is hampered by lack of population. The Northeast is densely populated and is a large sugar producer. Coastal rainfall is steady, but the interior is subject to calamities of drought and flood. The Southeast is a complex area of terrain, from coastal swamps to stepwise increases in elevation which were cleared for cattle pastures. In addition to being an important mining region, it contains many of the industrial cities. Sao Paulo is a separate economic region because of its outstanding development. Its interior produces coffee, sugarcane, cotton, oranges, and cattle. The South is tall-grass prairie and deciduous, and has many European descendants. The Central West is an eroded hilly plateau, with some rural lands, and is sparsely settled.

Urban growth is rapidly occurring, mostly from rural migration. Despite lack of development, the country has incredible resource and agricultural potential due to its sheer size. It has grown rapidly and is the world's leading producer of many commodities. Development of the vast resource and agricultural potential (2.1 billion acres, given adequate fertilizer and water) suffers from lack of proximity to the internal market areas, and thus agriculture has lagged relative to overall economic development. Furthermore, there is a noticeably poor labor productivity and inadequate use of fertilizers and machines. Coffee production (1/3 of export earnings) has declined, due to policies of crop diversification, but gains have been made in other crops. Most forest reserves are untapped and inaccessible, and much mining potential remains. Most growth has been in manufacturing, with imports of capital equipment and raw materials, including oil. Inflation is staggering and interest rates are high. Development is aimed at industries important to national economic development (agriculture, forestry and fishing) and at stimulation of backward regions and curbing inflation.

Transportation development is still at an early stage, particularly in the less populated areas. Also, traversing the Great Escarpment and other inland plateaus creates long, circuitous routes. Scarcity of domestic capital is a further deterrent to transport development. Road operating costs are very high and the rail network is poorly connected, poorly built and manufactured, and operated inefficiently. Air freight has increased, and airplanes have even been used to carry some bulk commodities, due to lack of alternative facilities! About 1500 airports exist, most of which are small, unpaved and useful for light aircraft.

Indonesia

Indonesia is an archipelago consisting of 13,667 islands, most of which are uninhabited. The principal islands are Java, Kalimantan (shared with Malaysia), Sumatra, Celebes and Irian Jaya. The major islands are characterized by rugged, volcanic mountains, covered by dense tropical forests, sloping down to coastal plains, often with alluvial swamps. Rainfall is plentiful at all times of the year, particularly in the monsoon season, with the dry season becoming more defined in the eastern parts of the country. Only 10 percent of land area is devoted to agriculture, with most of that development in Java, the most populous and developed island. The country is basically rural, with 85 percent of the population in rural areas, clustered in small villages around fertile rice fields and terraces. They are largely self-sufficient and near subsistence level. No large urban movement is occurring, and the population distribution is very uneven. Rice is the cornerstone of agriculture; rubber, coffee, palm oil, sugar, tea and spices are also important. Timbering and mining (including oil) are rapidly growing industries and major contributors to foreign exchange earnings. Development has been heavily dependent on foreign aid and technical assistance, particularly in tapping the country's abundant mineral resources.

Only Java and Sumatra have reasonably well developed transport systems. Freight movements are dependent on sea transport, with major population centers close to the sea. Rail is restricted to short distances, and internal roadways are poorly developed.

The economy has shown fairly stable growth since the revolutionary period of the mid-1960s, although the full impact of the recent financial collapse of Pertamina, the large government-run conglomerate, is not yet known. Nevertheless, the country is characterized by a stable political environment and a sense of unity and national pride.

Social programs are aimed at increasing private enterprise, particularly in rural areas. Farmers are being trained in better use of fertilizers, and emphasis is being placed on improving health care and facilities. Emphasis in the near future is on self-sufficiency in food, development of industry, improvement of transport and other infrastructures, and creation of employment opportunities.

Special Data Sources

The Brazilian Government has been conducting a national aerial survey, Project RADAM, a good part of which is complete and has been documented in a series of volumes and maps (Ref. 36). A large quantity of the data from this survey was obtained and utilized in this study. Of particular significance are Project RADAM maps entitled "Potential Uses of the Land" in which detailed regional summaries have been made to specify possibilities for development in terms of agriculture, livestock raising, mining, and forestry. These maps were instrumental in conceiving and evaluating transport market opportunitites in the Amazon region which has been designated a prime are for future development in the long-range plan of the Brazilian Government.

In a project partially funded by the World Bank, a similar survey is in progress in Indonesia; however, the results of this survey were not available for inclusion in the present study. Nevertheless, based on the experience gained in using the RADAM data, it is likely that a similar approach can be recommended for other countries in which air applications are sought in future studies. The LANDSAT data tapes generated by NASA could be the basic source by which land use interpretation may be made (Ref. 102).

Despite the lack of such specific information, it was possible to carry out the Indonesian case study by utilizing the results of a 1972 study entitled "Transportation in Indonesia," which was commissioned by the Department of Transport, Communications and Tourism, and funded in part by the World Bank (Ref. 59). This multi-volume report is considered confidential, and copies cannot be obtained for private use. A set of volumes is available for study at the World Bank, and a thorough review of them was made during the course of the study.

Transport Problems

Brazil

In the past, transportation planning in Brazil has relied heavily on road development. In the Amazon region, especially, the basic scheme for settlement and resource exploitation has been to link the existing centers of population with the more populous coastal citites by driving highways through the rain forest (Ref. 103). However, these links are only thin ribbons of unpaved surface in an extremely vast area which is virtually uninhabited and unexplored. Furthermore, there is a tendency for large stretches to wash out in the rainy season, leaving the existing villages unreachable except by river and air transport for several months each year. Even when the highway is passable, there is little or no infrastructure extending from it. It is not surprising then, the the Government's attempt to encourage migration into this region has not met with rapid success (Ref. 104).

In addition to the very large area in which potential development might be most fruitful, and the fact that the best areas may not be near the primary road or river routes to the coast, the ecology of the Amazon basin has been found to be far more delicate than was anticipated. When large areas are cleared of the dense tree cover, serious erosion occurs in the rainy season and the result is a barren zone rendered useless for agriculture or forestry (Ref. 64). The Government has attempted to prevent wholesale deforestation by enacting laws against it, but surveillance and policing of so vast an area is not an easy task (Refs. 105 & 106). Full-time surveillance, such as is facilitated by LANDSAT, for example, may be the ultimate answer to this problem.

Although Brazil has many rivers, inland waterways are not the solution to all transportation problems because most are navigable only for short stretches. Furthermore, the steep escarpment along much of the coast creates precipitous falls in most cases. Similarly, rail and road links to the major coastal cities are rendered difficult and circuitous by this natural barrier to surface transport.

The plan to develop the Amazon region is formalized in the concept of agricultural, cattle, and mineral "poles." (Ref. 35) These poles are initial concentrations of agricultural, livestock ranching and mining activity which will ultimately become population and commercial centers. The general locations of the poles are shown in Fig. B-1; also shown are the existing surface transport routes through the region, namely, the Amazon River and the Amazon Highway system. All of the highway links shown are either completed, under construction, or in final stages of planning.

Based on the RADAM survey, it is possible to identify the occurrence of resources in the Amazon region, as shown in Fig. B-2. This map shows the approximate locations of zones favorable to various agricultural, livestock and mineral developments. Data concerning the present and potential values of these opportunities are indicated in Tables B-1 and B-2 which show present production and known resources relative to corresponding world figures, and the present trade values of some commodities to the Brazilian economy.

Indonesia

Unlike Brazil, transport planning in Indonesia has formerly lacked a rational basis. Only recently has the Government begun to address the great problems which were precipitated by a long period of neglect after nationalization of facilities following independence from Dutch rule, and the revolution of the mid-1960s. The first 5-year development plan stressed rehabilitation of existing facilities and some progress was made (Ref. 33). However, most road and rail vehicles are old and undependable. Frequent breakdowns, overloading of vehicles, delays, and government-imposed rates are some of the basic problems which require attention, and large capital investments will be required to make the necessary improvements. On the

POLAMAZONIA AND THE ROAD NETWORK

(DEVELOPMENT POLES)

(PAVED, UNDER PAVING, GRAVEL, UNDER CONSTRUCTION, AND PLANNED ROADS)

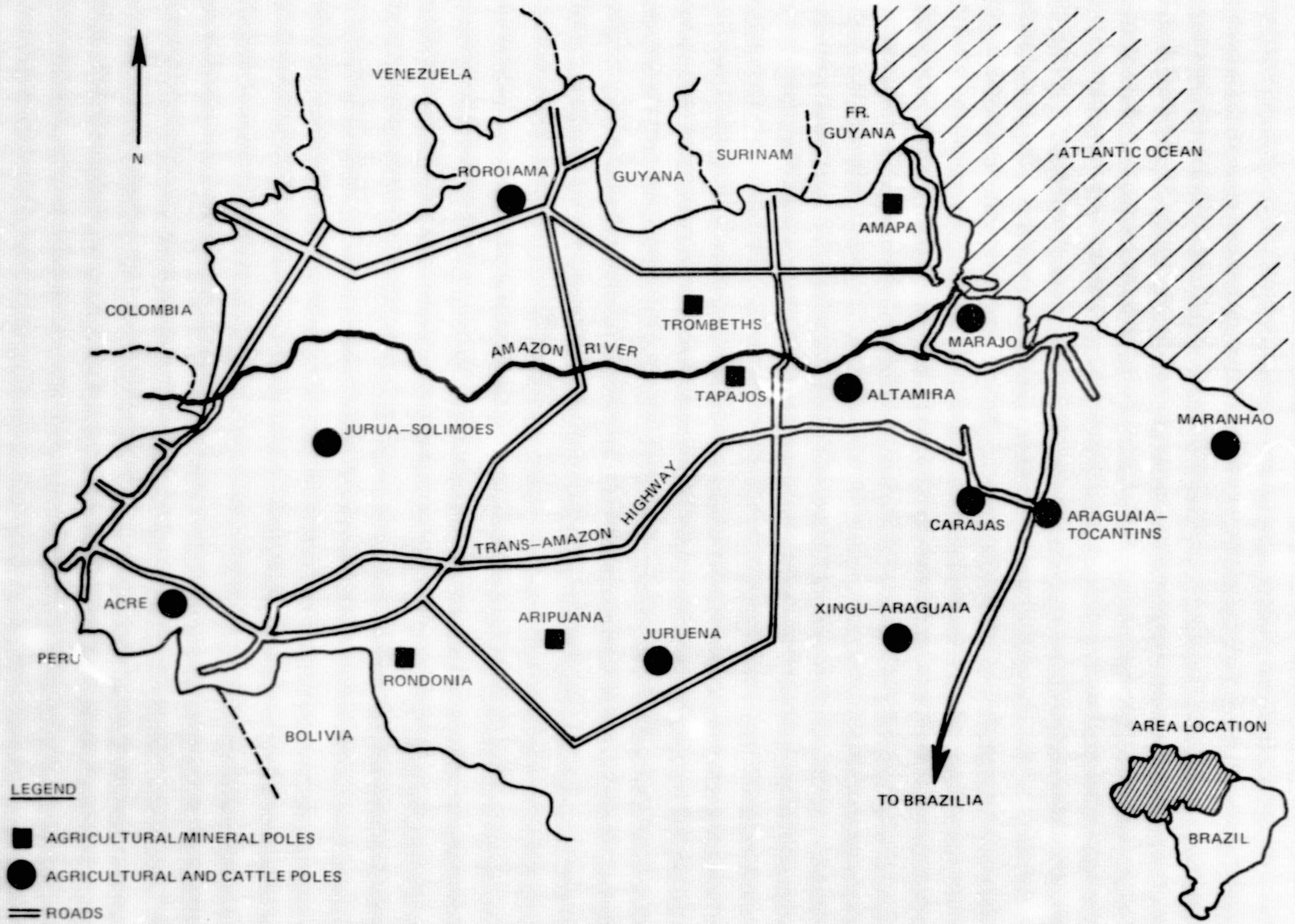

FIG. B-1

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KNOWN POLAMAZONIA DEVELOPMENT POTENTIAL

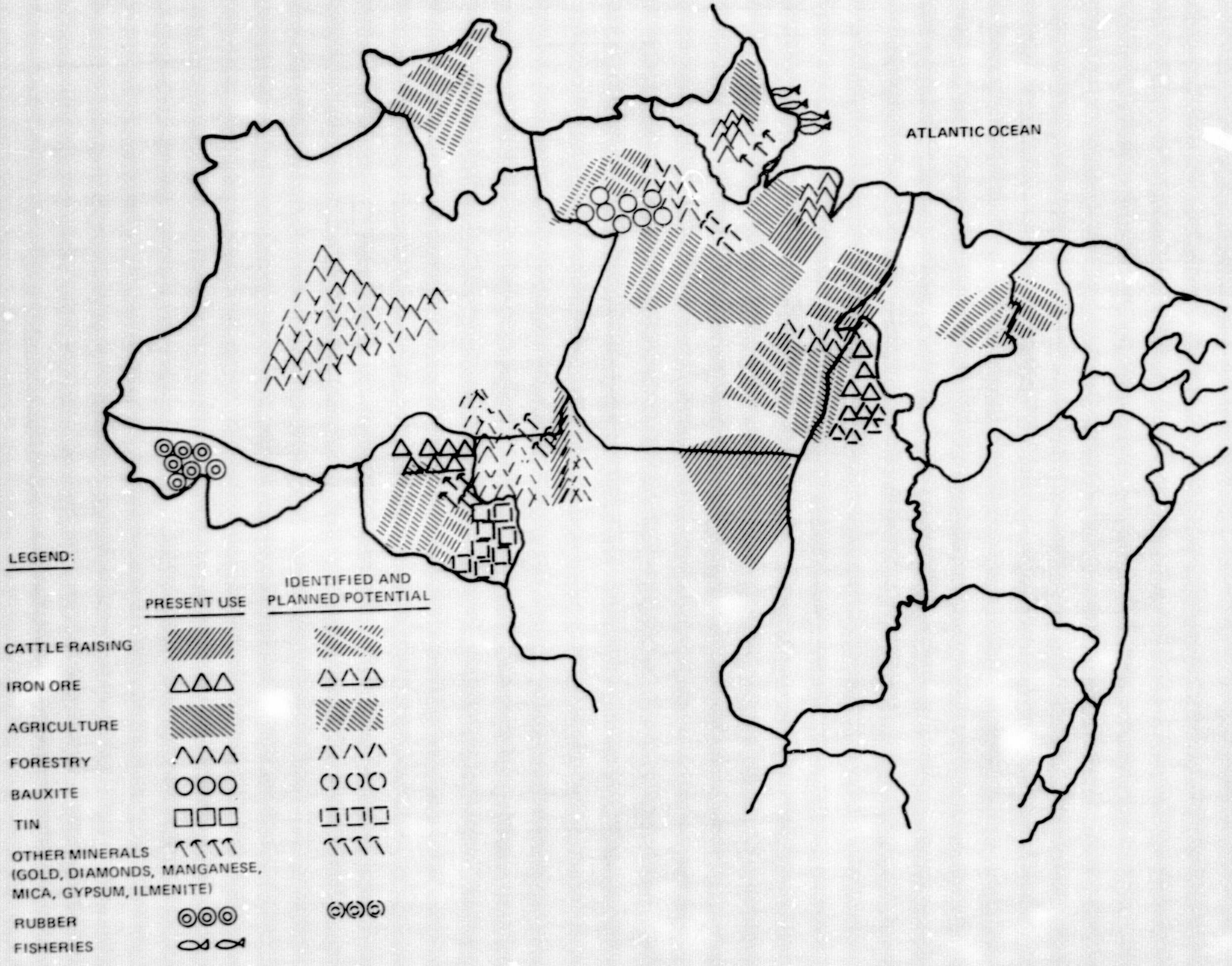

FIG. B–2

77–07–84–2

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TABLE B-1

BRAZIL: AGRICULTURE

Agricultural Commodity	1974 Production 10^3 Metric Tons	% of World Production	Value of 1975 Exports $\$10^6$	% of 1975 Export Value
Coffee	1,620	33.3	852	9.9
Soybeans	7,700	13.5	1,150	13.3
Cocoa Beans	165	11.4	220	2.6
Timber	137,700	9.8	162	2.0
Sugar	6,930	8.8	770	8.9
Palm Oil	247	6.1	-	-
Corn	17,284	5.9	151	1.7
Tobacco	304	5.8	142	1.6
Livestock	158*	5.4	-	-
Cotton	564	4.2	98	1.1
Meat	2,902	3.1	49	0.6
Ground Nuts	479	2.7	70	1.8
Canned Fish	35	2.2	-	-
Rice	6,483	2.0	-	-

*10^6 Head

TABLE B-2

BRAZIL: MINERAL RESOURCES

Mineral Resource	1974 Production 10^3 Metric Tons	% of World Production	Est. Reserves Metric Tons	% of World Reserves	Net Value of 1975 Trade(2) $\$10^6$	% of 1975 Export Value
Iron Ore	41,205	8.12	65×10^9	-	909	10.5
Manganese Ore	1141.5	12.48			81	0.9
Uranium			9700	0.9	-	-
Asbestos	819	15.8	-	-	-	-
Chromium Ore	124	4.0	-	-	+	-
Magnesite	275	2.5	-	-	+	-
Tungsten Concentrates	1,001	2.1	-	-	+	-
Tin "	3,555	2.0	10×10^6	-	-	-
Zinc	94	1.7	-	-	+	-
Bauxite	900	1.2	1×10^9	-	0	-
Salt	1,552	1.0	-	-	+	-
Lead Ore	25	0.7	-	-	+	-
Gold	5,864(1)	0.6	-	-	-	-
Nickel	3,500	0.5	300×10^6	-	+	-
Crude Oil	8,442	0.3	102×10^6	0.1	-	-
Phosphate Rock	221	0.2	-	-	-	-
Coal	2,582	0.2	3.3×10^9	-	-	-
Niobium Ore	-	-	1800×10^6	-	0	-
Oil Shale	-	-	-	40	0	-

(1) kg (2) + and - indicate positive or negative trade balance too small to be reported individually

remote islands, where future development may be concentrated, transport facilities are almost nonexistent. Roads are few and impossible to maintain in good condition; rivers, where they exist, are useful mostly for floating logs; and airfields cleared for WW II use have been reclaimed by the jungle.

Air transport plays a vital role in Indonesia in promoting national cohesiveness because of the long distances between the outer islands and the major centers on Java, Bali and Sumatra. This means that future development of the resources on these islands must rely on air and water transport. Lack of port and inland transport facilities probably dictates use of airplanes, at least as an interim solution.

Although Indonesia is a large country consisting of some 3000 inhabited islands, only the major islands, particularly Java, have been developed to any large extent. Announced Government policy to settle and develop the outer islands should result in gradual change, and the need to generate capital for general development of the economy should be sufficient encouragement to promote exploitation of resources in remote areas. As shown in Figs. B-3 to B-6, the occurrence of known resources in Indonesia is impressive. Future exploration will undoubtedly expand these reserves in both magnitude and geographic occurrence, since it has been estimated that only 5 percent of the country's land area has been systematically explored and mapped in any fair detail. Tables B-3 and B-4 indicate the types of agricultural and mineral products presently being produced and the resources known to exist.

Economic Scenarios

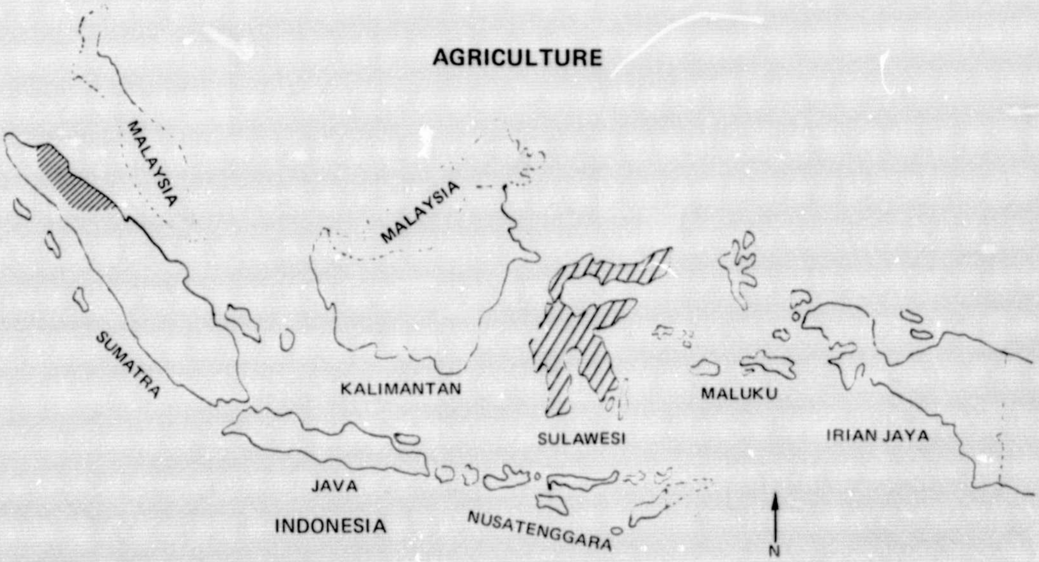
Baseline economic scenarios were derived for Brazil and Indonesia to provide a framework for transport developments in the 1975-to-2005 forecast period of the study. The forecasts were predicated on nominal population projections, and were carried out independently for the agriculture, industry, and service sectors of both economies. Since the projections were to be carried out to the year 2005, it was convenient to divide the forecast period into three parts. The near-term period encompassed the existing development plans, which extend from the present through 1980. The 1980-to-1990 decade comprised the near-to-mid-term period, which is beyond present planning but not too distant for reliable forecasting. The long-term forecasts were for the 1990-to-2005 period.

The basic projection of economic growth which was made was that of gross domestic product. The approach taken in making this projection was to forecast the growths of labor supply and productivity in three basic sectors: agriculture, industry, and services. Productivity in a labor sector was defined as the GDP contribution of that sector per employed worker. Since both labor supply and productivity grow at different rates in each sector, overall economic growth depends on the aggregate effects of shifting labor emphasis within the economy and improving productivity of workers in each sector.

AGRICULTURE

III TOBACCO
IIII SUGARCANE
I I I RUBBER

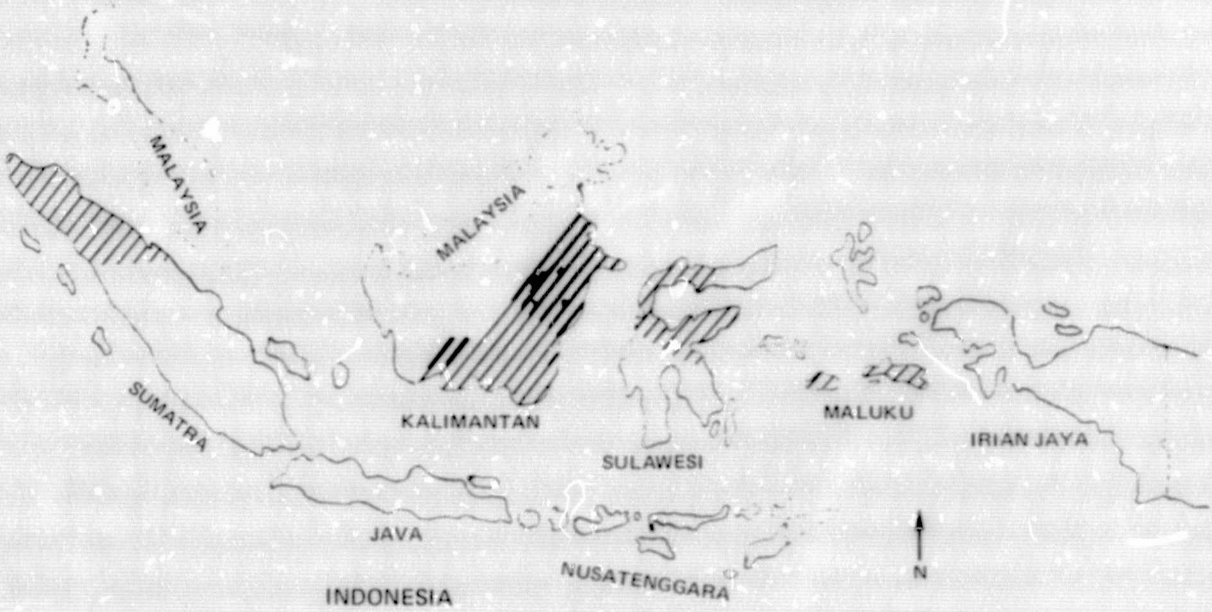
AGRICULTURE



IIII –PALM OIL AND KERNELS
I I I –COPRA

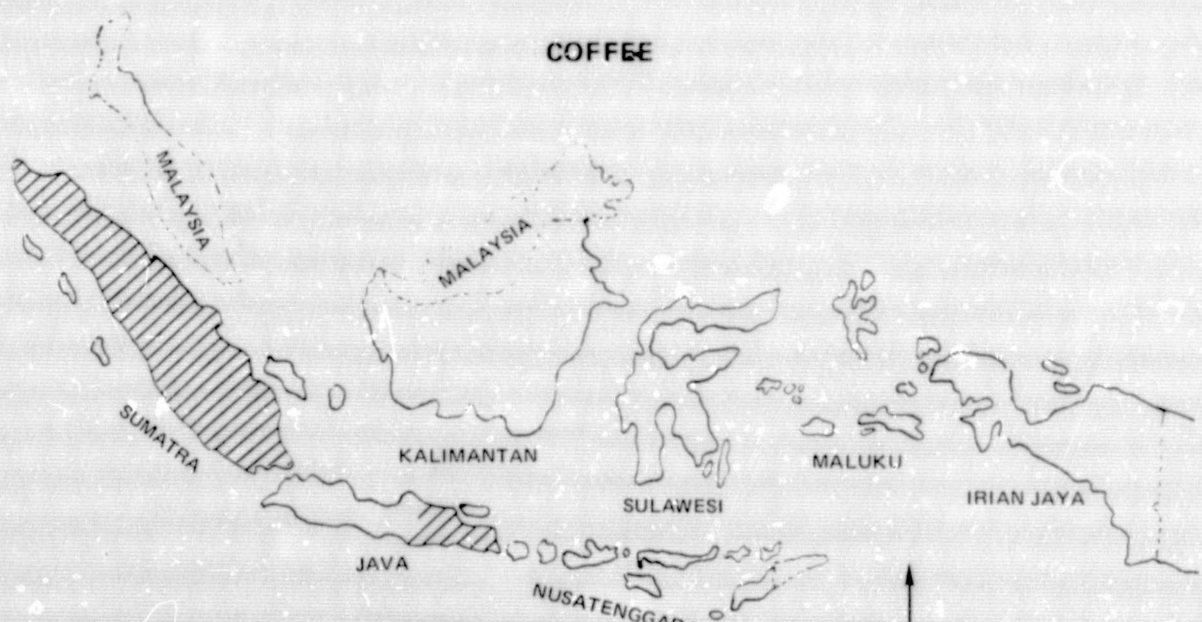
CORN AND CASSAVA–WIDESPREAD,OFTEN AS SECONDARY DRY SEASON CROPS TO RICE

FORESTRY



NOTE : HEAVY SHADING INDICATE PRIME AREAS

COFFEE



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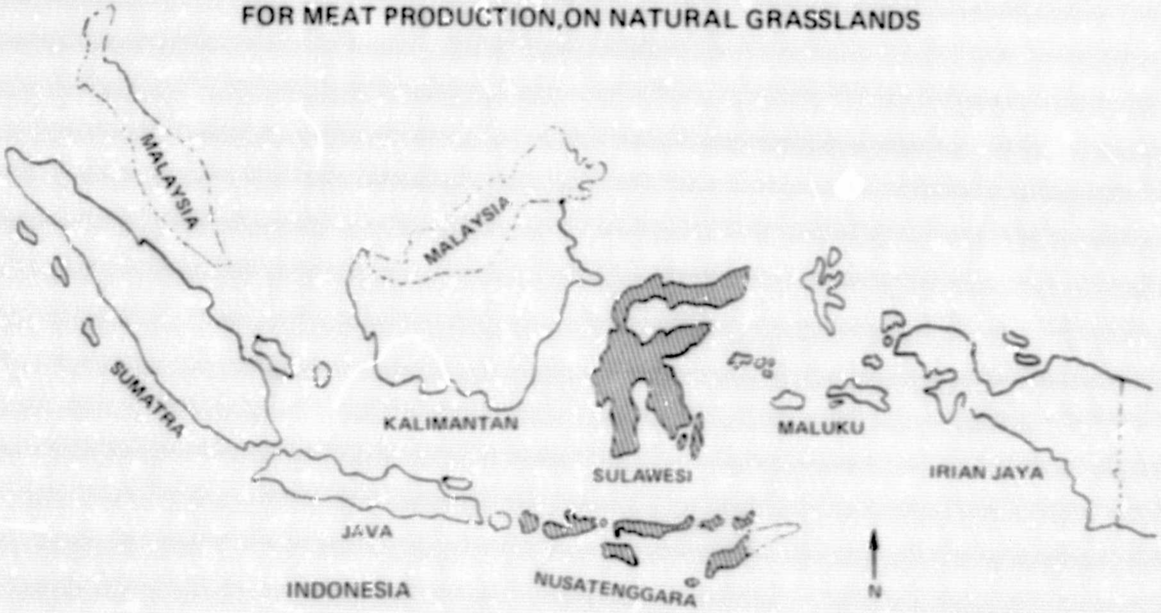
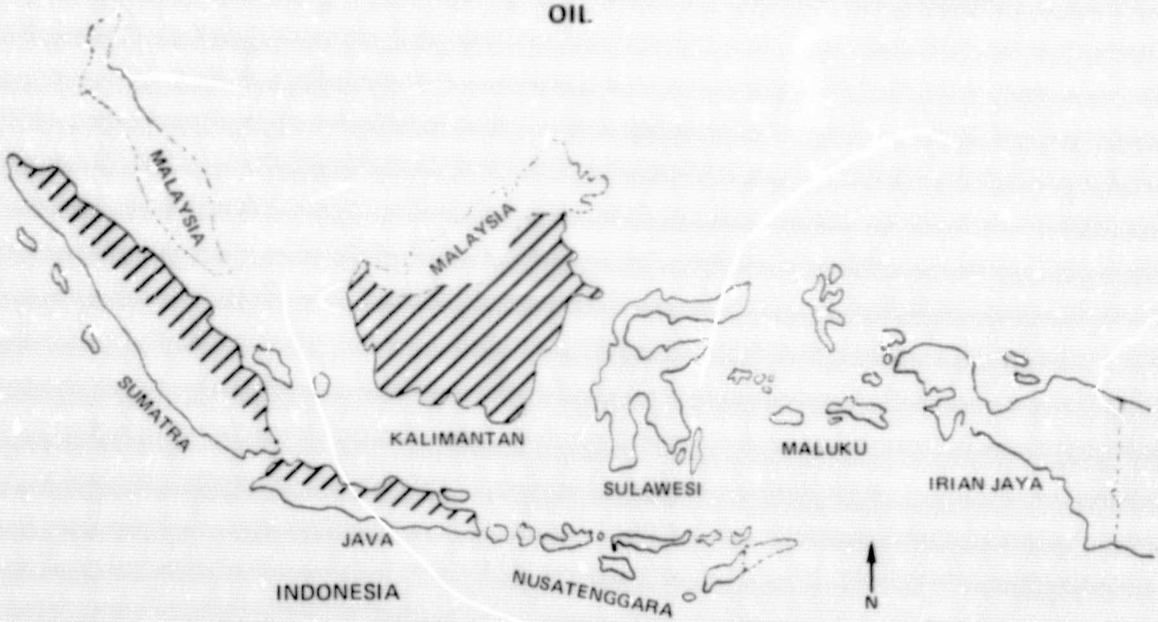
LIVESTOCK RAISING FOR MEAT PRODUCTION,ON NATURAL GRASSLANDS

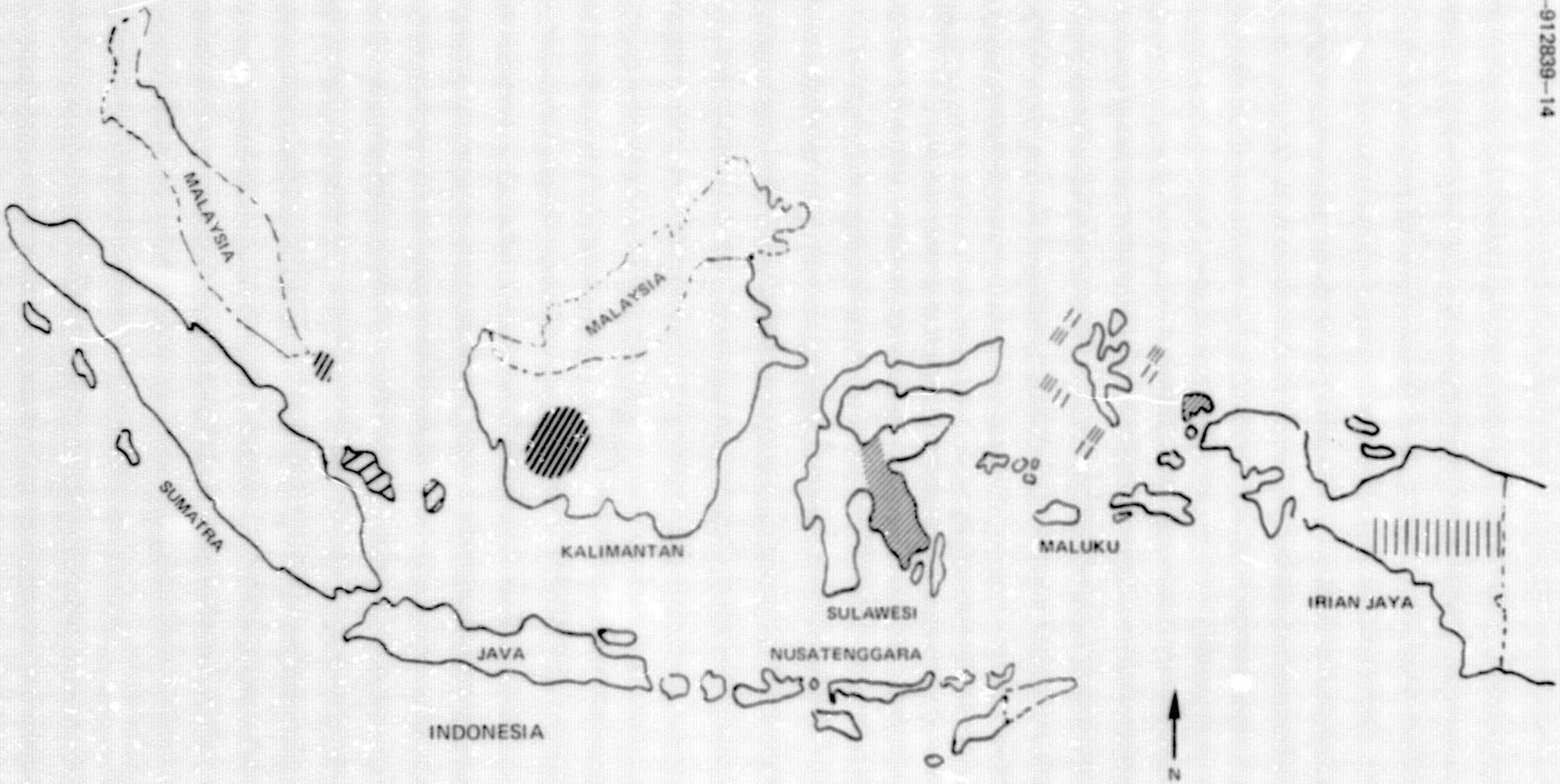


OIL



NOTE: LARGE AREAS UNDER EXPLORATION SURROUNDING SUMATRA AND KALIMANTAN,REACHING UP INTO THE SOUTH CHINA SEA, ACROSS THE JAVA SEA,AND THE WATERS OF MALUKU AND IRIAN JAYA

MINERALS



NOTE: ONLY 5% OF LAND MAPPED GEOLOGICALLY IN FAIR DETAIL BY 1973!

- TIN
- NICKEL
- COPPER
- BAUXITE

ALSO LESSER SIGNIFICANT KNOWN DEPOSITS:

LOW GRADE COAL– KALIMANTAN,SUMATRA,W.JAVA

MANGANESE,SOME GOLD AND SILVER–JAVA

DIAMONDS–KALIMANTAN

FIG. B–6

TABLE B-3

INDONESIA: AGRICULTURE

Agricultural Commodity	1974 Production 10^3 Metric Tons	% of World Production	Value of 1975 Exports $\$10^6$	% of 1975 Export Value
Natural Rubber	842	24.9	360	5.1
Palm Oil	406	10.1	159	2.2
Timber	134	9.6	512	7.2
Rice	22,730	7.1	-	-
Tea	55	4.5	52	0.7
Coffee	182	3.8	100	1.4
Ground Nuts	525	3.0	-	-
Tobacco	122	2.3	36	0.5
Fish	1,342	1.9	83	1.2
Sugar	935	1.2	-	-
Corn	3,240	1.1	6.4	0.1
Cassava	11,400	-	23	0.3
Copra	1,276	-	31	0.4
Pepper	-	-	23	0.3

TABLE B-4

INDONESIA: MINERAL RESOURCES

Mineral Reserves	1974 Production 10^3 Metric Tons	% of World Production	Est. Reserves Metric Tons	% of World Reserves	Net Value of 1975 Trade $\$10^6$	% of 1975 Export Value
Tin Concentrates	25.6	14.2	-	-	140	2.0
Nickel Ore	21	2.8	$70x10^6$	-	21	0.3
Crude Oil	68,000	2.4	$1614x10^6$	2.1	4933	69.4
Bauxite	1,290	1.7	$78x10^6$	-	-	-
Natural Gas	5,730,000	0.5	$425x10^9$*	0.7	-	-
Manganese	7.6	0.1	-	-	-	-
Copper	-	-	$3x10^6$	-	-	-
Coal	156	0.007	$163x10^6$	0.015	0	0

* cubic meters

Some historical data for the decade of the 1960s is given in Table B-5 for Brazil and Indonesia. Included are the numbers of workers employed in each sector, their productivities, and the share of GDP contributed by each sector. At the right of the table are growth rates which describe the relative changes of these parameters in this period for each country. The trends are quite similar.

In each case, the total labor force grew at a rate less than the general population. This difference is expected because the fraction of people of working age (participation rate) declines with improvements in infant mortality and life expectancy; a longer education period also affects the labor supply growth rate. In the period shown, these effects were more significant in Indonesia than in Brazil. Indonesia's population grew at 2.1 percent/yr during the 1960s but the labor force increased at a rate of only 1.5 percent/yr. In Brazil, the corresponding rates were 2.8 percent/yr and 2.7 percent/yr, respectively.

Most of the labor force growth occurred in the industry and service sectors, with a much smaller growth in agriculture, although agriculture remained the largest employment sector in both economies. Similarly, the highest growth in GDP occurred in industry and services, particularly the former. However, whereas industry had already overtaken agriculture in Brazil by the beginning of the decade, agriculture remained predominant in Indonesia. These trends are indicative of the relative states of development in the two countries. A comparison of productivities also suggests the attainment of a more advanced stage in Brazil.

The growth patterns for Indonesia were greatly affected by domestic turmoil and nationalization of Dutch industries in the early part of the decade. Productivity, in particular, declined in the agricultural and service sectors. Most of the industrial growth indicated occurred in the latter half of the period. The first half of the 1970 decade has seen a continuation of the industrial growth rates and a resurgence in the other sectors.

Projected growth rates for labor force and sector productivities are shown in Table B-6 for both Brazil and Indonesia. These forecasts reflect not only the historical patterns indicated in Table B-5, but also stated national plans for development and trends predicted by informed observers. Labor force growth rates are predicted to be somewhat less than population growth in Brazil as the economy matures, and equal to or greater than population growth in Indonesia, which is in a much less advanced stage of development.

A reemphasis on Brazilian agriculture should keep productivity growth high in that sector, while industrial and service sector productivities continue at slightly lower rates. These estimates reflect the historical trends in both the balance and stability of Brazil's economy.

TABLE B-5

Historical Development Data

BRAZIL

Labor Sector	1960 Empl't 10^6	1960 GDP $\$10^6$	1960 Product. \$/Worker	1970 Empl't 10^6	1970 GDP $\$10^6$	1970 Product. \$/Worker	1960-70 Growth Rates Empl't %/Yr	1960-70 Growth Rates GDP %/Yr	1960-70 Growth Rates Product. %/Yr
Agriculture	12.163	5,178	426	13.071	8,238	630	0.72	4.75	3.99
Industry	2.963	8,343	2,816	5.264	24,026	4,564	5.92	11.16	4.95
Services	7.525	15,247	2,026	11.210	36,382	3,245	4.07	9.09	4.82
TOTAL	22.651	28,768	1,270	29.545	68,646	2,323	[illegible].70	9.09	6.22

INDONESIA

Labor Sector	1961 Empl't 10^6	1961 GDP $\$10^6$	1961 Product. \$/Worker	1971 Empl't 10^6	1971 GDP $\$10^6$	1971 Product. \$/Worker	1961-71 Growth Rates Empl't %/Yr	1961-71 Growth Rates GDP %/Yr	1961-71 Growth Rates Product %/Yr
Agriculture	24.862	7,370	296	25.297	6,238	247	0.17	-1.65	-1.81
Industry	2.697	1,474	547	3.842	3,096	806	3.60	7.70	3.95
Services	7.019	4,556	649	10.887	4,975	457	4.49	0.89	-3.45
TOTAL	34.578	13,400	388	40.026	14,309	357	1.47	0.66	-0.83

TABLE B-6

Projected Growth Rates

Country	Period	Growth Rates, %/Yr			
		Labor Force	Productivity		
			Agriculture	Industry	Service
Brazil	1970-1980	2.7	4.0	3.0	4.0
	1980-1990	2.6	4.0	3.0	3.0
	1990-2005	2.0	3.0	3.0	2.0
Indonesia	1970-1980	2.3	2.0	5.0	2.0
	1980-1990	2.5	3.0	5.0	2.0
	1990-2005	2.6	3.0	5.0	2.0

The anticipated trends in Indonesia are based on a steadily improving industrial sector led by oil production. Continued difficulty in improving agricultural and service productivities is forecast despite emphasis on these sectors in the national plan for 1974-1979.

Historical patterns of shifting employment from the agricultural sector to the industry and service sectors are shown in Fig. B-7 for the industrialized nations: Great Britain, the United States, and Japan. The trend in the developmental period has always been a steady decline in the percentage of workers employed in agriculture, accompanied by growth of industrial employment to the range of 30 to 40 percent of the total. Employment in agriculture levels off at a very low figure under 5 percent. Thus, the service sector, which is the remainder after agriculture and industry are accounted for, becomes dominant in the mature stage of the development process. The trends show that the period of development has contracted, the US developing faster than Great Britain, and Japan developing faster then the US. A more recent trend has been the formation of a large service sector at an early stage of development in LDCs. Both Brazil and Indonesia fit this pattern.

In projecting the declining importance of agriculture, these historical observations have served as a guide. The projected curves for the two countries have steeper slopes than the developed countries shown on the diagram, in keeping with the historical observation that today's LDCs can benefit by the experiences of the developed nations and thereby shorten the period during which development occurs.

When these predicted trends in labor force and productivity are applied to base-year (1970) values, the resulting projections are as shown in Fig. B-8. Also shown are the forecasts of GDP for each country to 2005, based on the labor and productivity trends. The average GDP growth rates over the 1970-to-2005 period are indicated below with the corresponding historical values from the 1960s.

	GDP Growth Rate, %/yr	
	Historical	Forecast
Brazil	9.09	6.58
Indonesia	0.66	7.50

As shown, Brazil's rate of growth is forecast to continue at a high rate, although somewhat less than the rapid expansion of the 1960s. Indonesia, which underwent a decade of revolutionary change in the base period, is forecast to advance at a more rapid rate than Brazil. But, as the curves in Fig. B-8 show, Indonesia will still trail well behind Brazil in both productivity and GDP by 2005.

SECTORAL LABOR FORCE DISTRIBUTIONS

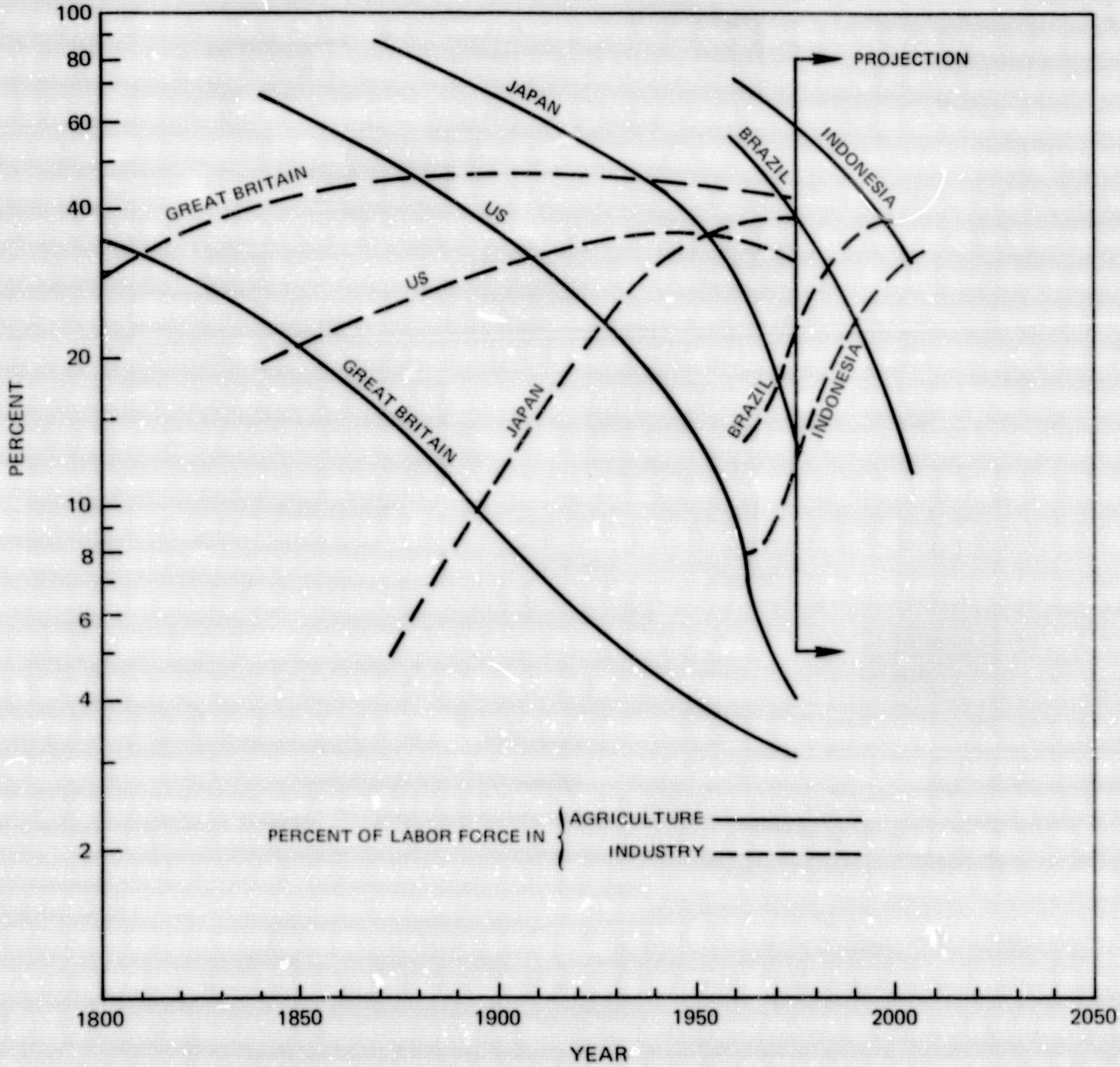
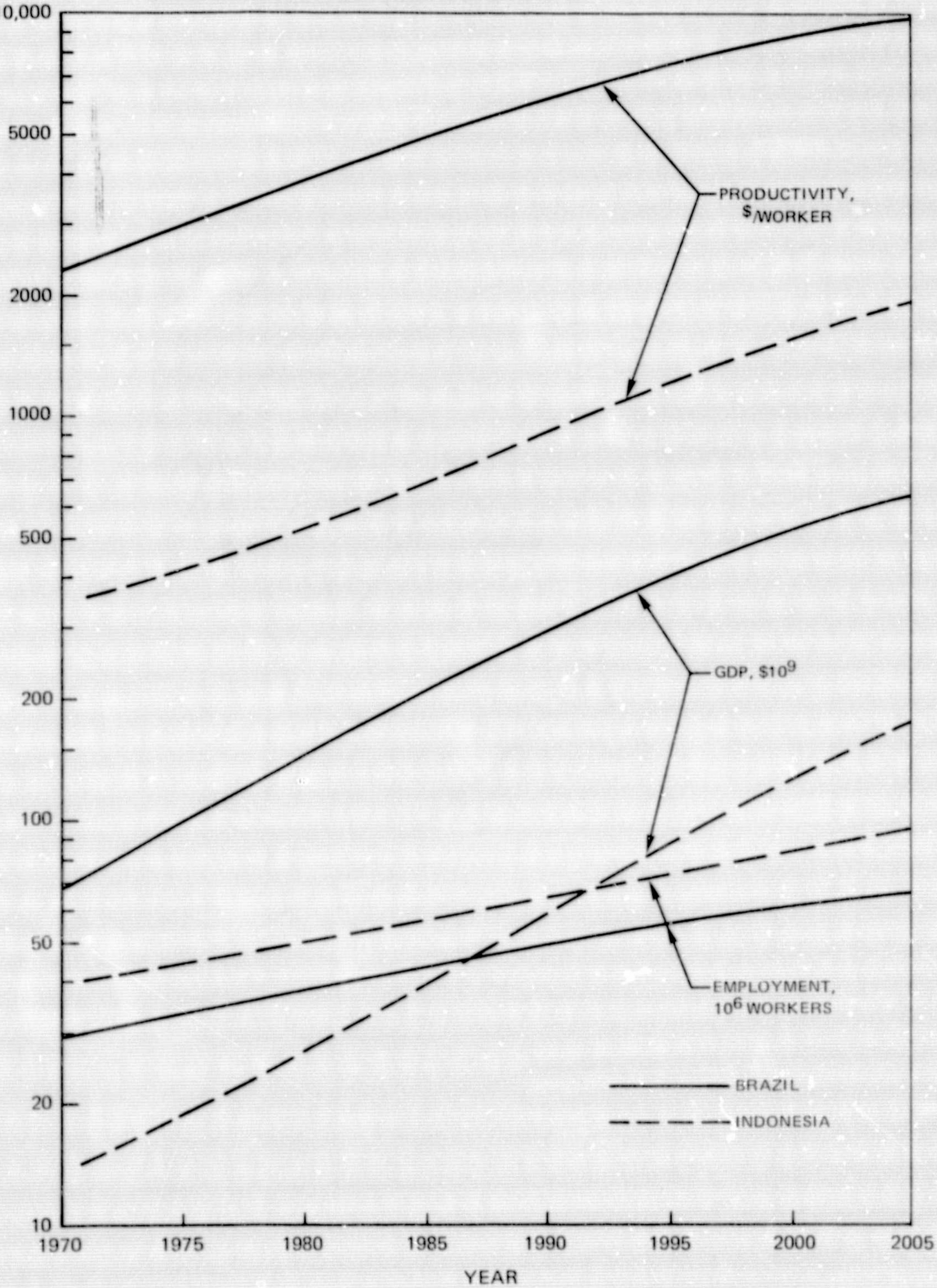


FIG. B–8

ECONOMIC GROWTH PROJECTIONS

BRAZIL AND INDONESIA



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APPENDIX C

OPERATING COSTS

Air Transport

What is described here is a method of calculating airplane direct operating cost (DOC) in which the estimation procedures have been conceived with LDC-type airplane operations in mind. Use of the standard ATA procedure would not be appropriate because it is predicated on the experience of American trunk carriers operating in a modern, sophisticated air transport system. Adaptation of the ATA method format is not feasible because data required to alter the empirical derivations to reflect the LDC environment are not available. Therefore the simplified approach described here was developed as a means of portraying the cost of LDC airplane operations. Although it is not likely that the results obtained by this method will correlate with the limited data available from published sources (Refs. 107-121), the method does at least provide a consistent format for comparing airplanes in an unconventional operating environment. What follows are discussions of each of the five component cost derivations: crew, depreciation, insurance, maintenance and fuel.

Crew

It is assumed that the crew cost, in \$/block-hr, is a function of the number of crews required to keep the airplane in operation, the cost per crew, and the annual airplane utilization, in hours.

$$DOC_{Crew} = \frac{\text{Cost/Crew x No. Crews}}{U}$$

If each crew flies 60 hours/month, the number of crews required is U/720. Therefore,

$$DOC_{Crew} = \frac{\text{Cost/Crew}}{720} \qquad \text{if } U \geq 720$$

and

$$DOC_{Crew} = \frac{\text{Cost/Crew}}{U} \qquad \text{if } U < 720$$

The cost/crew is primarily a function of the type and size of airplane. Representative values for U.S. experience are as follows:

Airplane Type	Cost/Crew ($/Yr)
Light Twins	30,000
Business Jets	50,000
Turboprop and Piston Airplanes	70,000
Helicopter	85,000
2-Engine, Regular-Body TF Airplanes	130,000
3-Engine, Regular-Body TF Airplanes	190,000
4-Engine, Regular-Body TF Airplanes	220,000
3-Engine, Wide-Body TF Airplanes	240,000
4-Engine, Wide-Body TF Airplanes	290,000

Since these crew costs are based on U.S. airline experience, they are not directly applicable.* Therefore they must be scaled, using appropriate labor rates for Brazil and Indonesia relative to the U.S. The only presently available information suggests that the rates shown above should be reduced by a factor of two for Brazil, and by a factor of four for Indonesia.

Depreciation and Insurance

Both of these cost elements are primarily dependent on airplane purchase price and utilization

$$DOC_{Dep} = C_{A/C} \frac{(1 + SF)(1 - RV)}{U \cdot T_D}$$

and

$$DOC_{Ins} = C_{A/C} \frac{R_I}{U}$$

where SF is the spare factor, RV the residual value, T_D the depreciation period, $C_{A/C}$ the airplane purchase price and R_I the insurance rate

For the purpose of this study, the spares factor can be set at 0.15, the residual value at zero, and the insurance rate at 0.02.

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* An exception would be situations in which foreign-owned and operated aircraft are contracted to perform tasks in LDCs. This type of operation is not uncommon and has the advantage that it circumvents the large capital cost hurdle a LDC faces in acquiring expensive, new aircraft

Maintenance

The most difficult cost component to estimate is maintenance. Even in U.S. carrier operations, maintenance costs are difficult to determine for specific aircraft. Some simple correlations of maintenance cost with airplane empty weight for helicopters, small- and medium-sized airplanes, and large airplanes are shown in Figs. C-1, C-2 and C-3, respectively. Data specific to remote areas and LDCs are sparse and conflicting. The best policy appears to be to use the U.S. experience for each generic airplane type as the basis for estimating maintenance costs. Therefore, referring to the figures, maintenance cost is assumed to be a linear function of operating weight empty (OWE).

$$DOC_M = M_1 + M_2 \quad \frac{OWE}{1000}$$

where OWE is in kg.

The following values of M_1 and M_2 are derived from Figs. 4-6.

Airplane Type	M_1	M_2
Helicopter	0	50
Small and Medium Size A/C	0	20
Large A/C	90	3.5

Fuel

A rate of fuel use can be specified for each airplane, based on the design payload, range and cruising speed. Depending on the price of fuel, C_F, the direct cost of fuel in $/hr is

$$DOC_F = 32.9 \times 10^{-4} \ W_F \ C_F$$

where W_F is in kg/hr and C_F is in ¢/gal.

Typical Results

A list of candidate aircraft was assembled for use in the mode evaluations. These airplanes, characteristics of which are given in Table C-1, included existing and planned aircraft, as well as some hypothetical aircraft. Characteristics summarized in the table are representative values for the kinds of operating regimes in which the airplanes would normally operate. Range and fuel rate data were based on carrying the maximum payload.

C-4

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HELICOPTER MAINTENANCE COST

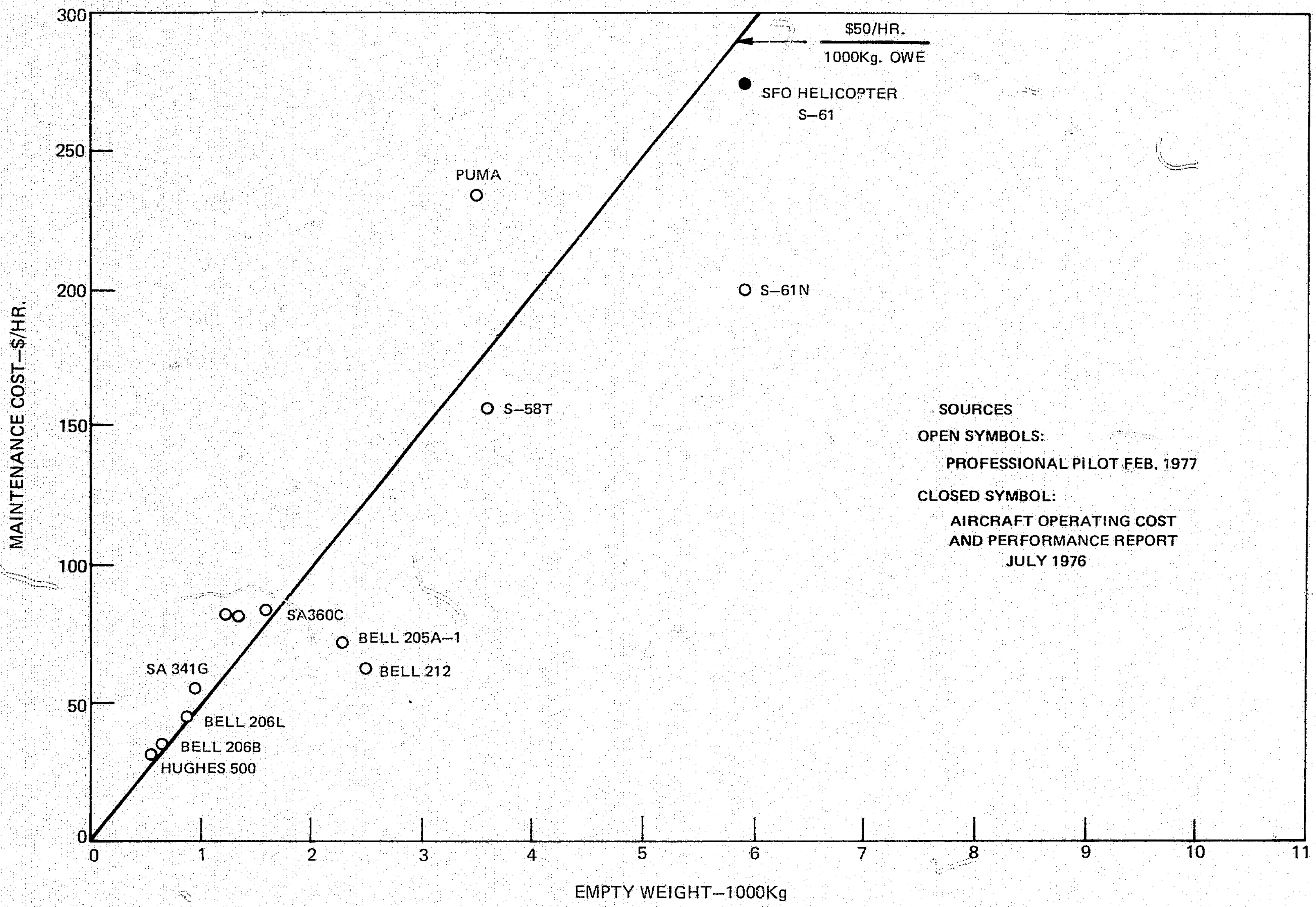

FIG. C-1

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SMALL AND MEDIUM-SIZED AIRPLANE MAINTENANCE COST

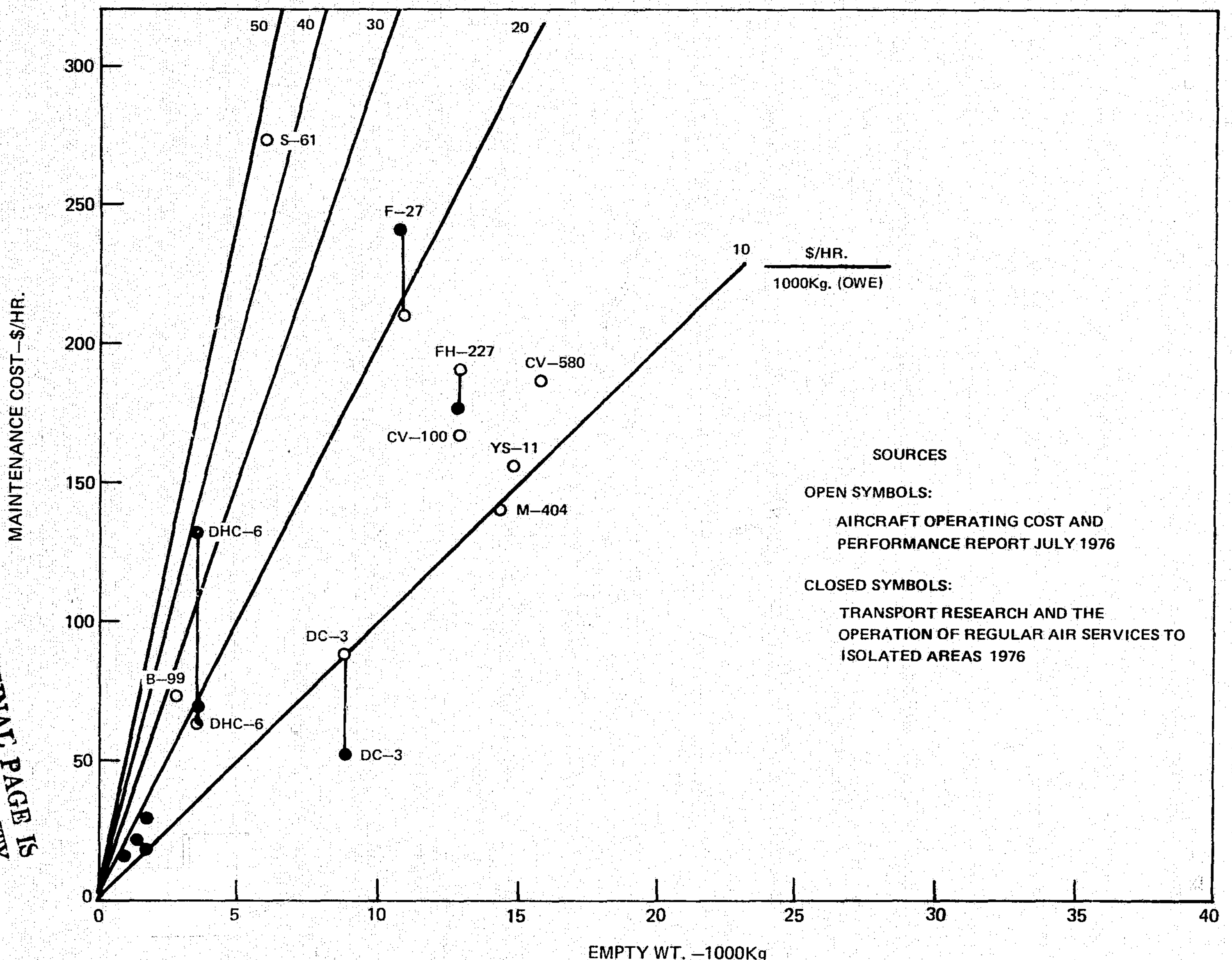

FIG. C–2

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LARGE–AIRPLANE MAINTENANCE COST

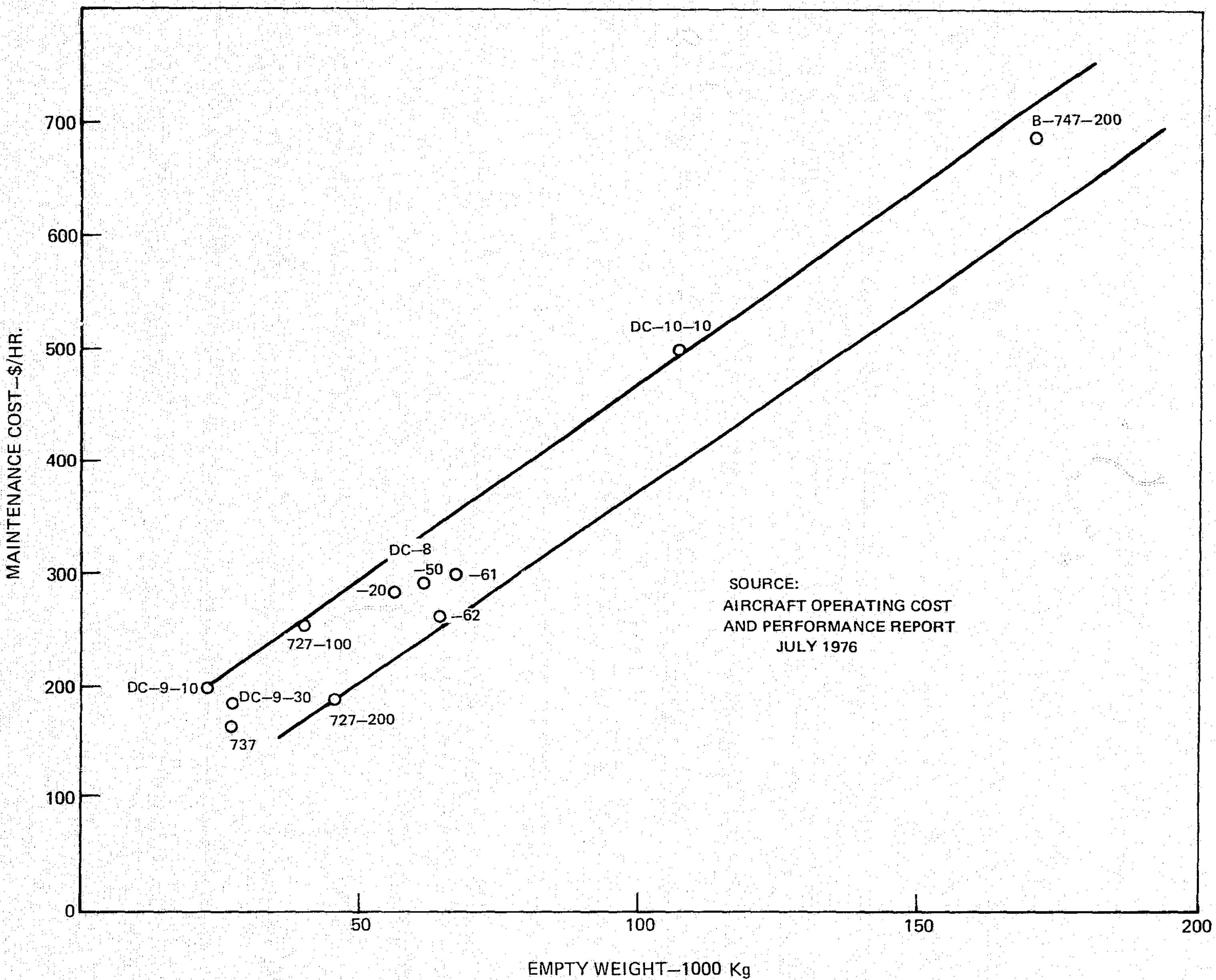

FIG. C–3

77–08–2–2

TABLE C-1

AIRCRAFT CHARACTERISTICS

Category	Aircraft	Availability[1]	Gross Wt. kg	Oper. Wt. Empty kg	Max. Payload kg	Cabin Width m	Range km	Cruise Speed km/hr	Field Length m	Fuel Rate kg/hr	Purchase[2] Price New $\$10^6$	Estimated DOC $/Block-hr
2- Eng. TP CTOL	F-27	1990	20,500	11,300	5,550	2.8	2,300	475	1,650	720	2.05	527
4- Eng. TP CTOL	Fercules	1990	70,650	32,900	15,000	3.0	3,370	565	1,035	3,770	8.15	1,697
Light Twin	Beech Baron 58P	New	2,767	1,902	544	1.1	1,105	365	825	104	0.27	108
Light Helicopter	AS 350	New	1,900	1,075	400	1.7	700	220	0	133	0.24	122
Business Jet	Lear 25C	New	6,805	3,280	1,735	1.5	1,315	815	1,900	1,020	1.27	330
Business TP	Super King Air 200	New	5,710	3,530	725	1.4	2,075	515	785	355	0.96	211
Small STOL	BN2A	2005	2,990	1,710	820	1.1	960	275	300	130	0.17	109
	DHC-6	2005	5,670	3,385	1,635	1.6	320	350	520	665	0.74	287
	EMB-120	New	5,600	3,380	1,800	1.6	246	355	680	545	0.84	279
2- Eng. TF CTOL	VFW-614	New	19,960	12,180	4,100	2.7	1,575	720	1,220	1,480	4.00	832
	DC-9-10	2005	38,560	22,610	10,900	3.1	1,300	820	1,980	2,910	5.30	1,285
	B-737-200	2005	53,000	27,500	15,700	3.5	2,540	850	1,970	3,135	7.25	1,522
3- Eng. TF CTOL	B-727-100	2005	72,600	41,150	13,300	3.5	2,780	875	2,425	4,535	10.16	2,212
	B-727-200	2005	95,000	46,720	18,595	3.5	3,900	915	2,970	5,130	10.95	2,440
Small Fixed-Wing	SD3-30	New	9,980	6,640	2,655	2.0	730	365	1,200	330	1.30	344
	B-99	New	4,945	2,665	1,360	1.4	1,350	455	1,200	300	0.83	234
Advanced STOL	DHC-7	New	17,465	10,795	4,900	2.6	515	445	710	755	3.70	619
	Externally Blown Flap	Future (1985)	67,600	45,255	13,610	3.6	925	765	915	6,670	14.35	2,726
	Augmentor Wing	Future (1985)	96,430	66,465	13,610	3.6	925	850	610	14,000	18.55	4,261
	Advanced STOL	Future (1985)	77,500	53,500	12,250	3.6	1,200	755	610	7,700	13.20	2,154
Helicopter	B-204B[3]	1990	4,310	2,085	1,680	1.5	360	220	0	275	0.85	245
	B-222	New	2,950	1,805	725	1.5	685	240	0	145	0.90	203
	S-76	New	4,400	2,400	1,180	1.9	740	230	0	255	0.90	254
	S-58T	1985	5,900	3,575	1,560	1.5	470	235	0	375	0.91	314
	Puma	1990	6,400	3,500	1,630	2.7	510	265	0	645	1.88	410
	S-78	Future (1985)	8,480	5,000	2,630	2.3	500	295	0	500	2.90	497
	S-61	New	8,620	5,925	890	2.0	825	225	0	485	3.22	541
	S-64[2]	New	21,320	10,220	7,540	NA	370	175	0	1,655	6.50	1,030
Advanced VTOL	HLH	Future (1985)	53,525	28,096	20,410	8.0	170	260	0	7,710	18.70	3,320
	Compound Hel.	Future (1985)	65,725	44,410	13,610	3.9	320	425	0	9,725	12.20	4,280
	ABC Hel.	Future (1985)	69,700	48,000	13,610	3.9	320	650	0	15,255	16.00	5,334
	Tilt Rotor	Future (1990)	88,950	66,450	13,610	3.9	320	725	0	18,470	23.90	7,759
	Tilt Wing	Future (1985)	58,560	37,600	13,610	3.9	925	725	0	5,585	15.70	4,026
	Direct Lift	Future (1985)	76,850	50,600	13,610	3.9	925	875	0	11,495	21.70	5,854
	Tilting Stowed Rotor	Future (1995)	89,320	64,900	13,610	3.9	925	805	0	9,080	23.00	6,501
LTA	Small	Future (1985)	91,300	60,405	27,700	-	965	130	0	425	10.00	1,195
	Large	Future (1985)	315,465	189,850	111,450	-	3,220	97	0	455	40.00	3,390
	HLA	Future (1990)	147,850	67,165	69,560	-	185	111	0	6,130	11.00	3,672

(1) Date indicates last year of availability as used aircraft, or first year of availability for future aircraft. "New" indicates that aircraft will be purchased new, as required.

(2) 1977 Dollars.

(3) Payloads based on external load.

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Based on the characteristics shown, estimates of DOC were made using the analysis described above. Results which are shown in the last column of Table C-1 give DOC on a $/block-hr basis for each airplane. Although the figures shown for airplanes evaluated in the main text are not identical to those used (because of different operating conditions), the estimates are indicative of the relative costs of the airplanes when compared on a consistent basis.

Road Transport

Representative figures for road transportation costs in remote areas of developing countries are shown in Table C-2. These data are intended for use only within the context of an initial screening of transport opportunities. Road transport costs vary greatly with local conditions. Road construction and maintenance costs, in particular, are sensitive to topographical factors, climatic conditions, traffic levels, labor costs and other variables which are difficult to quantify. More accurate estimates of transport costs, therefore, can only be made on a case-by-case basis. Much greater detail would have been necessary to arrive at better estimates, but such detail was not possible in the broad analyses undertaken in this study.

The data used have ben derived from a Harvard/MIT study done for the Venezuelan Orinoco region, adjacent to the Brazilian Amazon basin (Ref. 122). This study was determined to be the best readily available source of information due to the similarity of the two regimes and the degree of detail included. In the study, differences in transport costs were specified for various road types, traffic volumes, and types of equipment. These were based on transport of bulk commodities, primarily iron ore and steel products, assuming 80 percent to 100 percent truck load factors with no return loads.

The study was performed in the early 1960s and costs were given as 1959 price levels. For this reason the costs, although somewhat dated, were adjusted to account for price changes between 1959 and 1976 and are expressed in constant 1976 U.S. dollars. These were computed based on labor, capital and foreign exchange requirements and the change in their relative price indices (Ref. 123).

Results are expressed as costs per kg-km, a parameter that can be easily applied to a variety of situations with different line-haul distances and transport volumes. As would be expected, truck operating costs decline as the quality of the road surface is improved. As road usage becomes heavier, higher road standards result in lower total costs. Unit cost decline rapidly due to the large fixed costs for road construction and maintenance.

TABLE C-2
TYPICAL ROAD COSTS IN DEVELOPING COUNTRIES
Source: Ref. 122

Costs in $\$/10^6$ kg-km[1]

Road Type	Road Life (yrs)	Annual Tonnage (10^6 kg/yr)	Range of Costs: Truck Operations[2]	Range of Costs: Road Construction and Maintenance[3]	Range of Costs: Total	Mean Cost: Truck Operations	Mean Cost: Road Construction and Maintenance	Mean Cost: Total
Paved	25	50	70 - 74	420 - 776	490 - 850	72	599	671
		150		141 - 259	211 - 333		200	272
		200		106 - 195	176 - 269		150	222
		500		49 - 88	119 - 162		69	141
		1000		25 - 45	95 - 119		35	107
		2000		13 - 23	83 - 97		18	90
Gravel	15	50	136 - 141	301 - 449	437 - 590	139	375	514
		150		105 - 164	241 - 305		135	274
		200		79 - 133	215 - 274		106	245
Earth	4	50	161	230 - 418	391 - 579	161	324	485

NOTES: 1. All figures expressed as annual costs escalated to 1976 dollars by relative price indices of labor, capital and foreign exchange inputs.

2. Truck size range is 7800 to 23,500 kg. Estimated vehicle life is 600,000 km.

3. Expressed as annual cost at a 10% discount rate. Excludes terminal costs. Ranges of road construction costs per km are:

Paved: \$191,600 - 353,100
Gravel: 119,800 - 187,300
Earth: 36,500 - 66,300

APPENDIX D

METHODOLOGY FOR SOCIOPOLITICAL ANALYSIS

In the earlier phases of this study, applications for advanced air transport technologies were identified which may provide potential future markets for aircraft in developing countries. Systematic economic and technological feasibility analyses were carried out to compare aviation technologies with alternative transport modes in each application.

Although technological and economic feasibility are critical determinants of transportation choices, a variety of additional development objectives will also influence decisions in developing countries. Therefore, a Sociopolitical Analysis was conducted to compare air with alternative transportation modes considering a wider range of factors, including: implementation problems, operational factors, socioeconomic impacts, resource utilization and political considerations.

A planning balance sheet approach was incorporated to compare the sociopolitical impacts of air with alternative transport modes for each of the four primary aircraft applications identified in the study. Using this approach, a set of detailed planning objectives was identified to serve as criteria in evaluating transportation alternatives. Weightings were then specified to indicate the relative importance of each criterion, and alternatives were rated by determining their relative impacts in terms of the various criteria.

Finally, overall comparisons of net benefits were approximated by calculating aggregate ranking scores for alternative transport modes. Aggregate scores represent the sum, for each mode, of ratings assigned on criteria multiplied by weights for the respective criteria.

Individual sets of ratings and net scores were determined to analyze each of the four air technology applications in order to account for differences in the sociopolitical impacts associated with transport modes in different situations. Since the assignment of relative weightings to various planning criteria is necessarily subjective, a sensitivity analysis was performed to determine changes in conclusions that would result from emphasizing particular planning objectives.

As noted above, five general categories of policy objectives were anticipated to influence choices of transportation modes in developing countries. These are: ease of implementation, objectives for transportation systems operations, the degree to which the transportation system advances socioeconomic development goals, resource utilization considerations and political objectives. Specific policy objectives covering both economic and noneconomic considerations were defined as criteria under each policy category. These objectives are itemized in Table D-1. As indicated, specific criteria associated with implementation of transportation plans include minimization of foreign exchange requirements, and maximization of salvage values. In addition, noneconomic factors such as lead time required for construction, the ability to open service expeditiously, possibilities for institutional delays, and requirements for expatriate construction labor are accounted for.

Similarly, criteria defining transport system operation objectives include reliability, safety, and requirements for expatriate operational personnel. Transportation planning objectives related to socioeconomic development cover the generation of employment opportunities in both construction and the operation of transport facilities, the effects of these jobs on upgrading technical skills in the labor force, and the impacts of transportation investments in stimulating secondary industries within the country. Additional socioeconomic benefits are created by transportation facilities in supplying professional, administrative, and emergency services, in providing a means of mobility for the general population, and in establishing a multipurpose network of infrastructure to accommodate long-term economic growth.

Resource utilization issues are curently becoming critical considerations in industrialized countries as well as developing regions. Energy conservation, particularly the minimization of fuel imports, protection of the physical environment, and access to sources of primary materials are identified as specific goals for transportation planning under this category of objectives. Finally, political objectives may represent extremely important determinants of transportation planning decisions in developing countries. Political criteria include national defense, promotion of political stability and national unity, and the contribution of transportation facilities to national pride and prestige.

In carrying out the analysis, weightings were assigned by the study team to indicate the relative importance of the various criteria in Table D-1. A percentage-type weighting system was applied in which the sum of weightings designated for all criteria equalled 100. A positive, nonzero weight was assigned to each criterion so that all objectives were incorporated in comparing alternative transportation modes. Weightings were divided first among groups of objectives and then allocated among specific criteria in each group.

Qualitative ratings for the air mode and the appropriate surface modes in each application were determined by the study team to assess costs and benefits. It should be stressed that the suitability of different transport modes and the degree to which transportation planning objectives are achieved will depend on unique situations and characteristics for any particular application. Thus, precise quantification of costs and benefits for the generalized transportation scenarios under consideration was not possible,

TABLE D-1

PLANNING BALANCE SHEET FORMAT FOR OBJECTIVES

OBJECTIVES	UNITS OF MEASUREMENT	WEIGHTS
IMPLEMENTATION		
Open Service Expeditiously	Months	4
Minimize Foreign Exchang Req'mts.	$	6
Min. Need for Expatriate Labor (Constr)	Person-Years	3
Avoid Instit. Delays at Intern. Level	Prob. of Months	1
Secure High Salvage Value	$ or Equiv.	1
Subtotal		15
OPERATION		
Provide for Maximum Reliability	Prob. Days of Service Interr./yr	7
Provide for Maximum Safety	Anticip. Level of Damage Claims/yr	5
Min. Need for Expatriate Labor (Oper.)	Person - Years	3
Subtotal		15
SOCIO-ECONOMIC DEVELOPMENT		
Create Jobs for Available Work Force		
- In Construction	Person - Years	4
- In Operation/Maint.	No. of permanent jobs	7
Foster Upgrading of Tech. Skills	No. of skilled work trained/yr	5
Provide Reliable & Affordable Means of Mobility for General Popul.	No.Person-Km	5
Provide Fast & Comfortable Means of Mobility for General Population	Time Distance	5
Provide for Emergency Services	Time Distance	4
Encourage Establ. of Secondary Industries	Probability	3
Build-up of a Multipurpose Long-Range Infrastructure Network	Policy Judgment	2
Subtotal		35
RESOURCE UTILIZATION		
Conserve Energy, Part. Imported Fuel	Barrel Equiv/yr	7
Protect Physical Environment	Tons of Emiss./yr	5
Maximize Access to Primary Materials	Policy Judgment	8
Subtotal		20
POLITICAL		
Upgrade National Defense Capability	Policy Judgment	6
Promote Political Stability and National Unity	Policy Judgment	6
Generate National Pride	Policy Judgment	3
Subtotal		15
GRAND TOTAL		100

nor is such specificity likely to contribute additional validity to the comparative analysis. Suitable units of measurement for each criterion are indicated in Table D-1 for purposes of guiding comparisons and establishing a common basis for review. However, sociopolitical impacts were not evaluated quantitatively according to these indicators. Furthermore, the weighting factors in the table were applied universally; i.e., they were not estimated separately for each of the four applications.

In each application, relative ratings with respect to each criterion were estimated on a five-point scale. The best mode was designated a score of five, and ratings for alternatives were assigned according to subjective assessment of their benefits and costs relative to that mode.

Several further assumptions were made in rating alternative transportation modes. First, in all cases the capacity of transportation facilities provided is expected to be sufficient to meet demands. Thus, the comparative effectiveness of alternative transportation modes has been evaluated rather than the suitability or performance of different modes in specific applications. Second, the evaluation process has been carried out from the viewpoint of the national governments in question. These are the prime implementing agencies in developing regions, and transportation services will be established only if they are in the national interest. The objectives of other relevant groups such as local communities, suppliers of equipment and foreign firms operating in the country, while important, are not causative, although they might be considered at a further stage of analysis.

Table D-1 indicates weightings assigned by the study team to the various sociopolitical criteria. Socioeconomic development considerations have been specified as the most important group of objectives, with a combined weighting of 35 out of 100 total points. Resource utilization objectives are given a combined weighting of 15. Implementation, operational, and political factors have been designated the next most important sets of objectives with combined weightings of 15 points each.

Weightings also vary for specific criteria within groups of objectives. Minimization of foreign exchange requirements has been identified as the most important implementation goal, while institutional delays and the salvage values of transportation facilities are allocated relatively low weightings. Reliability and safety considerations predominate in the operational criteria.

In the socioeconomic development category, the creation of jobs, provision of transportation for professional and administrative personnel, emergency services and general population mobility are assigned relatively large weights. Access to sources of primary materials and energy conservation were designated as important resource utilization criteria, as were national defense and unity under political objectives.

APPENDIX E

METHODOLOGY FOR LOW-DENSITY MODE EVALUATION

Description of Methodology

The following is a single approach for an economic evaluation of transportation alternatives for a given application. The approach taken in determining the "optimum" mode is one of minimizing cost in order to meet a demand. Variables used in estimating the present value ("discounted cost") reflect the choice of a particular technology and its costs of operation, and the expected demand and its growth rate for a particular region. The formulation is essentially the same as one presented by DeNeufville and others (Ref. 11), though extended for use in both passenger and cargo applications.

The basic equation is:

$$P_j = I_j + C_j V_o \left(\frac{1 - e^{-(r-g)T}}{r-g} \right) + F_j \left(1 - e^{-rT} \right) = \text{Total Discounted Cost,} \quad (1)$$

where:

V_o = Initial volume of cargo, in tons, for a particular distance

g = Annual growth rate of volume

r = Discount rate, or opportunity cost of capital

P_j = Present value of investment, operating and overhead costs, for technology j

I_j = Investment costs (initial capital costs)

C_j = Unit direct operating costs

F_j = Annual overhead costs (fixed costs)

T = Project period

The total discounted revenue Q would be the present value of each year's volume times the fare per unit of transportation supplied, π_j, or

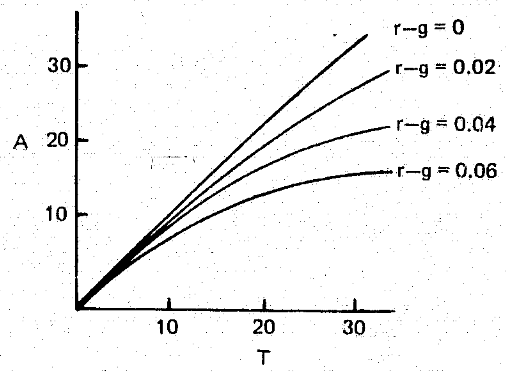
$$Q = \pi_j v^*$$

It can be shown that

$$v^* = \frac{V_o}{r-g} \left(1 - e^{-(r-g)T} \right) = V_o A = \text{Total Discounted Volume} \quad (2)$$

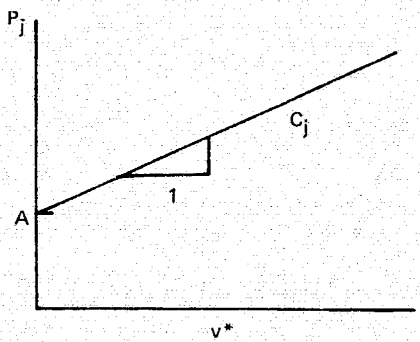
where $$A = \frac{1}{r-g}\left(1 - e^{-(r-g)T}\right) = \text{Factor to convert initial volume to discounted volume, in units of time} \quad (3)$$

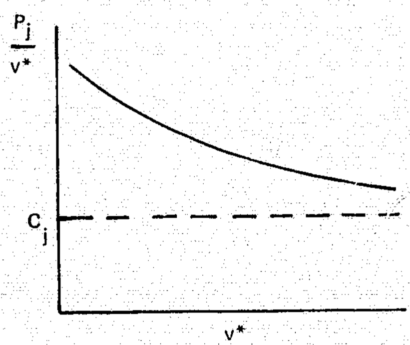
There are several interesting relationships which can be seen. As the discount rate (opportunity cost) increases relative to the growth rate, the discounted volume becomes smaller.



In fact, if $r > g$ and $T \to \infty$, $v_\infty^* = \frac{V_o}{r-g}$

Also, as volume goes up, costs go up proportional to the direct operating cost, but average unit costs go down, as one would expect.





Combining Eq. (1) and (2) the final expression can be simplified to

$$P_j = I_j + C_j v^* + \frac{F_j}{r}\left(1 - e^{-rT}\right)$$

Data Requirements

Discount Rate

The discount rate is the shadow price or opportunity cost of capital, assumed to be 10 percent of analysis. H indicates the time value of money or the competition for alternative uses of the capital among various projects in the economy

Investment Cost

The investment cost is the initial construction cost of a project.

Unit Direct Operating Costs

Unit cost is a uniform cost which accrues irrespective of the volume of transportation. Included are crew, fuel and oil, and maintenance costs, insurance, and depreciation for the vehicle. For the infrastructure, direct maintenance and costs of operation per unit of transportation are included. Vehicle-related costs are considered as direct operating costs, and additional capacity is assumed to occur in a continuous manner; i.e., there is no "lumpiness" in these investments.

Annual Overhead Costs

These costs are fixed annual costs of operation, such as administration and maintenance, not related to the volume of traffic utilizing the facility.

Initial Volume, Annual Growth Rate, Project Life

These estimates correspond to the market scenarios chosen. A range of growth rates was used, depending on the assumption of an optimistic or pessimistic economic scenario.

Implications for Technology Comparison

By entering initial volumes, expected growth rates, opportunity costs, and technological costs (i.e., DOC, investment, and overhead costs), a basis for modal comparison can be made and sensitivity analyses performed. For example, the "optimum" or lower cost mode as a function of total discounted volume can be seen as the following:

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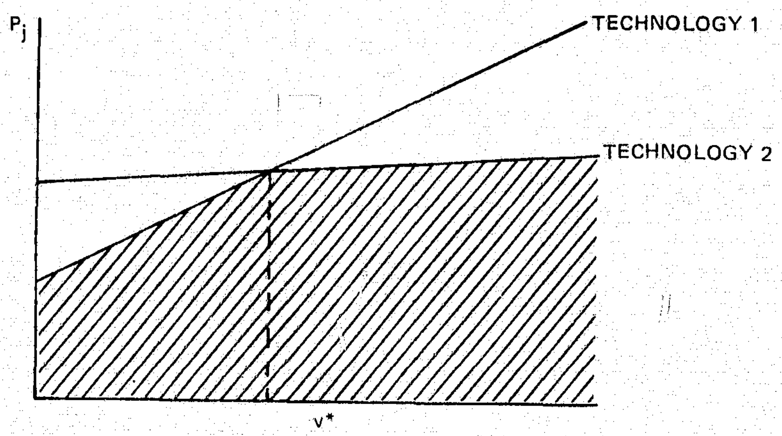


Technology 1 would be preferable under conditions of low volumes, high opportunity cost of capital, and small growth rates. A more capital-intensive system is desirable at lower opportunity costs of capital, higher growth rates, and higher volumes.

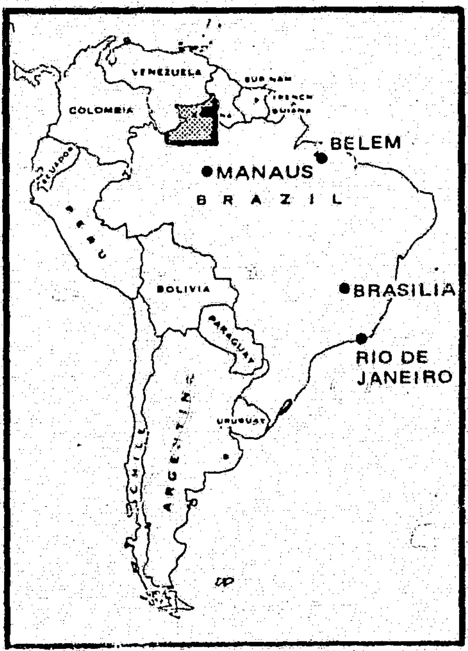
Although this model permits evaluation of air transportation for a specific project, the ability to perform sensitivity analyses makes this a useful tool by which to generalize the results. The model has been formulated for a given distance, but the analysis can be done for several distances to get the technology comparison as a function of distance. Of importance here is the assumption that no additional demand is stimulated which would increase traffic volumes as the quality and level of offered service improve. Of course, development of a transportation infrastructure itself is expected to result in more rapid development of the region, the impacts of which are discussed in the main text in a qualitative way and are reflected by the assumed growth rate.

APPENDIX F

CANDIDATE AIRPORT/INDUSTRIAL CITIES

Boa Vista/Roraima Region

As noted in the accompanying map, the Boa Vista/Roraima region is located in the northern part of Brazil bordering on Venezuela (on the north and west) and Guyana (on the north and east).



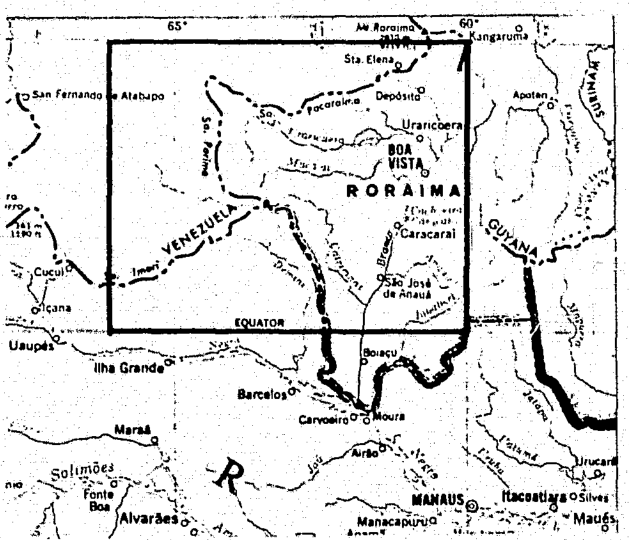
It contains the Roraima "pole", one of 15 priority areas in Brazil's plans for Amazonia. The capital city of Roraima is Boa Vista, with a population estimated at 46,000. Because it is located so close to the border, its airport is identified as an "international" airport, even though the only present scheduled airline service is a one-flight per day B-737 shuttle, on Cruzeiro, between Boa Vista and Manuas, a city having 164,000 population some 600 km to the south.

The major river in Roraima is the Rio Branco which is navigable, from the Rio Negro, to the river port of Caracarai, 120 km south of Boa Vista. According to the publication "Amazonia," the region is given high priority in the Polamazonia plan because of good potential for pasture and farming, though according to Project RADAMBRASIL, a comprehensive aerial survey, very little area suitable for agrigulture exists. The possibility of a meat processing plant is being considered for exporting meat to Venezuela and other countries as well as to other parts of Brazil. Aside from large areas suitable for planted and natural pasturage, the region is highly suitable for the production of timber.

Of the total area in the region (250,740 sq km), a significant portion is planned to be set aside for national parks (87,206 sq km, or 35%) and forests (28,336 sq km, or 11%), and additional land is set aside for the preservation of flora and fauna (16,568 sq km, or 6.6%). Half of the total area, including some of that in the above preserves, is protected for ecological conditions or is classified as area for utilization subject to specific studies. Consequently something less than half of the area will be available for development.

Some mineral resources exist in the ar a, though the occurrence is not as wide-spread as in other regions (Tapajos, for example). Noted on the geological map are deposits of titanium, zircon, niobium, manganese, tantalum, thorium, copper, bauxite, molybdenum, and iron. A few abandoned diamond, silver, and gold mines dot the area north of Boa Vista. Generally, the topography is flat or gently rolling along the major rivers, but becomes hilly and mountainous in the north and west approaching the borders with Guyana and Venezuela.

A possible location for an airport city is in the immediate vicinity of Boa Vista in the northeastern quadrant of the Roraima planning area. Boa Vista is located on the Rio Branco and is at the intersection roads heading east toward the Guyana border, heading north to the Venezuelan border, and south and west to connect with planned roadways into the neighboring State of Amazonas. Primary transportation is by roads and shallow-draft rivercraft south to the river port of Caracarai, and then by water via the navigable portion of the Rio Negro. The Rio Negro is a major waterway, wider in that region than the Amazon, which joins the Amazon at the city of Manaus. The surface distance between Boa Vista and Manaus is over 800 km, as compared with a 600 km air distance. There is a stretch of rapids (Cachoeira Caracarai) in the Rio Branco about 100 km south of Boa Vista which restricts river travel to shallow-draft boats and which may impede conventional river transportation, though the possibility exists that the passage may be improved by dredging a deep water channel. However, Boa Vista would appear to be an ideal location for river access by surface-effect craft because the river is over a kilometer wide for much of its length and the rapids could easily be traversed by such vehicles.



Should the existing shallow-draft limitation on river travel impose a severe impediment to the development of Boa Vista as an airport city, an equally suitable location would be at Caracarai. Both cities have flat, only moderately valuable pasture land close at hand of suitable size, and without apparent legal restrictions. It could be possible to develop an airport city on the order of 6 by 10 km in dimension, a size quite suitable to provide the buffer zone required of an airport city located in a sparsely settled region typical of interior Brazil.

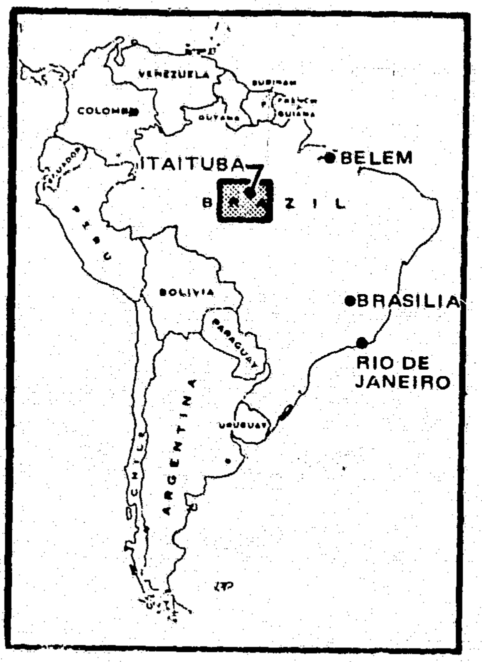
Of the two locations, Boa Vista is preferred for its proximity to good cattle-raising country and the development of a meat packing industry, and Caracarai is preferred for its proximity to timber country and the development of a lumber industry. Either is well located for exploiting the mineral resources of the area.

Since the two sites are only 120 km apart, a choice of the precise location for an airport city is not critical at this point. They both enjoy a remoteness and lack of transportation infrastructure desirable for the development of an airport city, and both have rich, exploitable resources close at hand. Typical air distances and travel times to logical markets (or transshipment points) for products originating in Roraima are shown in the following table.

TRANSPORTATION ALTERNATIVES FROM RORAIMA/BOA VISTA

Market	Approx. Population	By Air Distance	By Air Time	By Surface Approx. Time
Belem, Brazil	850K	1500 km	2 hrs	10 days
Brasilia, Brazil	1.2 million	2500	3	13
Rio de Janiero, Brazil	5 million	3500	4+	20
Cayenne, Fr. Gu.	35K	900	1+	12
Paramaribo, Surinam	300K	700	1-	13+
Georgetown, Guyana	400K	525	40 min	14
Caracas, Ven.	1.5 million	1100	1.4 hrs	17
Maracaibo, Ven.	1 million	1500	2	18
Bogota, Col.	2 million	1500	2	20
Guayaquil, Ecu.	1 million	2300	3	25
Lima, Peru	1 million	2500	3	27
LaPaz, Bolivia	800K	2300	3-	29
Ascuncion, Par.	600K	3150	4	28
Santiago, Chile	1 million	4200	5-1/4	34
Buenos Aires, Arg.	4.5 million	4200	5-1/4	25
Montevideo, Ur.	1.4 million	4200	5-1/4	25
Miami, Fla.	-----	3400	4-1/4	22

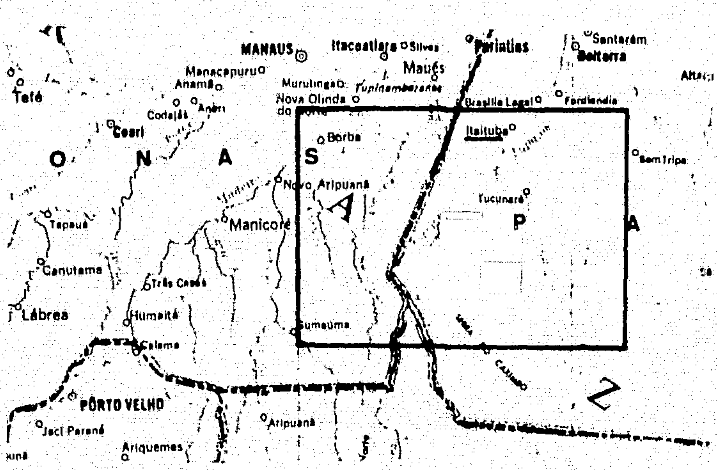
Tapajos Region



As noted on the accompanying map, the Tapajos region is located in the northern part of Brazil, partly in the states of Amazonas and Para. The region is traversed by the Transamazonian Highway, which in that region is an improved gravel road, and contains many rivers, the largest of which is the Rio Tapajos, a wide, partly navigable river which empties into the Amazon to the North. The largest "city" in the region is Itaituba, with a population of about 2500. The city has an airport but, presently, no scheduled air service.

The region is characterized by a wide variety of resources, particularly timber, but also has significant area suitable for planted pasturage. Considerable acreage is suitable for farming, and a wide variety of mineral resources are found in the area, with seemingly heavy deposits of gold, tin, niobium, tantalum, and topaz, and considerable iron and manganese. Aiding in the development of the area will be a planned Curua-Una hydroelectric plant generating 20 megawatts located just to the north of the Tapajos region.

Very little of the area is set aside for national forests (well under 1 percent), and areas whose use is restricted for protection of the eco-system represent only 10 percent of the total. Some 34 percent of the area is designated as area whose use is subject to specific studies. Consequently, the area is largely open for development, particularly by comparison with other planning regions in Polamazonia.



Probably the most appropriate location for an airport city is at Itaituba near the northern boundary of the region (in the State of Para) which is located at the furthest reach of the navigable portion of the Tapajos River. It is located on the Transamazonian Highway which heads north and east toward the populated regions of northern Brazil and south and west toward the interior of Amazonas. It is located about 1200 km, by river, (900 km by air) from the major port city of Belem, the capital of Para.

Just adjacent to the city of Itaituba is a flat, heavily wooded area which could easily be cleared for the required area needed for the airport city. The area is on the Transamazonian Highway and can be made to border the banks of the Rio Tapajos. Surrounding the region is good farming country (to the south and east) and heavily timbered land suitable for immediate timber production. Also in the immediate vicinity is considerable area suitable for planted pasturage. No large deposits of exploitable minerals are located in the immediate vicinity of Itaituba , but heavy deposits of virtually all other minerals are located not far away.

An interesting possibility for the region is the use of air-cushion barges to supply, by river, the raw material needs of an airport city located at Itaituba. The river, which south and west of Itaituba is characterized by many rapids restricting its use by conventional craft, is very wide (several kilometers, in places). The rapids should be easily negotiated by air-cushion vehicles of the SRN-4 size and larger. The river traverses the parts of the region which are most heavily endowed with mineral wealth, as well as vast areas of timber. The Tapajos River is also fed by many small rivers and tributaries whose banks provide large areas well-suited for farming.

The town of Jacareacanga, some 300 km along the river (and highway, which parallels the river in this region) to the southwest, would be an ideal location for an outlying base for air-cushion vehicle operations. Vast quantities of resources could be brought overland or up and down the rivers by conventional transport for consolidation and subsequent ACV transport from Jacareacanga to the airport city at Itaituba. As the region around Jacareacanga becomes depleted of resources, the ACV outpost could be moved further south into regions of equally heavy resources.

As in the case of Roraima/Boa Vista, the remoteness of Itaituba, in terms of conventional transport, offers powerful leverage for the use of air transport. While Itaituba is somewhat closer to the port city of Belem, by river (a six-day rather than a ten-day trip), the relative times, by air and surface, to possible markets for Itaituba airport city products is still overwhelmingly favorable to air transport. The following abbreviated table illustrates the point.

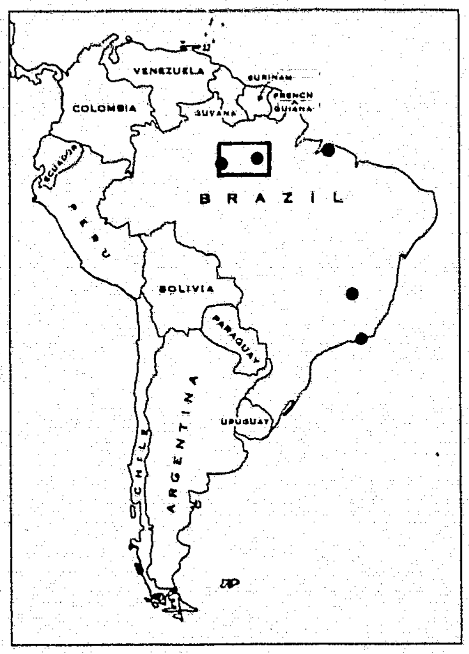
TRANSPORTATION ALTERNATIVES FROM ITAITUBA

Market	By Air Distance	By Air Time	By Surface Approx. Time
Belem	900 km	1.1 hrs	6 days
Brasilia	1600	2.0	9
Rio de Janiero	2400	3.0	16
Paramaribo	1100	1.4	9
Georgetown	1200	1.5	10
Caracas	2000	2.5	13
Maracaibo	2400	3.0	14
Bogota	2200	2.8	16
Quayaquil	2600	3.3	21
Lima	2400	3.0	23
La Paz	1900	2.4	25
Ascuncion	2250	2.9	24
Santiago	3500	4.5	30
Buenos Aires	3300	4.2	21
Montevideo	3300	4.2	21
Miami	4300	5.5	18

In terms of its suitability as a site for an airport city, the Tapajos region meets all the criteria established in the previous discussion of the Roraima/Boa Vista region, but even more so. Tapajos has the same resources but, in the case of timber and minerals, far greater potential. While its cattle-producing potential is somewhat less, its farming potential is much greater. This factor has great significance because not only does the potential exist for the export of agricultural products (air transportable even by U.S. standards -- witness the San Joaquin, California experience) but the existence of locally grown produce is an important benefit for sustaining the airport city, itself. Not only does it not have to import agricultural products, but it can provide employment to farmers and all of the needed occupations employed in the food production and food retail businesses.

While the unit value of fresh, frozen, and chilled vegetables imported from Latin America is low in comparison with other products (36 ¢/lb), air transportability is high (12%) because of the perishable nature of the commodity. A mineral commodity which apparently exists in Tapajos is silver. Its unit value, in partly worked condition, is about $64/lb and over 90 percent is transported by air.

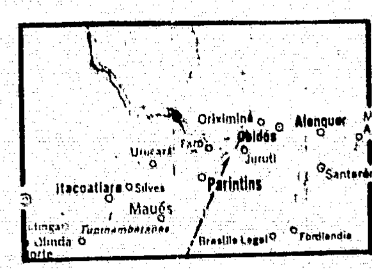
Santarem Region



The accompanying map shows the Santarem Region in central Amazonia, in north central Brazil, adjoining and just north of the Tapajos Region described in the previous section. The Santarem Region lies just west of the Belem Region along the Amazon River. The northern boundary of the region is in the Equator.

The major city in the Santarem Region is Manaus, located on the western edge of the region, with a population of about 450,000. Manauns, an important city during the rubber-exporting boom in the early 1900s, has extensive air service to all major cities in South and Central America and even has direct flights to Miami, Los Angeles, Tokyo and Paris, with connecting service to other cities in the U.S. and Europe.

Another city of significant size is Santarem, located on the Eastern edge of the region, with a population of about 140,000. Santarem also has significant air service, using B737s, to other cities in Brazil.



Both cities are on the Amazon River, Santarem being at the confluence of the Amazon and Tapajos Rivers. The cities are separated by about 720 km along the river, and are about 600 km apart by air.

Although this region is relatively close to the more populous northern coastal region of Brazil (970 km, by river, from Belem), it is still remote in terms of modern surface transportation. Except for dead-ended roads connecting cities or towns within the interior (Santarem does have a road connection with the Transamazon Highway some 230 km to the south), surface travel is strictly by water. As with the majority of interior Brazil, it is virtually undeveloped.

The Santarem region is amply endowed with resources, the dominant resource appearing to be timber, but with significant pasture land and farming country. There are large deposits of bauxite and smaller occurrences of limestone, tin, iron, gypsum, and titanium, and a deposit of rock salt at Aveiro. By comparison with Roraima and Tapajos, the Santarem region is remarkably free of restrictions as to use of the land. Of the 295,160 km^2 in the region, less than 2 percent is limited for ecological reasons, and only about 3 percent is intended for use as national parks and forests.

While both Manaus and Santarem are good candidates for the location of an airport/industrial city, Santarem appears to have somewhat higher qualifications, notable among which is the location of the Curua-Una hydroelectric plant just 70 km away. The availability of electric power plus the heavy deposits of bauxite within 200 and 300 km, by river, suggest an aluminum-based industrial development. Together with the timber and cattle resources similar to other regions studied, a significant potential exists for rapid regional devlopment through the excellent transportation offered by an air-centered system. Excellent river transportation for the raw materials which could be processed at a Santarem airport/industrial city is provided by the Amazon which extends west to Manaus (720 km away) and beyond, into the State of Amazonas, by the Rio Negro west of Manaus, and by the Tapajos River which is navigable to the city of Itaituba, 300 km to the south. As discussed earlier, further access to resources could be achieved by use of air cushion barges operating over normally nonnavigable portions of the Tapajos River south of Itaituba, on the Rio Branco in the Roraima region, and on other tributaries of the Amazon.

According to the regional plan, the Santarem region contains the Trombetas Pole, one of the 15 priority areas in Brazil's plans for Amazonia. The area just north of the city of Santarem, across the Amazon River, has been proposed for cultivation, with particularly good potential for the growing of rice, corn, cocoa, coffee, dwarf mallow, cassava, beans, pepper and rubber. The flatland bordering the Amazon throughout its course through the region has been recommended for growing rice, beans, jute, dwarf mallow, and corn. Areas further away from the river, embodying some 30 percent of the area of the entire region, have been recommended for cocoa, guarana, pepper and rubber. These areas are particularly suited to timber production, with yields of 100 to 140 cubic meters per hectare. In all of these areas, cattle raising is practical as well. Beyond these areas bordering the Amazon, agricultural and forestry utilization is not recommended, though almost the entire region is heavily forested, with mineral deposits or possible deposits throughout the region.

Selection of Site for Airport/Industrial City

While any of the three regions studied in detail offer good potential for the siting of an airport/industrial city, the Santarem site just discussed has been chosen, primarily for its high potential for the production of aluminum and high-value-added products which can be produced in it. Because of the extensive forests and range land in the immediate area, good potential also exists for the timber and livestock industries. While it is the least remote of any of the interior Amazonian regions, the lack of a transportation infrastructure indicates the potential success of an air-centered system which is the basis of the airport city concept.

Although Santarem has been chosen as a case-study location, the good potential of the other regions studied (and the probable potential of other interior regions not studied) indicates that a good possibility exists for the creation of other A/I cities in Brazil and other LDCs if the case study indicates a probability of success. A detailed study of the Santarem A/I city is given in the main text of this report.

APPENDIX G

AIRCRAFT INDUSTRIES IN DEVELOPING COUNTRIES

A brief survey of the airplane industry in developing countries was made to identify those countries with a significant airplane industry and the types of airplanes being produced. Excluding the countries of Western and Eastern Europe, North America, Australia, and Japan, the six countries include: Brazil, Argentina, India, Israel, Mexico, and Spain. The classes of airplanes being produced in these countries are: 2-4 passenger, light airplanes; agricultural airplanes; utility transports; and fighter and attack military airplanes. Of the six countries, India, Israel, and Spain have the most developed airplane industries, manufacturing, under license, various types of advanced military fighter and attack airplanes, as well as components for large commercial transports.

The airplane industries of Argentina and Brazil employ about 3500 people each. The more-developed industry of Israel employs 17,000 people, India 38,000 people, and Spain about 8000 people.

In this survey, stress was placed on airplanes of indigenous design used for transportation purposes. A summary of the characteristics of various light, utility transports designed and manufactured in LDCs is provided in Table G-1. The type of utility transport produced by developing countries is a multipurpose airplane. Its uses include civilian and military transportation of both passengers and cargo, medical evacuation, agricultural development, exploration and mapping. Basic to the performance of these airplanes is the ability to operate from short, unprepared fields with lengths between 300 and 900 m. Ease of maintenance and minimal dependence on airport ground facilities are also design requirements.

The Fabrica Militar de Aviones (Military Aircraft Factory, FMA) of Argentina designed and built the IA 50GII to meet Argentine Air Force (AAF) specifications for a twin-turboprop, multipurpose airplane to serve as a troop carrier, photographic and survey airplane, and executive transport. The first two went into service with the AAF in 1967 and a total of 41 airplanes were produced.

EMBRAER of Brazil, wich was created as a state-owned industry in 1969, has also designed a twin-turboprop, light transport, the EMB-110 Bandeirante (Pioneer), of similar size and performance as the FMA IA 50GII. The EMB-110 was tested to Federal Air Regulations (FAR-23) specifications and the first three were delivered to the Brazilian Air Force in February 1973. By December 1976, 150 Bandeirantes had been sold, including export order from

TABLE G-1

LIGHT UTILITY TRANSPORTS DEVELOPED IN LDCs

Country	ARGENTINA	BRAZIL		ISRAEL	SPAIN
Manufacturer	FMA	EMBRAER		IAI	CASA
Airplane Designation	IA 50G11	EMB-110	EMB-120	IAI-201	C.212
Name	-	-	-	Arava	Aviocar
Max Gross Weight, kg	7200	5600	7000	6800	6300
Empty Weight, kg	3925	3380	4200	4000	3900
Payload, kg	1500	-	-	2350	2000
Passengers	15	15	24	24	16
Engine Number and Type	(2) Turboprops	(2) Turboprops	(2) Turboprops	(2) Turboprops	(2) Turboprops
Manufacturer	Turbomeca	P&WACL	P&WACL	P&WACL	AiResearch
Designation	Baston VIA	PT6A-27	PT6A-45	PT6A-34	TPE 331-5-251C
Rating, 10^3 m-kg/sec	70.7	51.7	85.2	57.0	59.0
Max Cruise Speed, km/hr	500	434	484	326	360
Takeoff Distance to 15m, m	670	539	539	360	484
Landing Distance from 15m, m	600	680	700	283	385
Number Ordered	41	129	-	34	92
Number Produced	41	44	-	23	30
Production rate/mo	-	4	-	3	4
Countries Where in Use:					
Argentina	41	-	-	-	-
Bolivia	-	-	-	6	-
Ecuador	-	-	-	10	-
Mexico	-	-	-	5	-
Nicaragua	-	-	-	1	-
El Salvador	-	-	-	2	-
Israel	-	-	-	3	-
Brazil	-	129	-		-
Indonesia	-	-	-	-	6
Jordan	-	-	-	-	4
Portugal	-	-	-	-	28
Spain	-	-	-	-	42
Venezuela	-	-	-	-	12

Chile and Uruguay. A stretched, pressurized version of the Bandeirante (EMB-120), with 24 seats and the more powerful PT6A-45 engines, has also been designed. In addition to its own designs, EMBRAER has also built over 450 light single and twin Piper aircraft under license, and has built 100 MB.326 GB jet trainers under license from Macchi.

The Israeli IAI-101 Arava, developed by Israel Aircraft Industries LTD (IAI), was designed to fulfill tne need for a twin-turboprop, light transport with short-field takeoff and landing (STOL) performance and rough-field landing capabilities. Design work started in 1966 and a type certificate was issued in April 1972. By the end of 1975, 34 Aravas were on order and the production rate was 3 per month.

The Spanish Air Force also developed a twin-turboprop, light utility STOL transport to fulfill a variety of military and civil roles, but primarily to replace older transports such as the Douglas DC-3. The Spanish airplane is built by Construcciones Aeronauticas SA (CASA) and has the designation C.212 Aviocar. The Aviocar is able to fill six main roles: 16-seat paratroop transport, freighter, ambulance, photographic aircraft, crew trainer, and 19-seat passenger transport. The airplane has STOL capability that enables it to use unprepared landing fields of about 400 m in length, and has been designed for operations in remote areas with little or no support facilities. All these airplanes are examples of the utility airplanes being produced in quantity by developing countries. However, most of the utility transports currently in use in LDCs were manufactured in the developed world. The list of airplanes in use includes: Britten-Norman BN-2A Islander (in use in over 80 countries); Short Skyvan and SD3-30; the deHaviland Aircraft of Canada DHC-6 Twin Otter (in use in over 36 countries), and the DHC-5 Buffalo; and the Swiss-designed and built Pilatus Porter PC-6.

Implications for US Manufacturers

Although aircraft manufacture is regarded as a significant step in the development of technological skills, there are definite limits to such ventures in LDCs. The aircraft programs which all but the most advanced LDCs can realistically undertake, are confined to relatively small aircraft, and the highest-technology components (engines and avionics) must be imported from the developed world. These restrictions are not likely to change in the immediate future. Transport aircraft up to about the 50-passenger size may be feasible for LDCs, but manufacture of large aircraft is probably decades off. Also, when a country's technological infrastructure has evolved to the point where development of a large transport airplane can be undertaken (on other than a licensed production basis), it can be argued that the country is no longer a member of the "developing-nation" group. Hence, competition by LDCs in the large transport airplane field, and in the development and manufacture of aircraft engines, is not a near-term threat to the US aircraft industry.

Relating these arguments to the airplane applications described in the main text, it appears that at least the requirements of the general aviation applications (emergency relief, exploration and mapping, technical assistance) and the low-density passenger transport market could be fulfilled by LDC manufacturers. Not all LDCs will compete in this market, but the ones that do (Brazil, Spain, India, etc.) would be the major markets for US manufacturers. Therefore, it appears that this light aircraft market could be a risky one for direct competition with LDCs (except for engines and avionics) unless licensing agreements for LDC production are accepted as the standard. Even then, the long-term outlook is questionable.

BIBLIOGRAPHY

1. Abouchar, A.: Systematic Influences on The Transport Sector: A Comparative Analysis of Yugoslavia and Brazil. Association of Comparative Economic Studies Bulletin, 14:1-8, Winter 1972-73.

2. Acevedo, J. E.: Comparison of Air and Ground Transportation in Developing Countries. Civil Engineer Thesis, M.I.T. Dept. of Civil Engineering, February 1971.

   This thesis presents and analysis of an underdeveloped region in Colombia. Indicators of economic development are chosen and differences in development trends between subregions partially explained by differences in transport services. Transport modes are represented by user costs and benefits assessed by reduction in these costs and improvements in economic indicators. Air and roadway costs are shown and trade-offs discussed.

3. Adler, H. A.: Sector and Project Planning in Transportation. International Bank For Reconstruction and Development, World Bank Staff Occasional Paper No. 4, 1967.

4. Adler, H. A.: Economic Appraisal of Transport Projects: A Manual with Case Studies. Indiana University Press, Bloomington, 1971.

5. Agency for International Development: A.I.D. Research Abstracts. Volume 1, Number 2, AID Reference Center, Washington, D. C., PB 226163, October 1973.

   The A.I.D. Research Abstracts Quarterly describes current research documents of interest to scholars, planners, and scientific investigators around the world. It is hoped that the distribution of this information about important new knowledge will stimulate an exchange of ideas and papers between scholars and planners in developing countries and those in developed countries.

6. Agency for International Development: Science and Technology for International Development: A Selected List of Information Sources in the United States. Office of Science and Technology, Washington, D. C., TA/OST/72-7, March 1972, NTIS PB 210104.

   This very useful report presents a list of libraries and other organizations which have relatively complete and comprehensive holdings of publications pertaining to science and technology in LDC's. For each of these organizations, information is provided concerning the nature and strength of the collections, publications issued, information services provided, and the individual to contact for further assistance. AID-related reports are listed, as well as those by various other international and regional organizations. Included are references on the resource potential of LDC's.

BIBLIOGRAPHY (Cont'd)

7. Agency for International Development. Science, Technology, and Development. Volume V. Transportation. PB 207498, 1962

Volume 5 of a twelve volume series on science and technology in developing countries, includes the following papers: General, social, political, and economic factors in relation to transport for less developed areas; strategy planning for transportation; Transportation in large metropolitan centers, The urban passenger transportation problem; Highway planning and programming; Phase building of railroads and equipment; Air cargo transport feeder operations; Movement by pipeline; Harbors, marine terminals and waterways; Integration of overseas and domestic transportation; New techniques for temperature control of perishable goods in transport and storage; Scientific research for future transportation; and Earth sciences and modern transportation.

8. Agency for International Development. The Application of Geochemical, Botanical, Geophysical and Remote Sensing Mineral Prospecting Techniques to Tropical Areas (State of the Art and Research Priorities). Washington, D. C., NTIS, PB 213230.

9. Aircraft Manufacturing in the Developing Nations. Interavia, December 1976.

10. Alamuddin, N.: The Problems and Prospects for Air Transport - Third World View. Arab Wings, July-August 1974.

Air transport in the Third World shares many of the same problems as the world at large. In addition, there is a shortage of human resources, in the form of technical and managerial skills. A shortage of financial capital persists, and the lack of an adequate infra-structure. Legislation and air agreements ignore or disfavor developing countries. Finally, a small domestic market and the small size of airplanes hampers growth.

11. Alamuddin, N.: A Look at Airlines and the Third World. Air Transport World, September 1974.

See previous article by the same author.

12. Allen, W. B.: Assessing the Benefits of Transport Investment in a Developing Nation. Transportation Research Forum - 10th Annual Meeting, October 23-24-25, 1969.

BIBLIOGRAPHY (Cont'd)

This paper studies transport investment in the context of the whole economy. The effect of transportation on the production possibility frontier is analyzed, for three types of productive processes. The chief port producing services, the hinterland producing the export good, and both sectors producing overland transport services for the movement of the export goods from hinterland to port.

13. Amazonia is Developing in Every Direction. Brazilian Bulletin. August 1974.

14. Another New DC-3. Flight International, 24 July 1976.

The TAMCO (Turbo Airliner Manufacturing Company) Turbo-Commuter is the latest attempt to update the Douglas DC-3, and is aimed at US commuter carriers and third world carriers -- its undercarriage is seen as better for undeveloped fields.

15. Arata, W. H., Jr.: Planning Airports to Serve Air Transportation in Underdeveloped and Emerging Nations. American Institute of Astronautics and Aeronautics, Paper 7-1268, 1970.

16. Asebe, E.: A Basis for Transportation Network Planning Decisions in Ethiopia. M.S. Thesis in Transportation, Northwestern University, 1972.

17. Avianca Hurdles Colombia's Terrain, and Problems, to 51-Year Success. Air Transport World, August 1970.

18. Bar-Zakay, S. N.: Technology Transfer Model. Technological Forecasting and Social Change. Vol. 2, 1971.

This summary of a RAND report presents a model of technology transfer, similar to a PERT technique. It concludes that both donor and recipient must have considerable analytic capabilities for successful technology transfer, and that the assessment must be performed by the developing countries themselves.

19. Baranson, J.: Industrial Techniques for Developing Countries. Frederick A. Praeger, New York, 1969.

This book is a collection of essays relevant to the design and transfer of appropriate technology for new industrializing economies. It not only deals with the need for creative technology to fit local needs, but also the importance of marketing and manufacturing arrangements associated with various scales and techniques of production. Various equipment and products for developing economies are discussed, including airplanes. More detailed analysis is made of the automotive sector and resource-based processing industries.

BIBLIOGRAPHY (Cont'd)

20. Baranson, J.: Technology for Underdeveloped Areas: An Annotated Bibliography. Pergamon Press, New York, 1967.

21. Beier, G. J. and G. C. Hidalgo: Roles for Airships in Economic Development. Proceedings of Conference on Lighter Than Air Technology. MIT, 1976.

22. Bell, M. A. M., et al.: Impact of Harvesting of Forest Environment and Resources. Canadian Forestry Service.

23. Bhalla, B. K., N. Svanqvist: Optimizing Lo[illegible]ing Costs. Government of India and VNDP/FAO Logging Training Repo[illegible], 1968.

24. Bickers, D. H.: Financing Transport Projects in Developing Countries. Chartered Institute Transport Journal, 37:159-65, September 1976.

25. Bonney, R. S. P.: Transportation in Rural Areas. Ekistics, January 1970.

    This paper briefly describes the British Road Research Laboratory's study of African roadway's costs and induced benefits of roads in regional development.

26. Bovy, P. H. and R. A. Gakenheimer: Urbanization and Urban Transport Planning in Developing Countries: A Selected Bibliography. Council of Planning Librarians Exchange Bibliography No. 895, October 1975.

    A bibliography in 3 major sections: Part A - Transportation and Development: Deals primarily with transport on a national and regional scale. Part B - Urban Transportation Planning: Topical organization by 11 major subject areas including a listing of major urban transportation planning studies, by country. Part C - Transportation Information Sources: Lists the most readily available sources of a statistical and bibliographical nature, including periodicals.

27. Brazil Builds Multinational Dam. Daily Press, Newport News, VA., September 6, 1976.

    Discusses economic and resource development of the Plata Basin in Uraguay, Paraguay, northeastern Argentina, eastern Bolivia, and southern Brazil, as influenced by the Itaipu hydroelectric project.

28. Britton, F.: Alternative Transportation Technologies for Developing Countries. OECD, Paris, 1973.

29. Brown, R. T.: Transport and the Economic Integration of South America. Brookings Institution, Washington, D. C., 1966.

BIBLIOGRAPHY (Cont'd)

This book discusses the role of the transport planner in the economic progress of the continent. It contains a geographic description of the regions of S. America, the intra-South American trade and transport, the resources and the population and income patterns. Shipping policies as a means of economic integration of LAFTA regions are discussed, with some mention of other modes of transport. The book contains much useful factual information about the continent, although somewhat dated.

30. California University, Berkeley: Opportunities for Cost Reduction in the Design of Transport Facilities for Developing Regions. Inst. of Transportation and Traffic Engineering. PB 207502, 1970.

The document provides the results of an examination of traditional designs of transport facilities in the developing countries with a view to reducing total initial and/or operating costs, or to reducing costs devoted to the imported elements. The topics include: road cost analysis and design standards; road construction cost model; and road maintenance cost model: opportunities for cost savings in highway engineering design; economics of one-way bridging; potential cost savings in the design of water crossings; potential cost savings in the design and use of ground vehicles; opportunities for cost reductions in aircraft, airways, and airports; potential cost-savings in the selection of waterway and harbor techniques; harbors and associated facilities; economic models for choice of transport techniques in developing countries; tradeoffs between construction costs and maintenance costs.

31. California University, Berkeley: Opportunities for Cost Reduction in the Design of Transport Facilities for Developing Regions. Volume 1, Inst. of Transportation and Traffic Engineering. PB 195597, March 1970.

The study explores the problem of the selection of low cost technologies for provision of transportation in developing countries. It surveys the range of technologies that might be used, investigates analytical approaches and suggests bases for selecting among resource and cost alternatives. Volume I discusses at length various problems relating to technologic choice in the field of road transport. Among the problems treated are the development of cost functions, design standards, pavement type, water crossings one-lane bridging and vehicle types. Statistical tables, graphics, and lists of references appear at the end of the chapter when appropriate.

32. California University, Berkeley: Opportunities for Cost Reduction in the Design of Transport Facilities for Developing Regions. Volume 2. Inst. of Transportation and Traffic Engineering. PB 195598, March 1970.

BIBLIOGRAPHY (Cont'd)

The chapters comprising the second of two volumes discuss potential cost savings in the design and use of ground vehicles: reduction of cost in aircraft, airports and airways; savings in the selection of waterway and harbor techniques; and economic models for the choice of levels of transport investment.

33. California University, Berkeley: Opportunities for Cost Reduction in the Design of Transport Facilities for Developing Regions. Annex to Volumes 1 and 2. Inst. of Transportation and Traffic Engineering. PB 198035, December 1970.

The annex is a supplement to a study that examines designs of transport facilities in the developing countries with a view toward reducing initial and/or operating costs, or to reducing costs devoted to imported elements. For the annex, research is focused on economic and engineering aspects of low cost road construction. A production-function based model is developed for road maintenance cost estimation. Surface maintenance is considered in detail. Principal variables included are time, climate, and traffic volume. Another section of the annex contains a discussion of tradeoffs between construction costs and maintenance costs.

34. Caterpillar Performance Handbook. Caterpillar Tractor Company, October 1976.

35. Campbell, T.: Transportation in Developing Countries: Special Reference to Kenya. Traffic Quarterly, Vol. 28, March 1974.

This paper presents a general summary of transport planning in developing countries. The role of transportation and a historical perspective is given, with examples drawn from Kenya. 36. Campbell, T. C.: Transport and Its Impact in Developing Countries. Transportation Journal. 12:15-22, Fall 1972.

36. Campbell, T. C.: Transport and Its Impact in Developing Countries. Transportation Journal. 12:15-22, Fall 1972.

37. Carlson, P. R.: Application of Air Cargo Transport to Feeder Operations in Less Developed Areas. Transportation. (no date).

38. Cocorda, C.: Monographs on Various Countries. ITA Bulletin, September 24, 1973.

General economic and air transport data available from ITA, with Gabon as an example.

BIBLIOGRAPHY (Cont'd)

39. Colaco,.F. X.: Economic and Political Considerations and the Flow of Official Resources to Developing Countries. Development Center, OECD, Paris, 1973.

This report examines the assistance efforts of developed countries in the 60's. Statistical tests are made, comparing external aid and a country's domestic price inflation, budgetary and balance-of-payments difficulties.

40. Cornell University, Ithaca, N.Y.: The Natural Resource Potential for Regional Development of Limon Province: A Preliminary Survey. Program on Policies for Science and Technology in Developing Nations. PB226621, October 1973.

The study is part of a larger study to understand the appropriate role of science and technology in the development of a small country like Costa Rica. The Limon Survey may be described as a broad-brush survey of the natural resources existing in the region. This effort comprised gathering data relevant to the survey, evaluating the data, and suggesting studies for formulating policies for regional development. The study was made by a team from Cornell University in cooperation with Costa Rican consultants.

41. Coughlin, S.: The Application of the Airship to Regions Lacking in Transport Infrastructure. Proceedings of Conference on Lighter than Air Technology. MIT, 1976.

42. Dancak, M.: Economics of Air Transport in Developing Nations. ICAO Bulletin, February 1972.

This article argues that air services are more susceptible to rapid development than other modes, but that they cannot always be operated on a profitable basis, especially to remote areas. Except where tourism has developed, demand for air transport is inelastic, since it is mainly connected with public or private business.

43. Davis, H. E.: Opportunities for Cost Reduction in the Design of Transport Facilities For Developing Regions. University of California, Berkeley, Inst. of Transportation and Traffic Engineering, 1970.

44. de Neufville, R., J. Hoffmeister, and D. Shpilberg: Investment Strategies for Developing Areas: Models of Transport. Massachusetts Inst. of Tech., Cambridge Dept. of Civil Engineering, PB219292, January 1973.

BIBLIOGRAPHY (Cont'd)

The basic objective of the present study is to support Department of Transportation activities in advising developing countries on transport infrastructure improvements. Models of air, river and highway transportation are developed for use in the comparison of alternative investment strategies in transportation for developing areas. The work performed under this contract was executed simultaneously with a parallel contract (DOT-05 00080). The results, however, are presented here. For a full exposition, both reports would be considered jointly.

45. Department of the Army, Washington, D. C.: Africa: A Bibliographic Survey of Literature. PB787465, 1973.

Like the previous volume of the subject (DA PAM 550-5) which was issued in April 1967, the new edition endeavors to assess the problems and prospects in the vast continent. The difficulties and accomplishments are looked at from both a broad, regional point of view, as well as from a specific, national point of view. The work includes data on the strategic importance of Africa as a continent, and also provides facts and figures on the political, sociological, economic, and military aspects that contribute to the viability of individual African states. More than four thousand books, periodical articles, and monographs were searched in the preparation of this work. The body of material is supported by 91 appendixes and 53 maps, of which 18 are in color.

46. Desmas, G.: The Transport System as the Key to Development in Nigeria. Insititut du Transport Aerien, Paris, 1975, Report No. 1975/Z-E.

47. Doctors, S. I.: The NASA Technology Transfer Program: An Evaluation of the Dissemination System, Praeger Publishers, New York, 1971.

This study forms the second part of a larger research effort concerning the federal role in technology transfer. Its purpose is to determine the relative effectiveness of the NASA system of dissemination of technical documents to fee-paying industrial clients. Results of a field study are given to assess the merits of this horizontal transfer system. It concludes that more research is needed with the transfer process and that the existing program has not been particularly successful.

48. Drake, G. L., and J. E. Traylor: Thailand Transportation Coordination Study. Volume I, Wilbur Smith/Lyon Associates, Bangkok (Thailand), PB 210326, June 1, 1970.

Thailand has a rapidly expanding ecomony and has had an even more rapid growth of its transportation resources. The report provides an assessment of the efficiency with which the present transport

BIBLIOGRAPHY (Cont'd)

systems are employed, the factors underlying inefficiencies and possible corrective actions, the future course of the economy and consequent transportation requirements, the general direction of future investments, and selected implications of study recommendations. This first volume contains the basic description of the studies and findings.

49. Drake, G. L., and J. E. Traylor: Thailand Transportation Coordination Study. Volume II, Wilbur Smith/Lyon Associates, Bangkok (Thailand), PB 210327, June 1, 1970.

This second volume of the Thailand Transportation Coordination Study is comprised of technical appendices for use with the first volume. Its contents include: A survey of the economy of Thailand; a forecast of economic growth to 1978; determination of highway capacity; truck weights; motor fuel consumption; transportation investment plan; current and projected highway travel; highway cost allocation analysis; highway user charges; highway-user tax payments; passenger fares for rail, intercity bus, water, and domestic airline travel.

50. Driscoll, R. E. and H. M. Wallender, eds.: Technology Transfer and Development: An Historical Perspective. Fund for Multinational Management Education in Cooperation with Council for the Americas, New York.

51. Dunkel, E. V.: Air Afrique: Lifeline for Eleven Nations. Air Transport World. June 1974, pp. 16-20.

Describes participation of Air Afrique in the political and economic life of 11 African nations, the possibilities for future tourism in Africa, and the growth of air freight in the region. Problems of running a multinational airline are considered, including special requirements dictated by member nations.

52. Eckuns, R. S.: Appropriate Technologies for Developing Countries, M.I.T., Industrial Liaison Program, April 1977.

53. Economic Commission for Asia and the Far East. Transport and Communications in Asia and the Far East. Ekistics, January 1970.

This is a summary of progress on the Trans-Asian Railway Network Project.

54. Emerging Nations Use Private Lenders More, Causing Some Worries. Wall Street Journal, September 28, 1976.

BIBLIOGRAPHY (Cont'd)

55. FAO (Food and Agricultural Organization): Harvesting Man-Made Forests in Developing Countries. A Manual on Techniques, Roads, Production and Costs. Rome, 1976.

56. FAO (Food and Agricultural Organization): Logging and Transport in Eucalyptus Plantations. Rome, 1974.

57. FAO (Food and Agricultural Organization): Logging and Log Transport in Man-Made Forests in Developing Countries. Rome, 1974.

58. FAO (Food and Agricultural Organization): Technical Report of FAO/ Austria Training Course on Forest Roads and Harvesting in Mountainous Forests. Ossiach, Austria, 1-29 June, 1975. Rome, 1976.

59. Fairbanks, O. J. and C. R Yancey: Report of Private Investment Survey Team. Brazil Council for International Progress in Management (USA), Inc., New York, PB206973, December 31, 1967.

The report is comprised of the findings of an investment survey of the State of Ceara (Brazil), which was conducted in conjunction with the Companhia do Desenvolvimento do Ceara (CODEC). Economic recommendations were made with respect to transportation, electric power, communications, water, sanitation, irrigation, money and finance, taxation, education and training, agriculture and agro-industry, manufacturing, mining and minerals, and lumber and forestry. The establishment of an economic information center is outlined, and recommendations are made for an analytical and information-gathering system for feasibility studies. In addition, basic information is provided on Ceara for those not familiar with the State.

60. Fox, G. D.: Forestry in Developing Countries. Potentials, Constraints, and Opportunities. Agency for International Development, Washington, D. C. Office of Science and Technology. PB 212726, October 1972.

With about one-half of the world's forest area located in the developing countries, adequate forest programs to manage and exploit this renewable natural resource are an important aspect in economic development This preliminary analysis focuses on the following issues: principal factors inhibiting better management of forest resources; technical aspects of these inhibiting factors; practical steps that might overcome these problems; and likely impact on timber resources and utilization if such steps were taken.

61. French Speaking Africa: Economic and Air Transport Data. ITA Bulletin, November 6, 1972.

BIBLIOGRAPHY (Cont'd)

62. Fulkerson, G. J.: Saudi Arabia's Civil Aviation Guided in 12-Year Dual Aid Programme. ICAO Bulletin, February 1972.

63. Gallup, G. H.: What Mankind Thinks about Itself. Reader's Digest, October 1976.

Presents findings of the first global public opinion poll, indicating that the great majority of rural populations yearn to move to the big cities.

64. GEIPOT, Estudo do Transporte Fluvial nos Rios Parania, Parguai e Urugrai e sua Integracao ao Sistema Viario Terrestre da Regiao. Vol. 1, Summary 1973.

65. Gobetz, F. W.: Study of Potential Applications of Advanced Transport Aircraft in Developing Countries. Preliminary Report. UTRC R77-912839-3, June 1977.

66. Goodyear Aerospace Corporation. Balloon Logging Systems. Phase I - Analytical Study, Phase II - Logistics, 1965.

67. Grava, S.: Working Bibliography - Transportation in Less Developed Countries. Unpublished bibliography from a seminar on transportation in less developed countries, Columbia University, Graduate School of Architecture and Planning, Division of Urban Planning, Spring 1976.

68. Green, D. S. and M. B. Krauss: A Research Approach to the International Transfer of Technology. Progress in Assessing Technical Innovation - 1974. Technomatic Publishing Company, Westport, Conn. (complete report: Summary - PB 234704/AS, NTIS $3.00, Final - PB 233527/AS, $3.25).

This summary is based on an SRI report and proposes a "product cycle" theory of technology transfer. It maintains that high skill-intensive goods tend to be exported to LDC's where skills are scarce, where low skill-intensive goods are excluded because they can produce low skill-intensive goods themselves. On the other hand, the technology that produces these goods is only traded between developed countries, and low-skill technology is traded among LDC's.

69. Guide to the Dag Hammerskjold Collection on Developing Nations (A Selected Bibliography). Central Michigan University Press, Mount Pleasant, Michigan 1968.

A general bibliography of background and general works on developing countries, with emphasis on particular regions, countries and continents.

BIBLIOGRAPHY (Cont'd)

70. Haefele, Edwin T., and Eleanor B. Steinberg: Government Controls on Transport: An African Case, Brookings Institution, Washington, D. C., 1965.

This book gives a background of transport development in South Central Africa and the implications of recent (early 60's) political changes. A case is made for improving the utilization of existing facilities through inter-country agreements which could obviate the need for any new investment. Rail pricing policy is examined -- the need for cooperative regional economic cooperation and rail competition is strongly urged.

71. Hafner, James A. and David Janes: Transport Development in Southeast Asia; A Selected Bibliography. Council of Planning Librarians Exchange Bibliography No. 653.

72. Harvard University. Choice of Technology in Developing Countries. Some Cautionary Notes, Center for International Affairs, 1975.

73. Harral, Clell G.: Preparation and Appraisal of Transport Projects. US DOT, Office of Technology Assistance, Washington, D. C., 1968.

74. Hayes, A. W.: Ab initio Civil Aviation Development in Swaziland. ICAO Bulletin, February 1972.

Technical assistance to this land-locked country is discussed in the context of civil aviation, as a means of communication, access to neighbors, development of tourism and developing air mail and freight services.

75. Hogg, V.: Transport Planning at the Policy Level - Underdeveloped Areas. Transportation Research Forum - 12th Annual Meeting, October 18-19-20, 1971, Volume XII, No. 1

This study of World Bank/IBRD lending discusses investment, pricing and regulation of transport services. Effective transport investment planning is seen to depend critically upon the soundness of national development objectives and the resulting transport policy it is intended to reflect. Planning of all modes together with consideration of trade-offs is stressed, as well as establishment of priorities among sectors, only one of which is transport. Although use of shadow prices is required for investment, in reality a more pragmatic solution should be adopted, to produce adequate transport at reasonable prices.

76. Howe, J. D. G. F.: The Value of Time Savings from Road Improvements. A Study in Kenya. Road Research Lab., Crowthorne (England)., PB 198412, 1971.

BIBLIOGRAPHY (Cont'd)

The report examines the results of a study which considered how time savings resulting from road improvements in less developed countries should be valued. Although the monetary value of time savings are frequently the major benefit they are not normally taken into account in feasibility studies of road improvement schemes. The results suggest that in Kenya the relationship between income and car ownership, the hourly earnings of vehicle occupants traveling on business, and the value placed upon time savings by road users are not markedly different from those in the UK. The evidence supports the view that savings in traveling time in developing countries should be treated in a fashion similar to that adopted in developing countries.

77. International Bank for Reconstruction and Development. Statistical Indicators of Industrial Development - A Critique of the Basic Data. International Development Association, Development Economics Staff Working Paper No. 189, September 1974.

This paper contains a critical evaluation and compilation of some basic data needed for constructing statistical indicators of industrial development. Data are compiled for about 100 countries and growth rates are calculated. Some analysis is made to show that, depending on definitions of data used, conclusions drawn from the data may differ considerably.

78. Isard, Walter and John H. Cumberland, eds.: Regional Economic Planning - Techniques of Analysis for Less Developed Areas. OECD, Paris. 1960.

This collection of papers varies widely in approach level of abstraction and format, but deals with the common problems of industrial expansion, agricultural improvement and orderly urban development.

79. Johnson, H.: Economic Policies Towards Less Developed Countries. Brookings Institution, Washington, D. C., 1967.

80. Kanafani, A.: Transportation and Regional Development in Underdeveloped Regions. University of California, Berkeley, ITTE, 1972.

81. Kanafani, Adib: Transportation Systems for Developing Nations. IFAC/IFORS Conference on Systems Approaches to Developing Countries, May 28-31, 1973, Algiers, Algeria.

This paper proposes a systems framework for integrating transportation system planning into the regional development planning process. A simple model of demand is presented to represent linear regional transportation.

BIBLIOGRAPHY (Cont'd)

82. Kanafani, A.: Transportation Systems for Developing Regions. University of California, Berkeley, ITTE, 1973.

83. Keil, Bill: How Helicopters Can Help Solve the World Food Crisis. Rotor and Wing, November/December, 1975.

The article argues that the helicopter industry, through precise, aerial application, is more than capable of bringing about rapid increases in food and fiber production that will ease global inflation and alleviate human suffering. The problems confronting operators are largely political, involving the unwillinghess of the environmentalists to compromise on the questions of which chemicals should be made available.

84. Kendall, Sarita: The Development of Transport in Brazil. Bolsa R, 6:540-50, October 1972.

85. Kilewo, A. B. S.: Transport Progress in Practice: Air Transport in Africa; East African Airways Corporation Experience. Chartered Institute of Transport Journal, July 1976.

This paper, by the Chairman of East African Airways, discusses the obstacles encountered in air freight and its role in economic development. A proposal for a new multi-national freight airline is discussed, the possibilities for tourism, need for a coordinated transport policy and the importance of mutual assistance.

86. Kraft, Gerald, John Meyer and Jean-Paul Valette: The Role of Transporation in Regional Economic Development. 1971.

87. Kuhlman, W. H., and Max Klotzsche: Total Transportation System Study (includes a case study of Zaire). Cargo Market Development, Douglas Aircraft Company, 17 February 1976.

A series of presentation slides which presents a framework for transport analysis, with emphasis on air development in Zaire.

88. Lago, Armando M.: Cost Functions for Intercity Highway Transportation Systems in Underdeveloped Countries. Institute of Management Science, September 1966.

89. Lockheed Studies Twin Hercules Market. Aviation Week & Space Technology, February 14, 1977.

This twin-engine derivative of the Lockheed C-130, the Hercules turbo-prop transport designated the L-400, has been designed as a

BIBLIOGRAPHY (Cont'd)

replacement for the Douglas DC-3's, Fairchild C-119's and C-123's, and Douglas C-54 4-engine transports. Lockheed-Georgia is completing a market validation study involving 30 countries prior to making a production decision based on an initial batch of 30 aircraft.

90. Locklin, D. Philip: Economics of Transportation. Richard D. Irwin Co., Homewood, Ill., 1966.

91. Loy, Frank E.: The U.S. Program of Aviation Assistance to Less-Devloped Countries. Agency for International Development, Department of State, Washington, D. C., 1964.

92. Mahayni, Rlad G.: Transportation Planning in Third-World Countries. Council of Planning Librarians Exchange Bibliography No. 1108, August 1976.

An annotated bibliography focusing on the concern of transport as an economic sector which influences the spatial distribution of economic activities and the distribution of the social and political institutions, which in turn effect the development process itself.

93. Manning, G. K., ed.: Technology Transfer: Successes and Failures. San Francisco Press, 1974.

This book presents a series of addresses from a conference at Battelle Memorial Institute. It contains a diverse set of viewpoints, including perspectives on transferring technology to developing countries.

94. Martin, Brian V., and Charles B. Warden: Transportation Planning in Developing Countries. Traffic Quarterly, 19:59-75, January 1965.

This paper argues for a systems approach toward transportation planning and integration with the general economic plan. An overview of the Harvard-Brookings model is presented and its applications explained.

95. Meyer, John A., ed.: Techniques of Transport Planning. Brookings Institution, Washington, D. C., 1971.

96. Mexico Modernizes Its Air Navigation Facilities. ICAO Bulletin, February 1972.

97. Meyer, J.: Transport Technologies for Developing Countries. American Economic Review, May 1966.

BIBLIOGRAPHY (Cont'd)

98. Middle East Takeoff: Oil Makes the Going Great. Air Transport World, April 1975, pp. 28-53.

This special report on the Arab World documents the present status and future possibilities for each of 12 airlines serving 14 nations in the Middle East.

99. Mira, Luis Javier: Air Transportation in Less Developed Areas, Normative Models for Public Policy Making. MIT, S.M. Thesis, Dept. of Civil Engineering, R. de Neufville adviser, 1972.

This thesis deals with rather theoretical issues of the economics of air transportation on the low density routes of less developed or sparsely populated areas. Effects of higher frequency, assumed to be valuable to users at low traffic levels, are examined in relation to aircraft capicity, operating cost and fare. Conditions for an ideal social optimum are described from a consumer surplus view. It is found not to be attainable by a perfect competitive market because of differences in social values and user perceptives. Corrective regulatory measures to achieve a social optimum are described.

100. Mittal, Ram Kumar: Study of Interrelationship of Transport Activities with GNP For Various Countries. Proceedings of IFAC/IFORS Conference on Systems Approach to Developing Countries, Algiers, May 1973.

Existing transportation activities in different countries are correlated with GNP, transportation activities and relevant geographical characteristics to determine the extent of any inherent relationships using factor analysis.

101. Moavenzadeh, Fred and Janet Ann Rossow: The Construction Industry in Developing Countries, M.I.T. Technology Adaptation Program, Spring 1975.

This report discusses the role of construction in the process of development and its importance to economic growth, employment creation and income generation and redistribution. It examines the industry in the context of planning, design construction and maintenance, and uses information on five developing countries: Colombia, Korea, Iran, Kenya and Ethiopia. A thorough discussion of all aspects of construction is presented in this paper, including the role of multi-national firms.

102. Morawetz, David: Problems of Transport and Communications in the Andean Group. Harvard University, Cambridge, Mass. Center for International Affairs. (403 107).

BIBLIOGRAPHY (Cont'd)

The member nations of the Andean Group Customs Union, Bolivia, Chile, Colombia, Ecuador, and Peru stretch the full length of the South American continent and cover almost one fourth of its area. The paper examines the problems of transport and communications within this group of nations. It is demonstrated that high transport costs and poor communications are likely to limit the expansion of intra-Andean trade. Comparative data are presented for the European Economic Community, and some suggestions are made for reducing Andean transport costs. Also included is an examination of comparative freight rates for intra-Andean trade and for Andean trade with the U.S. and Europe.

103. Nzegwo, T. I. O.: The Transport Sector in the Socio-Economic Development of Nigeria. Chartered Institute Transport Journal, 36:90-6, May 1974.

This paper presents a broad summary of the history, geography, climate, vegetation, mineral and agricultural resources, and the role of transportation within overall development.

104. OECD, (Organization for Economic Cooperation and Development), Alternative Transport Technology for Developing Countries. OECD Development Center, Paris, 1975.

105. OECD, Choice and Adaption of Technology in Developing Countries. Development Center of the OECD, Paris, 1974.

Review of the discussions held at the study sessions held on Nov. 7-9, 1972. Includes bibliographical references.

106. OECD, Flow of Resources to Developing Countries. Paris, 1973.

This volume contains basic data for each member of the Development assistance Committee (DAC) as an update to a previous report for 1962-68, giving trends of private and public flows.

107. OECD, The Evaluation of Technical Assistance. Technical Assistance Evaluation Studies, OECD, Paris, 1969.

Comments by OECD-member delegates regarding evaluation of aid programs by synthesized in these proceedings.

108. Osayimwese, I.: Surrogate Choice of Transport Technology. Transportation Planning and Technology, June 1974.

109. Owen, Wilfred: Transportation, Communications and the Future. Ekistics, January 1968.

BIBLIOGRAPHY (Cont'd)

This very interesting paper argues for mobility and accessibility of knowledge and resources as a means for narrowing the gap between the rich and poor of this world.

110. Pai, P. A.: Transportation Infrastructure Decision. Transport Annual (India), August 1972.

This paper looks at transportation demand and methods to control it through modern technology, energy policy, and planning. Effects of air transport are discussed, although more in the context of developed countries. The importance of planning for future transport is emphasized, to develop efficient transport systems.

111. Paradoxes of Amazonian Development in Resource-Starved World. Journal of Developing Areas, July 1970.

112. Piekarz, Rolf R.: The Effect of International Technology Transfer on U.S. Economy. Progress in Assessing Technical Innovation - 1974. Technomatic Publishing Co., Westport, Conn.

This is one of a series of summary reports of National R&D Assessment Program Projects from NSF. It contains the opinion of four experts concerning U.S. technological innovation, foreign direct investment, licensing, employment and other issues, and the state of the art in analyzing and measuring these relationships.

113. Poor Countries Post Some Gains. Daily Press, Newport News, VA., September 23, 1976.

Reports results of a World Bank report that shows some economic growth of developing countries despite world recession and high inflation.

114. Poor vs Rich: A New Global Conflict. Time, December 22, 1975.

This special report describes the conflict between the five "Worlds". Common arguments against industrialized nations are discussed, and suggestions for actions by developing countries recommended.

115. Pratt and Whitney Aircraft. The World Environment, 1978-1987, June 1977.

116. Prest, Alan R.: Financing Transport in Developing Countries. Brookings Institution, Washington, D. C., December 1967, NTIS PB 218778.

BIBLIOGRAPHY (Cont'd)

This report presents a general background of transport financing principles with emphasis on road and rail. Modification of these principles is then discussed to account for practical application of this theory. Actual transport pricing practices and the overall position of the public trasport sector in selected countries is brought out, and the contrast made between the actual positions and the principles laid out. Policy issues and the administrative issues conclude this report.

117. Proceedings of the Conference on Tropical Hardwoods. Syracuse University - State University College of Forestry, Syracuse, N. Y.

118. Rakowski, James P., Ed.: Transportation Economics: A Guide to Information Sources. LC73-17584, 15BN 0-8103-1307-3.

119. Rao, S. Subba: Transportation Policies and Technology For Developing Countries with Special Reference to India. Fourth Annual Intersociety Conference on Transportation. Proceedings, July 1976.

This paper highlights the need for appropriate technologies in the area of transportation. Appropriate technology becomes essential to meet the specific local conditions as well as to satisfy social objectives. The discussion is specific to India.

120. Rendel, David: Design Characteristics of Aircraft for Safe Operation in Less Developed Areas. Transportation (no date).

121. Richardson, Ken: Shangri-La (Nepal Developing STOL Network Using Canadian Aircraft). Transportation Canada, March/April 1973.

This paper describes the use of Canadian Twin-Otters, provided through a $1.2 million CIDA development loan.

122. Roemer, Michael and Joseph J. Stern: The Appraisal of Development Project - A Practical Guide to Project Analysis With Case Studies and Solutions. Praeger Publishers, New York, 1975.

This "Manual" develops a realistic framework for project evaluation, sets forth pratical rules for assessing costs and benefits and illustrates their use in a series of case studies. Each case study deals with a different sector of the economy, including evaluation of a feeder road in Ghana.

123. Ruina, J. P.: Proceedings of the M.I.T. Symposium on Strategies for A.I.D. Programs in Selected Areas of Science and Technology. Volume 1, Summary, Massachusetts Inst. of Tech., Cambridge, Agency for International Development, Washington, D. C. PB242403, April 1974.

BIBLIOGRAPHY (Cont'd)

MIT sponsored a symposium, in April 1974, to examine areas of science and technology that might merit more attention in the future as well as to consider the scope, balance and perspective of the TA/OST program within the context of current nees and conditions in developing nations. The subjects considered were construction, transportation, housing, water resources and nutrition. The four volumes of this report contain most of the papers that were commissioned to formulate questions and issues.

124. Ruina, J. P.: Proceedings of the M.I.T. Symposium on Strategies for A.I.D. Programs in Selected Aras of Science and Technology. Volume 2, Housing, Transportation and Water Resources, Massachusetts Inst. of Tech., Cambridge, Agency for International Development, Washington, D. C. PB242403, April 1974.

The report contains materials on the part of a technology utilization symposium devoted to housing, transportation, and water resources, principally in the developing nations.

125. Sargon, S. Dick: Transportation in Developing Countries: Some Sensitivity Considerations. Transportation and Land Use Planning Abroad, Transportation Research Board, Special Report 168, 1976.

This paper briefly discusses some issues in evaluating transportation in developing countries. It stresses the need for improvement in collection and refinement of data, and presents a number of needs and recommendations for closing the gap between planning an execution.

126. Seshagiri, N.: A Fundamental Macro-planning Model of Transportation in Developing Countries. Transportation Research, Vol. 10, No. 6, 1976.

A network model for transport planning is proposed to account for "feedback" effects of transport development.

127. Slaser, Peter E., et al.: Space Technology Transfer and Developing Nations. NASA, Washington, D. C. Contractor Report 1222, 1968.

128. Spotlight on Transport. Africa, No. 54, February 1976.

Contains the following articles of interest:
"Vehicle Assembly in Africa"
"The Development of Roads, Railways and Bridges"
"International and Continental Highways of Africa"
"Effects of the Oil Crisis on Road Transport"
"The Political Economy of Africa's Roads"
"Japanese Take on Giant Pipeline Project"

BIBLIOGRAPHY (Cont'd)

129. Stanley William R.: Evaluation of Construction Priorities of Farm-to-Market Roads in Developing Countries: A Case Study in Liberia. Ekistics, January 1972.

130. Straszheim, Mahlon A.: The International Airline Industry. Brookings Institution, Washington, D. C., 1969.

131. Strengthened Merpati West Irian Operation Yield Good Growth. ICAO Bulletin, February 1972.

This article reports on the history and progress made in air transport development on the western half of the island of New Guinea (Indonesia). Joint UN/ICAO aid is described and its effects noted.

132. The African Region ... A Study of the Development of Air Freight and Air Mail. ICAO Bulletin, April 1971.

133. Thiel, Floyd I., Teruki Kitamure, Yasumasa Torii, Allan K. Sloan, and Daniel L'Huillier: Transportation and Land Use Planning Aboard. Transportation Research Board, Washington, D. C. Special Report, PB 255911/OST, 1976.

The papers discuss some of the ways that transportation and land use planning abroad is providing experience that can be helpful in the United States. Geographic areas from which experience is drawn include Japan, Canada, Europe, and the Middle East. Topics include noise and other transportation impacts, land use techniques to deal with these impacts, transit financing, public participation, 'pedestrianization' in various countries, pricing to restrain parking, truck regulation, highway needs in Canada, and transportation sensitivity considerations in developing countries.

134. Titus, R. R. and A. S. LeShane: Potential Roles for Helicopters in Arctic Gas Exploration and Production. United Technologies Research Center Report R75-111242-1.

135. Trzesnioski, A.: Logging in the Mountains of Central Europe. FAO, Rome, 1976.

136. Turnham, David: The Employment Problem in Less Developed Countries. Development Centre Studies, Employment Series, No. 1, OECD, Paris, 1971.

This study describes the nature and the ramifications of the problem, and contains a variety of empirical data.

BIBLIOGRAPHY (Cont'd)

137. United Nations: A Transport Strategy for Land-Locked Developing Countries: Report of the Expert Group on the Transportation Infrastructures for Land-Locked Developing Countries. UN Document No. TD/B/453/Add.1/, 1974, Sales No. E.74.II.D.5, Rer. 1.

Proceedings of the conference which met in Geneva at the Palais des Nations, May 14-23. It descibes the problem of transport development and coordination among these countries and then proposes a program of action of studies to review these problems and to reach agreement on their improvement and financing. The role of external assistance is discussed, and the specific applications of air transport to these problems.

138. United Nations, Department of Economic and Social Affairs: Air Cushion Vehicles for Use in Developing Countries. UN Document ST/ESA/2, Sales No. E. 74, VIII-2, 1974.

This is strictly a design proposal for air cushion vehicles as they might be used for this application.

139. United Nations, Department of Economic and social Affairs: The Application of Modern Transport Technology to Mineral Development in Developing Countries. New York, 1976, ST/ESA/43.

140. United Nations, Department of Economic and Social Affairs: Transport Modes and Technologies for Development. Sales No. E-70, VIII-1, ST/ECA/127, New York, 1970.

This report is oriented towards the technical aspects of transport in DC's. Although choice of technology should be based on the correct combination of labor and capital, decisions on transport investment choice should be based on economic or cost effectiveness, both from the standpoint of optimal allocation of resources and long-range development. Emphasis is placed on the cost and performance characteristics of various modes, including the air mode.

141. United Nations, Environmental Aspects of Transport for Natural Resources Development. Basic paper submitted for UN conference on Human Environment, Resources and Transport Division, Dept. of Economic and Social Affairs, United Nations, July 1971.

This report deals with the environmental impacts of alternative modes and gives many examples.

142. United Nations Industrial Development Organization Guidelines for Project Evaluation. New York, 1972, ID/SER. H/2.

BIBLIOGRAPHY (Cont'd)

143. United Nations: Institution Building for Transport Development in Developing Countries. Department of Economic and Social Affairs, UN Document No. ST/ECA/148, 1971.

144. United Nations: Transport Questions: Review of the Activities of the Activities of the United Nations System of Organizations in the Transport Field. March 9, 1970, Report No. 1970/E/4795, New York.

Report by the Secretary General on major transport problems of developing countries.

145. Wheatcroft, Stephen and Associates: Aviation and Tourism in Ethiopia. International Bank for Reconstruction and Development, Washington, D. C., January 1972.

146. Wood, Andrew D.: The Potential Use of Helicopters for the Transportation of Logs. Ottawa, 1962, NRC No. 7211.

147. World Bank Activities in the Transport Sector. Traffic Engineering and Control, December 1974.

148. World Bank: ATLAS: Population, per Capita Product, and Growth Rates. Published by World Bank, 1975.

Contains useful regional summaries of LDC trends in GNP and population as well as comparisons of UN and Atlas GNP estimation procedures.

149. World Bank: List of National Development Plans. International Bank for Reconstruction and Development, 4th Edition, 1973.

150. World Bank Research Report: Port Pricing and Investment Policies in Developing Countries. Research Report No. 671-13.