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High-Speed Rail in the Toronto-Ottawa-Mirabel-Montreal Corridor

by Christopher J. Boon and Dr. Richard W. Lake***

1. INTRODUCTION

DURING THE PAST two and a half years, a team from the Canadian Institute of Guided Ground Transport, under contract with Transport Canada Research and Development Center, has carried out an economic evaluation of high-speed guided ground passenger systems over selected routings linking Toronto, Ottawa, Mirabel and Montreal—the central portion of the so-called Canadian Corridor. The study examined three candidate ground systems—a 450 km/h magnetically levitated (Maglev) system, a 260 km/h (160 mph) electrified High Speed Railway (HSR), operating on a dedicated double track in a new right-of-way, and a 200 km/h (124 mph) diesel-electric Intermediate Speed Railway (ISR) operating on partial double track in a combination of existing and new rights-of-way, together with the air mode—conventional (CTOL) and short take-off and landing (STOL)—under different economic activity and petroleum availability assumptions. This paper summarizes the findings of the study with respect to the latter three modes—HSR, ISR and Air.

2. STUDY PERSPECTIVE

Since investment in transportation infrastructure involves, with few exceptions, substantial public expenditure, the question which an economic (profitability) evaluation must address is not "Would it be profitable for an entrepreneur to construct and operate such a system in the market?" but rather, "Which alternative investment is superior?" Insofar as this superiority can be measured in terms of cash flows to and from the government, the study maintained this public perspective. Costs were developed on that basis, with the fundamental evaluation parameter being full cost recovery unit ticket cost.

The governmental perspective on costs led to certain departures from cost levels and costing procedures that would apply to a private entrepreneur. The cost of petroleum is a good example. Canada is now a net importer of oil, so that a barrel of oil not consumed means a barrel decrease in imports required. Since the cost of this marginal barrel must be (at least) the world market price, this is the national cost. The fact that Canada chooses to subsidize the price of fuel so that the cost to a transportation company is substantially below this national cost is not relevant in this context, since government cannot effectively subsidize itself. On the other hand, the lower (subsidized) price would be the appropriate cost were an evaluation to be carried out on behalf of a transportation company.

Similarly, the government neither pays taxes nor allows itself capital cost allowance, although normal costs of capital do apply. However, there is a limit to the extent to which it is economically valid or practical to treat governmental investment differently from that of the private sector, so that tax payments (sales tax, etc.) were not excluded. The analysis did not take the public cost benefits approach that characterizes most governmental economic studies, and benefits like passenger time savings, noise reduction, and atmospheric pollution reduction were neglected.

To achieve the maximum degree of comparability, the study was structured so that the various alternative systems would be designed and costs developed to a uniform level of detail. While a similar level of design effort was devoted to each of the ground alternatives, the achievement of this goal paradoxically required unequal treatment of the air mode. Specifically, air provides the only existing high-speed service between the corridor cities, and so must be treated incrementally. The alternative ground systems, however, are essentially new operations, and were therefore treated as total systems. This difference in treatment extended to the level of cost determination, since cost data applicable to the corridor air services were available in sufficient detail, obviating the need to develop most unit costs.

The study also required to ascertain what, if any, conditions would favour the emplacement of high-speed ground systems. Since the economic evaluation of long-term investments involves a high degree of forecasting uncertainty, the definition of economic scenarios was deemed the most appropriate approach to this problem. This judgment was based on the need for economically consistent treatment of passenger demand and differential input-cost

**Canadian Institute of Guided Ground Transport, Queen's University at Kingston, Ontario, Canada.*

***Assistant Director, Research Canadian Institute of Guided Ground Transport, Queen's University at Kingston, Ontario, Canada.*

escalation. Optimistic, status quo and pessimistic scenarios were selected to represent high, moderate and flat economic growth possibilities. Specifically, the optimistic scenario (abundant cheap petroleum) assumed a one per cent (reducing) real fuel price escalation combined with a two per cent annual growth in real disposable income, while the pessimistic scenario (hopefully the other extreme) assumed six per cent fuel price escalation with no growth in real disposable income. The status quo presumed three per cent and one per cent for fuel price and real disposable income growth respectively.

The scenario escalation rates were not treated as constants, since differential escalation is essentially a self-correcting phenomenon. Beyond the short term, input substitution will serve to diminish the differential. This tendency for differential escalation rates to decay over time was modelled by

$$P_t = P_0 \prod_{t=0}^{n-1} (1 + \Delta e^{-\alpha t})$$

where: P_0 = price in the base year

P_t = price in the t^{th} year

Δ = the initial escalation rate

α = a parameter defining the rate decay

This exponential decay gave a schedule of forecast fuel-price single-year growth rates that, for the status quo scenario, reduced from three per cent in the first year to 2.5 per cent after ten years, two per cent after 21 years, and 1.5 per cent after 35 years.

The scenarios defined for this study should not be confused with optimistic, "best estimate" and pessimistic forecasts for the systems in general. While the optimistic scenario is truly optimistic for air, it is the pessimistic scenario that presents the most optimistic set of circumstances for high-speed rail.

3. SYSTEM ROUTINGS AND CHARACTERISTICS

The specific routing selected was Toronto-Kingston-Ottawa-Mirabel-Montreal, as shown in Figure 1. The Ottawa connection was dictated by passenger demand considerations—traffic originating or terminating there would be very important—while the Kingston and Mirabel termini were included for a combination of demand and terrain reasons.

Construction over a more direct Toronto-Ottawa routing would involve traversing the granite knob, lake and swamp conditions of the Canadian Shield, and would prove much more expensive. Effectively, the favourable terrain characteristic of the routing would be lost.

The selection of the central portion of the Windsor-Quebec City corridor should not be taken to indicate that the Windsor-Toronto and Montreal-Quebec City links would not also provide opportunities for high-speed rail. Particularly, as extensions to an original Toronto-Montreal system, these sections may well prove viable, but to build such a system at one time would not be practical, it would double the cost. It is also reasonable to assume that if the Toronto-Montreal link were to prove not viable, the best opportunity would be Edmonton-Calgary, not the less populous ends of the Windsor-Quebec corridor.

Travel demand between the corridor cities is substantial, has considerable potential for growth, and is now dominated by the private automobile and, to a lesser extent, by air—and both these modes are particularly vulnerable to substantial increases in the price of petroleum-based fuels.

The systems do not follow the same routing. There is some coincidence (in the eastern segment of the ISR and HSR systems) but in general they differ appreciably. The HSR routing is 604 km long, that of the ISR 601 km in length. Characteristics of the alternative systems, including origin-destination schedule times and station locations are given in Table 1. These characteristics, together with the scenario assumptions, govern the demand forecasts illustrated in Figure 2. The trip times were computed assuming limited speeds within the metropolitan areas and include acceleration and deceleration times, intermediate station stop times, and (for the ISR system) speed limitations due to curvature where the cost of straightening was judged not justifiable.[1]

The ISR designs involve 200 km/h (124 mph) diesel operation over partial double track with full-speed turnouts under the status quo and optimistic scenarios, and an electrified double track under the pessimistic scenario. The routing for these systems utilized existing rights-of-way to a greater extent than did that for the HSR. Rolling stock was fashioned after the Canadian LRC with major modifications to the locomotive and with-out the tilt-body feature in the coaches.

The track structure was designed to meet very high standards of alignment to ensure a smooth, safe ride. The design calls for 57 kg/m continuous welded rail on 2.5 m concrete ties, fastened with Pandrol clips. The minimum ballast section would be 35 cm (14") of specially-selected, high-density crushed rock. The routing would be completely fenced, with almost all road crossings grade-separated. A limited number of specially-protected grade crossings have been allowed, however.

ROUTING MAP

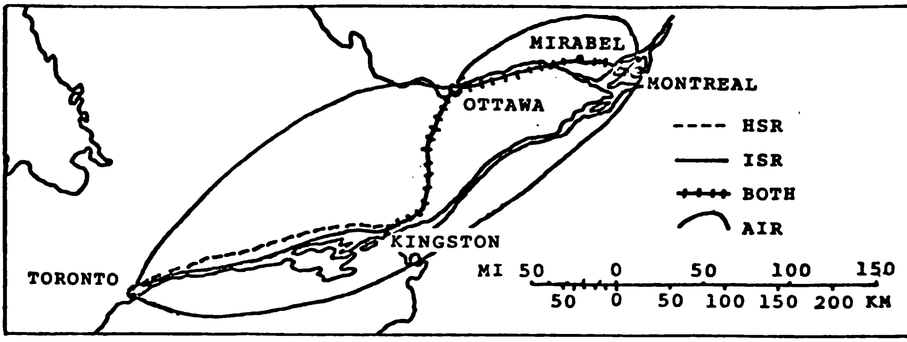

FIGURE 1

TABLE 1

CHARACTERISTICS OF CANADIAN HIGH-SPEED PASSENGER SYSTEMS FOR THE TORONTO-OTTAWA-MIRABEL-MONTREAL SECTION OF THE CANADIAN CORRIDOR

	HSR	ISR Electric	ISR Diesel	CTOL	STOL
Scenarios	Optimistic Status Quo	Pessimistic	Optimistic Status Quo	Optimistic Status Quo Pessimistic*	Optimistic
Route Length (ground system only)	604 km	601 km	601 km	-	-
Maximum Operating Speed	260 km/h (160 mph)	190 km/h (118 mph)	190 km/h (118 mph)	-	-
Equipment Type	Articulated electrified trainsets (similar to electrified TGV ordered by SNCF) in mix of 1-5-1 and 1-10-1 consists	Mix of diesel-electric locomotive-hauled consists similar to British HST and diesel-powered MU cars similar to Budd SPV 2000	Electrified locomotive-hauled consists with LRC-type (but non-tilting) coaches; consist will vary from 1-6 to 1-16-1	B757 or equivalent Post-1985; DC-9, DC-8 and L-1011 until 1985	DASH-7 or equivalent
Track Configuration	Full double track on dedicated right-of-way; 57 kg CWR on 2.5 m concrete ties with Pandrol clips; minimum ballast section 40 cm (16"); fully grade-separated	Full double track on new and shared existing rights-of-way; 57 kg CWR on 2.5 m concrete ties with Pandrol clips; minimum ballast section 35 cm (14"); partial grade separation	Partial double track on new and shared existing rights-of-way; 57 kg CWR on 2.5 m concrete ties with Pandrol clips; minimum ballast section 35 cm (14"); partial grade separation	-	-
Trip Times:					
Toronto-Kingston	1 hr, 07 min	1 hr, 27 min	1 hr, 27 min		
Toronto-Ottawa	1 hr, 46 min	2 hr, 21 min	2 hr, 21 min	2 hr, 31 min§	2 hr, 23 min§
Toronto-Mirabel	2 hr, 19 min	3 hr, 09 min	3 hr, 09 min		
Toronto-Montreal	2 hr, 44 min†	3 hr, 32 min†	3 hr, 32 min†	2 hr, 45 min§	2 hr, 26 min§
Kingston-Ottawa	38 min	53 min	53 min		
Kingston-Mirabel	1 hr, 14 min	1 hr, 40 min	1 hr, 40 min		
Kingston-Montreal	1 hr, 36 min	2 hr, 05 min	2 hr, 05 min		
Ottawa-Mirabel	34 min	45 min	45 min		
Ottawa-Montreal	55 min	1 hr, 09 min	1 hr, 09 min	2 hr, 06 min§	1 hr, 55 min§
Mirabel-Montreal	18 min	22 min	22 min		
Stations:					
Toronto	Union Station	Union Station	Union Station	Toronto International	Toronto Island
Kingston	near Elginburg	existing	existing	no stop	no stop
Ottawa	existing	existing	existing	Ottawa International	Ottawa International
Mirabel	Ste.Scholastique	Ste.Scholastique	Ste.Scholastique	no stop	no stop
Montreal	Central Station	Central Station	Central Station	Dorval	Expo'67 Parking
Earliest Operation	1986	1986	1986	current	1986

*The treatment of the air mode under the pessimistic scenario was limited.
†The HSR and Electric ISR could provide Toronto-Montreal non-stop service in 2 hr. 19 min. and 3 hr. 20 min. respectively. The partially double tracked ISR diesel-electric was not designed to provide non-stop service
§From "STOL and Short Haul Air Transportation in Canada," Transport Canada, July 1978. These figures include airport access times and hence are not fully comparable to the ground system trip times.

SYSTEM DESIGN VOLUMES, BY SCENARIO

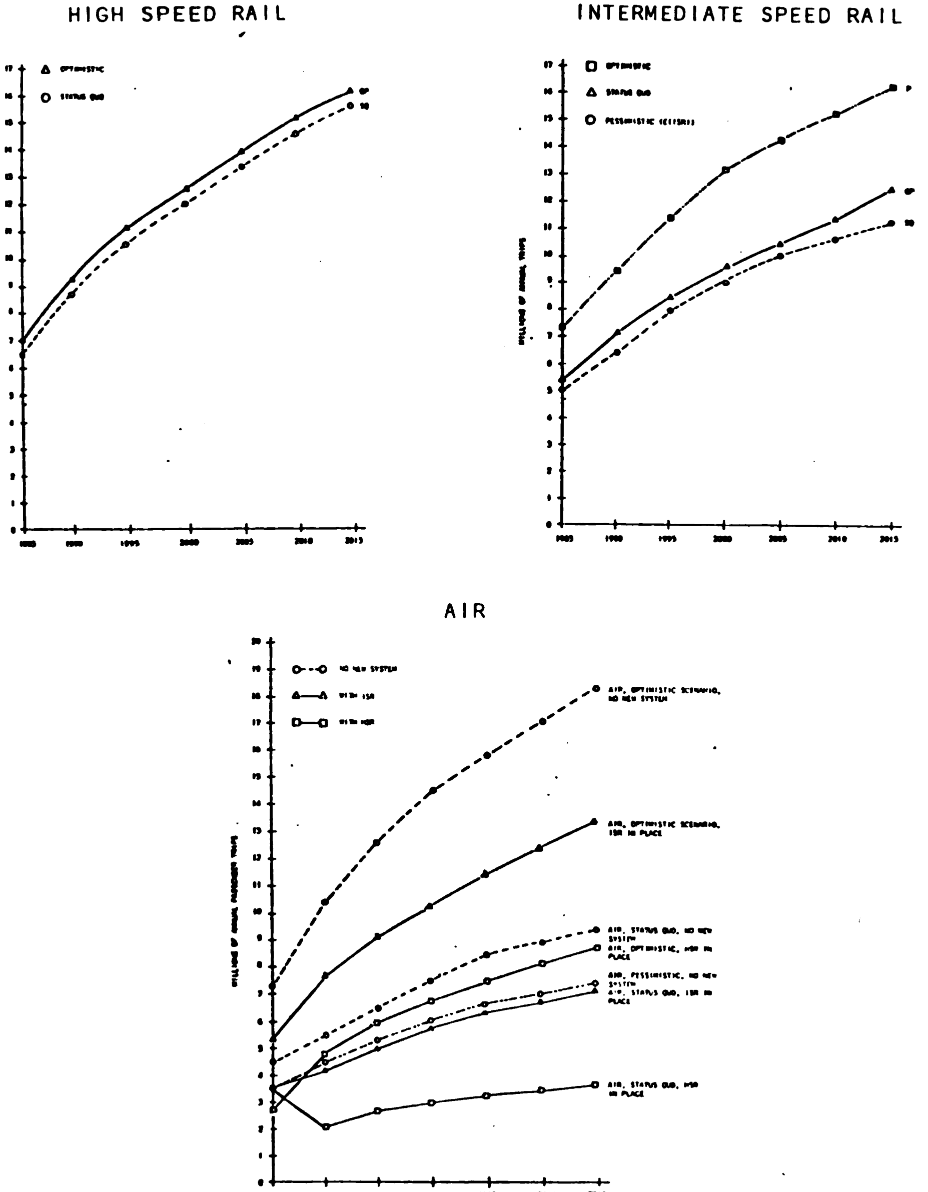

FIGURE 2

The system features full centralized traffic control (CTC) with in-cab signalling, with an operating crew of two—one engineman and one conductor per consist. Ten per cent of the coach fleet would be first-class, with all other seats at a 36 inch pitch. Airline-style food and beverage service would be provided. Cabin crews will vary with the consist make-up, but costs have been based on two stewards per first-class coach and one steward for each pair of economy coaches.

The HSR system infrastructure and rolling-stock have been designed to operate at speeds of up to 300 km/h, although operations, limited to

260 km/h, have been assumed. The fully double-tracked line would be electrified at 50 kV, with a limiting curvature of 0°35′ curvature. As projected demand will not require headways of less than twenty minutes, substation spacings of 100 km will be possible. The HSR track structure is similar to that for ISR, but a deeper minimum ballast section is required (40 cm rather than 35 cm). The line would be fully fenced and completely grade-separated.

The articulated electric trainsets are similar to the electric TGV developed for the SNCF, but feature wider coach bodies. Again, full CTC with in-cab signalling and a two-man operating crew have been specified, as were the same mix of first-class and regular coaches, on-board services and cabin crewing.

4. SYSTEM COSTS

As noted in Section 2, the costs for the ground systems and those for air were developed differently. Each ground alternative was designed and costed as a separate entity, with its own corporate (presumably Crown corporation) structure and independent administrative facilities. This may not prove to be the case, and VIA Rail Canada would certainly be a candidate operator. While this would be logical, a high degree of system independence was a fundamental presumption of the HSR and ISR system designs. The systems designed for this study are not incremental improvements in railway rolling stock and operations, but rather self-contained balanced systems employing state-of-the-art railway technology.

Air service, on the other hand, would be a continuation (and gradual improvement) of existing services (for CTOL), although the STOL service would represent, in part, a new system. Since it would have been inappropriate to compare new ground systems with the existing L-1011, DC-8 and DC-9 air service, the air mode was costed on the basis of replacement of the existing fleet with aircraft now in the design stage. For simplicity, introduction of the Boeing B-757 was assumed, but any equivalent aircraft designed for short-haul operations could be used. The STOL service would use the DeHavilland Canada DASH-7 aircraft. The following tables summarize capital and operating costs for the systems under the status quo assumptions and demand levels.

Tables 2 and 3 summarize the initial capital, ongoing capital and operating costs for the ISR and HSR systems respectively, over the period 1986-2015. Tables 4, 5 and 6 summarize the capital and operating costs attributable to the carrier operating the corridor air service and to the federal government, with no new ground system in place, with an ISR system and with an HSR system, respectively.

5. ECONOMIC EVALUATION

Since the passenger transportation system alternatives studied differ with respect to capital requirements, operating cost, implementation timing, service characteristics and throughput, a schedule of annual full cost recovery ticket cost equivalents based on individual system revenue requirements was selected as a common denominator evaluation criterion. Of course, these costs may not coincide with the ticket prices charged by a system operator, but they should allow a meaningful comparison of the various systems.

5.1 Methodology

The evaluation model used for this analysis, an extension of the MRAIL program,[2] considers the impacts of both general inflation and differential input cost escalation on costs, revenues and financial feasibility. Since the impact of inflation on total system costs is not consistent, but varies depending on the different capital investment requirements and the relative capital intensity of each option, cost escalation—both capital and operating—must be explicitly addressed.

Because modal choice dictates the level of capital intensity, the constant dollar approach to cost and price escalation (general inflation) is not appropriate for the transportation mode investment decision. Cost elements, especially those related to debt and capital consumption allowance tax savings, flow from escalated capital costs, but do not escalate in themselves—a cash flow aspect that the constant dollar approach cannot handle.

The model used starts with estimates for all cost components in terms of base year price levels, but rather than discounting both costs and revenues to determine the net present value of a project, it generates the revenue required per unit of output, subject to two constraints. First, it must be financially feasible (projected cash flow requirements including debt service must be met annually); secondly, the net present value of an acceptable return on equity must be zero. The output is a schedule of real (constant dollar) full recovery ticket costs over time, and a single number for comparative sensitivity analyses.

Consistent with the study perspective, it was assumed that the operator of a high-speed passenger system would be quasi-governmental or government-backed. Late 1979 market rates of 15 per cent for equity and 11.5 per cent for debt, selected as being appropriate and consistent with the 9 per cent general inflation rate, were applied to an assumed 50 per cent debt financing repaid in equal installments over the system life.

TABLE 2

ISR CAPITAL AND OPERATING COSTS, STATUS QUO SCENARIO ($1978 millions)

Initial Construction Costs								
Year	Land	Civil Construction	Signals & Communica-tions	Stations & Buildings	Rolling Stock and Motive Power	Engineering	Contingency	Total
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	5.00	0.00	5.00
1982	0.81	1.26	0.00	0.00	11.34	12.80	3.26	29.48
1983	0.81	50.75	0.00	0.00	0.00	9.81	5.91	67.28
1984	0.00	100.34	0.00	3.68	0.00	5.46	12.17	121.65
1985	0.00	191.80	36.91	16.00	53.60	15.66	36.56	350.53
1986	0.00	157.99	36.91	19.09	129.93	18.06	38.41	400.39
Total	1.63	502.13	73.82	38.78	194.87	66.79	96.32	974.33

Ongoing Capital and Operating Costs							
Year	Labour	Fuel	Materials	Other	Total Operating	Rolling Stock & Motive Power	Civil Contruc-tion
1986	24.28	6.06	14.32	1.65	74.56	0.00	0.00
1987	37.81	10.00	22.14	2.31	72.25	0.00	0.00
1988	39.20	10.91	22.79	2.24	75.14	49.85	0.00
1989	40.60	11.82	23.45	2.24	78.10	0.00	0.00
1990	41.99	12.73	24.10	3.52	82.34	1.34	0.00
1991	43.05	13.03	24.63	3.52	84.23	0.00	0.00
1992	44.10	13.34	25.15	3.52	86.12	0.00	0.00
1993	45.16	13.65	25.68	3.52	88.00	47.55	0.00
1994	46.22	13.95	26.20	3.68	90.06	0.00	0.00
1995	47.27	14.26	26.73	3.54	91.80	1.46	28.50
1996	48.10	14.60	27.09	3.52	93.31	0.00	0.00
1997	48.92	14.95	27.45	6.90	98.21	0.00	0.00
1998	49.74	15.29	27.81	6.90	99.74	32.43	0.00
1999	50.56	15.63	28.18	7.09	101.46	0.00	0.00
2000	51.39	15.97	28.54	2.44	98.34	4.18	1.85
2001	52.21	16.32	28.90	4.27	101.70	0.00	0.00
2002	53.03	16.67	29.26	4.08	103.04	0.00	0.00
2003	53.86	17.01	29.63	4.08	104.58	31.95	0.00
2004	54.68	17.36	29.99	4.08	106.11	0.00	0.00
2005	55.50	17.70	30.35	4.08	107.64	1.46	0.00
2006	56.29	18.06	30.75	4.08	109.19	0.00	0.00
2007	57.09	18.42	31.15	4.27	110.92	0.00	0.00
2008	57.88	18.77	31.54	4.08	112.28	29.27	0.00
2009	58.68	19.13	31.94	7.48	117.23	0.00	0.00
2010	59.47	19.49	32.33	7.48	118.78	1.55	0.00
2011	59.98	19.71	32.54	7.48	119.72	0.00	0.00
2012	60.50	19.94	32.75	2.46	115.64	0.00	0.00
2013	61.01	20.16	32.96	4.08	118.21	27.07	0.00
2014	61.52	20.38	33.17	4.08	119.15	0.00	0.00
2015	62.04	20.60	33.37	4.08	120.10	4.28	0.00

5.2 Results and Interpretation

A typical cash flow output from MRAIL for the Intermediate Speed Railway system is shown in Table 7. This summarizes cash flow requirements by year and type and generates a full-recovery cost per thousand passenger-kilometres in constant (1978) dollars.

The passenger-kilometre cost was further reduced to ticket costs for each of the ten city pairs according to the tapered ticket price structure used by VIA Rail Canada. These unit costs are shown in Table 8.

The results for the status quo scenario are illustrated in Figure 3. Unfortunately, their interpretation is generally complicated. The apparent superiority of the high-speed electrified system (HSR) over the intermediate-speed diesel (ISR) is distinct, but not substantial.

TABLE 3

HSR CAPITAL AND OPERATING COSTS, STATUS QUO SCENARIO ($1978 millions)

Initial Construction Costs									
Year	Land	Civil Construction	Power System	Signals & Communications	Stations & Buildings	Rolling Stock and Motive Power	Engineering	Contingency	Total
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	10.00
1982	16.11	1.88	0.00	0.00	0.00	12.24	22.39	8.00	60.63
1983	16.11	116.86	0.00	0.00	0.00	0.00	17.78	21.00	171.74
1984	8.05	135.36	25.76	0.00	3.82	0.00	9.08	23.44	205.51
1985	0.00	211.32	64.39	51.83	16.65	94.41	23.83	52.58	514.20
1986	0.00	123.80	38.63	51.83	20.00	225.54	24.14	48.41	532.44
Total	40.26	589.30	128.78	103.65	40.47	332.19	106.43	153.44	1,494.52

Ongoing Capital and Operating Costs							
Year	Labour	Electricity	Material	Other	Total Operating	Civil Contruction	Rolling Stock & Motive Power
1986	31.08	3.74	17.19	1.71	85.84	0.00	0.00
1987	48.63	5.09	26.60	2.36	83.48	0.00	0.00
1988	50.64	6.18	27.42	4.33	88.57	0.00	94.71
1989	52.64	6.47	28.23	4.33	91.68	0.00	0.00
1990	54.65	6.76	29.05	4.33	94.79	0.00	1.34
1991	56.08	6.97	29.62	4.54	97.22	0.00	0.00
1992	57.52	7.19	30.19	4.33	99.23	0.00	0.00
1993	58.95	7.41	30.76	4.33	101.46	0.00	70.07
1994	60.39	7.63	31.33	4.33	103.68	0.00	0.00
1995	61.82	7.85	31.91	5.05	106.63	3.13	1.46
1996	62.77	7.91	32.28	5.36	108.32	0.00	0.00
1997	63.72	7.98	32.66	7.90	112.26	0.00	0.00
1998	64.68	8.04	33.04	7.90	113.65	0.00	56.81
1999	65.63	8.11	33.41	7.98	115.04	0.00	0.00
2000	66.58	8.17	33.79	5.26	113.81	0.00	4.18
2001	67.55	8.44	34.15	5.05	115.20	0.00	0.00
2002	68.53	8.71	34.51	5.05	116.80	0.00	0.00
2003	69.50	8.98	34.87	5.05	118.40	0.00	48.01
2004	70.47	9.24	35.23	5.26	120.21	0.00	0.00
2005	71.44	9.51	35.58	6.46	123.00	0.00	1.46
2006	72.21	9.56	35.90	6.46	124.13	0.00	0.00
2007	72.98	9.60	36.21	6.46	125.26	0.00	0.00
2008	73.75	9.65	36.52	6.67	126.59	0.00	68.41
2009	74.52	9.69	36.83	7.93	128.98	0.00	0.00
2010	75.29	9.74	37.15	7.93	130.11	0.00	1.55
2011	76.01	9.78	37.41	7.93	131.14	0.00	0.00
2012	76.74	9.82	37.67	6.46	130.69	0.00	0.00
2013	77.46	9.86	37.94	6.46	131.72	0.00	48.80
2014	78.19	9.90	38.20	6.67	132.95	0.00	0.00
2015	78.91	9.94	38.46	6.46	133.77	0.00	4.28

Certainly, there is insufficient advantage to justify a design choice. Definition of the respective systems was arbitrary. Perhaps electric power will prove the key factor, perhaps it is shared versus exclusive right-of-way, or then again train speed might prove more important.

6. CONCLUSIONS

Despite the uncertainties, one thing is clear. For this corridor, a high-speed ground system enjoys a substantial and growing advantage over the air mode. In this respect, HSR enjoys an advantage over ISR, for it is forecast to attract a substantially larger number of travellers who would otherwise patronize air. Even this interpretation is difficult, however, since air is the existing system and should be treated incrementally. While the effect of intermediate speed rail is below the level where the efficiency of the air system is significantly undermined, the HSR is forecast to influence load factor, aircraft size and schedule balance to the extent that the unit costs borne by, and on behalf of, the remaining air patronage would rise substantially. This is a legitimate charge

TABLE 4

CAPITAL AND OPERATING COSTS, AIR, STATUS QUO SCENARIO NO NEW GROUND SYSTEM IN PLACE ($1978 millions)

	Carrier Costs					Governmental Costs	
	Capital	Operating					
Year	Aircraft	Labour	Materials	Other	Fuel	Operations and Maintenance	Major* Infra-structure
1980	-	-	-	-	-	-	0
1981	-	-	-	-	-	-	17.00
1982	-	-	-	-	-	-	25.00
1983	-	-	-	-	-	-	60.00
1984	-	-	-	-	-	-	17.00
1985	-	-	-	-	-	-	26.00
1986	473.668	41.31	16.83	16.20	42.87	70.870	44.00
1987	31.418	44.00	17.81	17.24	45.71	74.440	71.00
1988	26.583	46.31	18.73	18.14	48.12	78.190	26.00
1989	10.473	47.32	19.38	18.58	49.07	82.130	26.00
1990	24.165	49.45	20.30	19.42	51.25	86.260	139.00
1991	29.000	51.94	21.22	20.38	53.88	89.630	165.00
1992	18.528	53.58	21.96	21.04	55.56	93.140	204.00
1993	20.945	55.43	22.76	21.77	57.45	96.770	150.00
1994	24.165	57.54	23.64	22.60	59.64	100.560	250.00
1995	26.583	59.86	24.58	23.51	62.04	104.480	317.00
1996	47.528	63.82	25.72	24.99	66.35	106.930	42.00
1997	10.473	64.77	26.20	25.38	67.29	109.430	68.00
1998	0.000	64.87	26.50	25.46	67.29	111.990	43.00
1999	18.528	66.48	27.14	26.09	68.97	114.610	0
2000	10.473	67.44	27.65	26.48	69.92	117.300	0
2001	10.473	68.37	28.09	26.86	70.87	119.490	0
2002	8.055	69.12	28.50	27.17	71.60	121.730	0
2003	10.473	70.06	28.95	27.55	72.54	124.000	0
2004	37.656	73.16	29.89	28.71	75.90	126.320	0
2005	20.445	74.96	30.55	29.41	77.79	128.680	26.00
2006	473.668	75.04	30.79	29.47	77.79	130.780	26.00
2007	41.891	75.98	31.23	29.85	78.74	132.910	39.00
2008	37.056	76.91	31.67	30.23	81.58	135.070	65.00
2009	31.418	78.70	32.31	30.91	81.58	137.270	104.00
2010	24.165	78.79	32.57	30.98	81.58	139.500	0
2011	29.000	78.87	32.80	31.05	81.58	141.440	0
2013	18.528	78.95	33.03	31.11	85.45	143.410	0
2013	63.639	82.50	34.03	32.43	86.91	145.400	0
2014	40.276	83.89	34.55	32.97	87.85	147.420	0
2015	37.056	84.82	34.98	33.34	87.85	149.470	17.00

* Major project infrastructure expenditures apply to both corridor and non-corridor traffic, and cannot be divided without the imposition of an allocation scheme. However, this does not adversely affect the analysis, since the changes in airport capital expenditures resulting from changes in corridor traffic can be identified, and for the evaluation of alternatives, the differences between alternatives are more relevant than the absolute cost numbers.

against the rail system, but even so, the HSR superiority persists.

FOOTNOTES

1 One curve on the HSR system, at the point where the route crosses Riviere des Mille Iles, also carries a speed restriction, since further straightening, while technically feasible, would have been cost-ineffective. The increase in transit time is less than one minute.

2 See R. W. Lake, C. Schwier, J. A. Macdonald, "Evaluation of Modal Alternatives on the Basis of Transportation Unit Cost Schedules," **Logisitics and Transportation Review**, Vol. 15, No. 12.

TABLE 5

CAPITAL AND OPERATING COSTS, AIR, STATUS QUO SCENARIO IRS SYSTEM IN PLACE ($1978 millions)

	Carrier Costs					Governmental Costs	
	Capital	Operating					
Year	Aircraft	Labour	Materials	Other	Fuel	Operations and Maintenance	Major Infra-structure
1980	-	-	-	-	-	-	0.00
1981	-	-	-	-	-	-	17.00
1982	-	-	-	-	-	-	25.00
1983	-	-	-	-	-	-	43.00
1984	-	-	-	-	-	-	0.00
1985	-	-	-	-	-	-	43.00
1986	452.722	39.36	15.75	15.40	40.97	64.850	43.00
1987	-17.804	37.40	14.59	14.57	39.08	58.190	65.00
1988	20.945	39.22	15.32	15.28	40.97	61.210	109.00
1989	0.000	39.34	15.68	15.39	40.97	64.290	175.00
1990	10.473	40.33	16.27	15.79	41.92	67.700	0.00
1991	10.473	41.28	16.76	16.18	42.87	70.280	0.00
1992	0.000	41.39	17.07	16.27	42.87	72.950	0.00
1993	41.891	44.90	18.15	17.59	46.66	75.720	0.00
1994	5.638	45.48	18.59	17.85	47.17	78.600	100.00
1995	18.528	47.10	19.27	18.49	48.85	81.600	100.00
1996	18.528	48.68	19.84	19.10	50.53	83.600	100.00
1997	0.000	48.77	20.08	19.17	50.53	85.660	150.00
1998	10.473	49.70	20.52	19.54	51.47	87.760	250.00
1999	34.638	52.60	21.39	20.63	54.61	89.920	317.00
2000	0.000	52.60	21.65	20.70	54.61	92.130	25.00
2001	18.528	54.26	22.18	21.30	56.29	93.760	43.00
2002	0.000	54.33	22.37	21.35	56.29	95.410	0.00
2003	18.528	55.90	22.90	21.95	57.96	97.100	17.00
2004	10.473	56.82	23.29	22.31	58.91	98.810	25.00
2005	34.638	59.70	24.12	23.39	62.04	100.560	43.00
2006	431.777	59.77	24.31	23.44	62.04	102.180	0.00
2007	0.000	59.83	24.50	23.49	62.04	103.820	0.00
2008	31.418	60.75	24.69	23.85	62.99	105.500	0.00
2009	45.111	64.48	25.90	25.23	67.08	107.200	0.00
2010	10.473	64.55	26.10	25.29	67.08	108.930	0.00
2011	10.473	64.61	26.28	25.34	67.08	110.440	0.00
2012	10.473	65.52	26.65	25.70	68.02	111.980	0.00
2013	49.946	66.24	26.98	25.98	68.75	113.540	26.00
2014	16.110	67.15	27.35	26.34	69.70	115.120	26.00
2015	18.528	67.22	27.54	26.39	69.70	116.730	39.00

TABLE 6

CAPITAL AND OPERATING COSTS, AIR, STATUS QUO SCENARIO HSR SYSTEM IN PLACE ($1978 millions)

Year	Carrier Costs					Governmental Costs	
	Capital	Operating					
	Aircraft	Labour	Materials	Other	Fuel	Operations and Maintenance	Major Infra-structure
1980	-	-	-	-	-	-	0.00
1981	-	-	-	-	-	-	17.00
1982	-	-	-	-	-	-	25.00
1983	-	-	-	-	-	-	43.00
1984	-	-	-	-	-	-	0.00
1985	-	-	-	-	-	-	26.00
1986	405.194	30.05	13.57	13.64	36.67	53.580	26.00
1987	128.044	21.81	7.91	8.40	23.04	28.410	56.00
1988	0.000	21.87	8.09	8.45	23.04	29.950	82.00
1989	0.000	21.93	8.26	8.50	23.04	31.430	130.00
1990	8.055	22.65	8.60	8.78	23.77	33.030	44.00
1991	16.110	24.01	9.03	9.30	25.23	34.280	71.00
1992	0.000	24.06	9.19	9.34	25.23	35.590	0.00
1993	26.583	26.27	9.82	10.17	27.63	36.940	0.00
1994	0.000	26.33	9.99	10.21	27.63	38.340	0.00
1995	26.583	28.55	10.64	11.04	30.04	39.800	0.00
1996	0.000	28.58	10.74	11.07	30.04	40.730	0.00
1997	10.473	29.47	11.04	11.41	30.99	41.670	0.00
1998	10.473	30.36	11.35	11.75	31.93	41.640	0.00
1999	0.000	30.40	11.46	11.78	31.93	43.630	100.00
2000	31.418	32.99	12.15	12.73	34.78	44.640	100.00
2001	0.000	33.03	12.25	12.76	34.78	45.510	100.00
2002	0.000	33.06	12.35	12.79	34.78	46.390	150.00
2003	0.000	33.10	12.46	12.82	34.78	47.290	250.00
2004	10.473	33.99	12.75	13.16	35.72	48.210	300.00
2005	0.000	34.02	12.86	13.19	35.72	49.140	0.00
2006	254.554	34.06	12.95	13.21	35.72	49.910	0.00
2007	10.473	34.94	13.23	13.54	36.67	50.700	0.00
2008	5.638	35.43	13.43	13.74	37.18	51.490	0.00
2009	0.000	35.46	13.52	13.76	37.18	51.300	0.00
2010	29.000	37.19	14.00	14.40	39.08	53.130	0.00
2011	16.110	37.22	14.08	14.43	39.08	53.880	0.00
2012	0.000	37.25	14.17	14.45	39.08	54.640	0.00
2013	26.583	37.29	14.26	14.48	39.08	55.420	0.00
2014	0.000	37.32	14.36	14.50	39.08	56.200	0.00
2015	26.583	37.35	14.45	14.53	39.08	57.000	0.00

TABLE 7

MRAIL CASH-FLOW SUMMARY, ISR SYSTEM
STATUS QUO SCENARIO

HIGH SPEED PASSENGER STUDY

CANADIAN INSTITUTE OF GUIDED GROUND TRANSPORT, QUEEN'S UNIVERSITY

UNIT COSTS IN TERMS OF THOUSANDS OF WEIGHTED PASSENGER-KM

ESCALATION: 0.090 EQUITY CHARGE: 0.150 INTEREST RATE: 0.115 TAX RATE: 0.000 D:E RATIO: 1.0
COSTS ESCALATED FROM 1978 LEVELS: ALL CASH-FLOWS GIVEN IN LEGAL DOLLARS MILLIONS

YEAR	GROSS REVENUE	OPERATIONS COST	DEBT CHANGES	TOTAL DEBT	INTEREST	CAPITAL INVESTED	CCA TAX SAVINGS	COST INDEX	EQUITY FLOW	UNIT COST	COST $1978
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.090	0.000	0.000	0.000
1980	0.00	0.00	3.00	3.00	0.00	6.00	0.00	1.188	-3.000	0.000	0.000
1981	0.00	0.00	19.37	22.37	0.34	38.40	0.00	1.295	-19.371	0.000	0.000
1982	0.00	0.00	48.18	70.55	2.57	93.79	0.00	1.412	-48.183	0.000	0.000
1983	0.00	0.00	95.73	166.28	8.11	183.35	0.00	1.539	-95.731	0.000	0.000
1984	0.00	0.00	295.28	461.56	19.12	571.43	0.00	1.677	-295.277	0.000	0.000
1985	0.00	0.00	383.24	844.80	53.08	713.39	0.00	1.828	-383.237	0.000	0.000
1986	131.14	97.93	-28.16	816.64	97.15	0.00	0.00	1.993	-92.100	86.621	43.472
1987	339.64	168.11	-28.16	788.48	93.91	0.00	0.00	2.172	49.455	104.313	48.026
1988	374.09	192.35	-28.16	760.32	90.67	118.01	0.00	2.367	-55.114	106.425	44.9[illegible]
1989	414.75	219.98	-28.16	732.16	87.44	0.00	0.00	2.580	79.170	108.801	42.164
1990	466.24	254.86	-28.16	704.00	84.20	3.75	0.00	2.813	95.273	112.186	39.8[illegible]
1991	511.19	286.39	-28.16	675.84	80.96	0.00	0.00	3.066	115.693	118.222	38.561
1992	562.06	321.64	-28.16	647.68	77.72	0.00	0.00	3.342	134.539	124.931	37.353
1993	619.56	361.04	-28.16	619.52	74.48	173.56	0.00	3.642	-17.689	132.357	36.337
1994	685.13	405.71	-28.16	591.36	71.24	0.00	0.00	3.970	180.010	140.683	35.43[illegible]
1995	757.82	454.31	-28.16	563.20	68.01	127.93	0.00	4.328	79.408	149.560	34.559
1996	834.50	507.39	-28.16	535.04	64.77	0.00	0.00	4.717	234.185	160.759	34.080
1997	937.72	563.93	-28.16	506.88	61.53	0.00	0.00	5.142	264.104	176.330	34.29[illegible]
1998	1035.31	651.41	-28.16	478.72	58.29	181.75	0.00	5.604	115.698	190.034	33.9[illegible]
1999	1145.52	727.70	-28.16	450.56	55.05	0.00	0.00	6.109	334.608	205.253	33.59[illegible]
2000	1236.31	780.32	-28.16	422.40	51.81	39.83	0.00	6.659	336.183	216.252	32.477
2001	1382.82	863.87	-28.16	394.24	48.58	0.00	0.00	7.258	422.220	236.097	32.530
2002	1530.78	984.00	-28.16	366.08	45.34	0.00	0.00	7.911	473.283	255.343	32.277
2003	1696.79	1096.65	-28.16	337.92	42.10	275.51	0.00	8.623	254.178	276.756	32.095
2004	1881.28	1222.30	-28.16	309.76	38.86	0.00	0.00	9.399	591.960	300.284	31.948
2005	2056.33	1361.76	-28.16	281.60	35.62	14.91	0.00	10.245	645.889	326.091	31.829
2006	2314.07	1516.90	-28.16	253.44	32.38	0.00	0.00	11.167	736.627	354.484	31.743
2007	2569.06	1691.50	-28.16	225.28	29.15	0.00	0.00	12.172	820.253	385.976	31.710
2008	2847.35	1880.71	-28.16	197.12	25.91	388.35	0.00	13.269	524.231	419.778	31.639
2009	3207.51	2142.51	-28.16	168.96	22.67	0.00	0.00	14.462	1014.173	464.393	32.111
2010	3556.68	2393.00	-28.16	140.80	19.43	24.51	0.00	15.763	1101.578	506.001	32.100
2011	3929.74	2636.06	-28.16	112.64	16.19	0.00	0.00	17.182	1249.333	549.691	31.99[illegible]
2012	4247.41	2821.49	-28.16	84.48	12.95	0.00	0.00	18.728	1384.810	584.560	31.21[illegible]
2013	4726.93	3154.96	-28.16	56.32	9.72	552.61	0.00	20.414	981.491	640.332	31.367
2014	5222.25	3489.74	-28.16	28.16	6.48	0.00	0.00	22.251	1697.875	696.859	31.318
2015	5769.14	3859.52	-28.16	-0.00	3.24	103.93	0.00	24.254	1774.286	758.598	31.277

TABLE 8

FULL COST RECOVERY UNIT TICKET COSTS, ISR SYSTEM, STATUS QUO SCENARIO (all costs in $1978)

TICKET COSTS DEFLATED TO 1978 AT 0.090 ESCALATION, 0.150 EQUITY AND 0.115 DEBT

	TNTO KGTN	TNTO OTTA	TNTO MRBL	TNTO MTRL	KGTN OTTA	KGTN MRBL	KGTN MTRL	OTTA MRBL	OTTA MTRL	MRBL MTRL
CONST $	10.51	15.65	20.24	21.99	6.78	11.44	13.19	6.37	8.12	3.46
1986	11.15	16.60	21.46	23.31	7.19	12.13	13.98	6.75	8.61	3.67
1987	13.36	19.89	25.72	27.94	8.62	14.54	16.75	8.09	10.31	4.40
1988	12.73	18.94	24.50	26.61	8.21	13.85	15.96	7.71	9.82	4.19
1989	12.06	17.96	23.22	25.23	7.78	13.13	15.13	7.31	9.31	3.97
1990	11.49	17.10	22.11	24.02	7.41	12.50	14.40	6.96	8.87	3.78
1991	11.06	16.46	21.29	23.12	7.13	12.03	13.87	6.70	8.54	3.64
1992	10.66	15.87	20.52	22.29	6.87	11.60	13.37	6.46	8.23	3.51
1993	10.31	15.35	19.86	21.57	6.65	11.22	12.93	6.25	7.96	3.39
1994	10.01	14.90	19.26	20.93	6.45	10.89	12.55	6.06	7.73	3.29
1995	9.76	14.54	18.80	20.42	6.30	10.62	12.25	5.92	7.54	3.21
1996	9.57	14.25	18.43	20.02	6.18	10.42	12.01	5.80	7.39	3.15
1997	9.50	14.14	18.29	19.86	6.13	10.33	11.91	5.76	7.33	3.13
1998	9.33	13.89	17.97	19.52	6.02	10.15	11.70	5.65	7.20	3.07
1999	9.18	13.67	17.67	19.20	5.92	9.99	11.51	5.56	7.09	3.02
2000	8.94	13.31	17.21	18.70	5.77	9.73	11.21	5.42	6.90	2.94
2001	8.82	13.13	16.98	18.44	5.69	9.60	11.06	5.34	6.81	2.90
2002	8.72	12.98	16.79	18.24	5.62	9.49	10.94	5.28	6.73	2.87
2003	8.63	12.85	16.62	18.06	5.57	9.39	10.83	5.23	6.67	2.84
2004	8.57	12.75	16.49	17.92	5.53	9.32	10.74	5.19	6.61	2.82
2005	8.54	12.72	16.45	17.87	5.51	9.29	10.71	5.18	6.60	2.81
2006	8.47	12.60	16.30	17.71	5.46	9.21	10.62	5.13	6.54	2.79
2007	8.40	12.50	16.17	17.56	5.42	9.14	10.53	5.09	6.48	2.76
2008	8.35	12.42	16.07	17.45	5.38	9.08	10.47	5.06	6.44	2.75
2009	8.33	12.40	16.04	17.43	5.37	9.07	10.45	5.05	6.43	2.74
2010	8.28	12.33	15.95	17.32	5.34	9.01	10.39	5.02	6.40	2.73
2011	8.24	12.26	15.86	17.23	5.31	8.96	10.33	4.99	6.36	2.71
2012	8.15	12.14	15.69	17.05	5.26	8.87	10.22	4.94	6.29	2.69
2013	8.12	12.08	15.62	16.97	5.23	8.83	10.18	4.92	6.27	2.67
2014	8.09	12.04	15.58	16.92	5.22	8.80	10.15	4.90	6.25	2.66
2015	8.06	11.99	15.51	16.85	5.20	8.77	10.10	4.88	6.22	2.65

COMPARISON OF FULL-RECOVERY COST PER 1000 PASSENGER-KILOMETRES FOR STATUS QUO SCENARIO

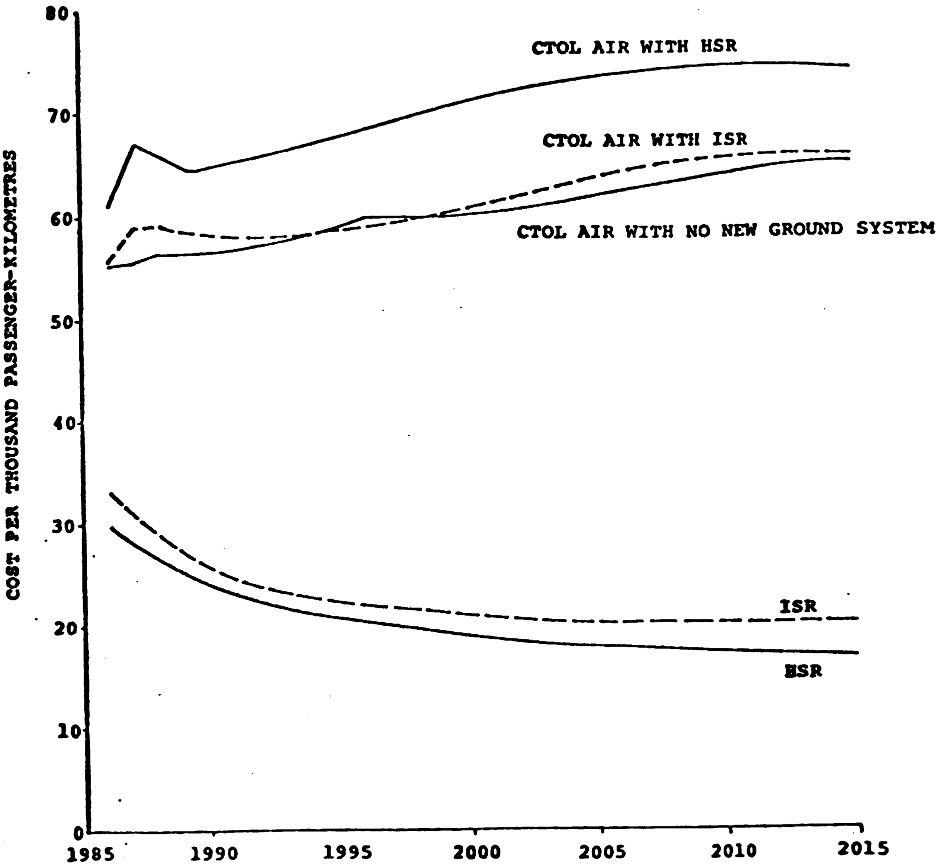

FIGURE 3