CLASSIFICATION DETERMINATIONS

The quantitative values produced by SAS evaluate the functional classification of public roads with apparent high accuracy. When calibrated against the current official qualitatively determined classification, the SAS rural model replicates rural functional classifications at a better than 90 percent match. The apparent accuracies of the SAS urban and urbanized models are also very fine, although slightly lower. However, the issue of accuracy is not easily addressed.

If a quantitative evaluation model fails to perfectly simulate a qualitative evaluation, any apparent inaccuracies may be due to an error in either of the evaluations. That is, the original qualitative classification may have been incorrect or the quantitative model may have been incorrectly designed and be insensitive to the true classification. The likelihood of absolute perfection in either type of evaluation is improbable. Thus Florida law mitigates against errors of evaluation by requiring a forum for resolution. The paragraph of Florida law that requires that classification evaluations by the department "shall utilize quantitative criteria" also requires that "the Department shall hold a full public hearing . . . as an integral part of its evaluation procedures in order to receive public input prior to making any determination of classification."

Taking into account both statutory evaluation requirements, the department intends to utilize the SAS quantitative criteria as its principal functional classification tool. It will, however, preserve the responsibility to consider other significant data as is necessary to assure that correct classification determinations are made.

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The Development of Transportation Cost Functions for Three Intercity Corridors of Costa Rica

EDWARD C. SULLIVAN

ABSTRACT

The findings of a cooperative University of California-University of Costa Rica study of the cost characteristics of transportation technology alternatives in three principal corridors of Costa Rica are summarized. The cost functions developed quantify the total fixed and variable costs of moving freight in each corridor as well as the corresponding energy consumption and the cost breakdown between domestic and foreign expenditures. Conclusions are drawn regarding the implications of these findings for the future development of intercity transportation in Costa Rica.

Selected results are presented of a study on alternative transportation technologies applied to interregional transportation needs in Costa Rica (1). The economic and physical consequences of several alternative rail and highway systems, including several systems currently in place, were estimated in order to provide a quantitative basis for future transportation investment decisions. The analysis was based on the particular transportation requirements and resource constraints of concern to Costa Rica.

The results of the study are cost and resource use relationships that can be used to compare different transportation improvements in light of the quantities of goods to be transported now or in the future. It is expected that the quantitative relationships from this study will be used with alternative planning scenarios concerning the future economic structure of Costa Rica in order to help define a comprehensive long-term program for orderly national development.

In order to concentrate on a limited number of issues of practical significance to Costa Rica, attention focused on the costs and physical consequences of alternative transportation technologies in three important transportation corridors of Costa Rica (Figure 1):

1. San José-Puerto Limón (from the national capital to the major Atlantic coast port); this mountainous corridor is now served by both rail and highway;
2. San José-Puerto Caldera (from the capital to the major Pacific coast port); this mountainous corridor is also now served by both rail and highway; and
3. Puerto Caldera-Liberia (parallel to the Pa-

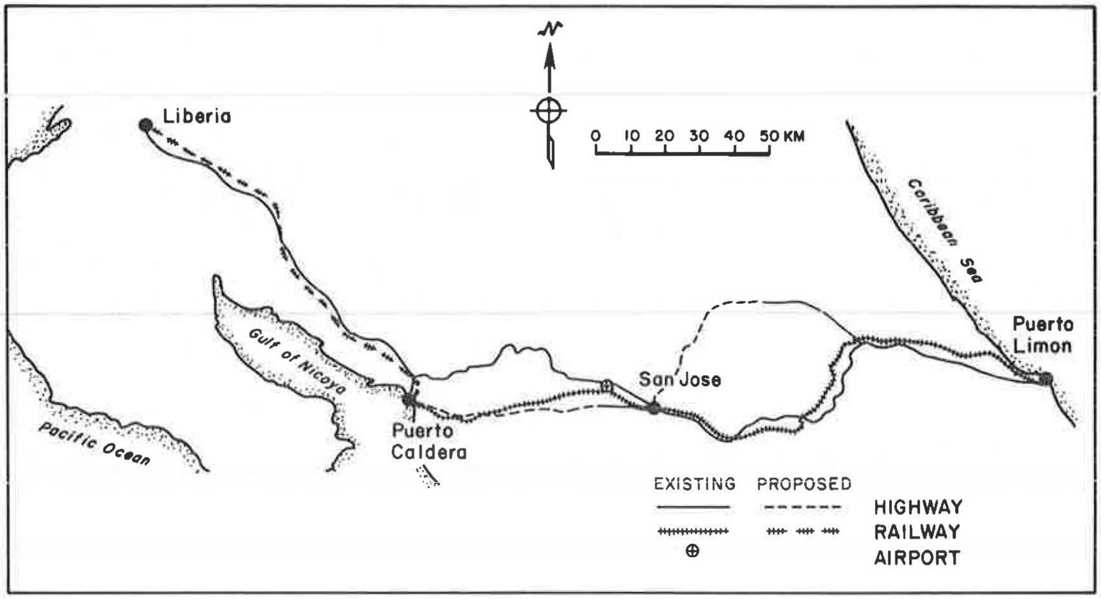

FIGURE 1 Overview of transportation alternatives.

cific coastline, north toward Nicaragua); this corridor is now served only by highway and is the location of anticipated development in agriculture and other sectors.

In each case, several transportation technologies were considered, including the existing systems and alternatives involving significant improvement to the existing facilities. Because the study emphasized transportation service to economic development, the analysis dealt only with the transport of freight. A wide range of possible traffic volumes was considered, ranging from current levels to traffic volumes approximately 10 times those now accommodated.

The study used a microcomputer-based transportation supply model called analysis of corridors (ANCOR) recently developed for estimating economic cost functions in national transportation planning. This model uses vehicle simulation and engineering cost methods to estimate quantities of resources consumed in the process of producing transportation. Resource consumption, of interest in itself, is converted to financial costs on the basis of productivity rates and factor prices, which incorporate components of domestic expenditures and foreign exchange.

TECHNICAL APPROACH

In recognition of the need to limit consideration to a small number of practical alternatives that have a reasonable chance of implementation in Costa Rica, it was decided to perform the applied-technology analysis for the following specific alternatives:

1. San José-Puerto Limón
   a. Existing rail system (nonelectric, poor alignment),
   b. Existing electrified rail line,
   c. Existing rail line with significant alignment improvements,
   d. Electrified rail line with significant alignment improvements,
   e. Existing highway,
   f. Existing highway with significant alignment improvements,
   g. New highway currently under construction.
2. San José-Puerto Caldera
   a. Existing rail system (electrified, fair alignment),
   b. Existing rail system with significantly improved alignment,
   c. Existing railway using diesel-electric propulsion (abandon electrification),
   d. Improved railway alignment using diesel-electric propulsion,
   e. Existing highway,
   f. Existing highway with improvements,
   g. New highway on separate alignment.
3. Puerto Caldera-Liberia
   a. Existing highway,
   b. Existing highway with improvements,
   c. New electrified rail system,
   d. New rail system with diesel-electric propulsion.

The detailed data characterizing the various alternatives are described in the final report of the study (1).

The study developed for each of the foregoing alternative technologies a family of cost curves indicating how costs and resource consumption vary with increasing amounts of freight to be transported. Figure 2 shows the general form of such a cost curve. The horizontal axis represents a multiple of the total volume of rail freight traffic transported in the particular corridor in 1981. The vertical axis illustrated here represents total annual cost. In the actual results, a variety of cost types (vertical axes) appear for each corridor and technological alternative. These correspond to the different cost components of interest, such as total fixed and variable costs, total domestic and foreign exchange costs, and vehicle energy consumption. Note that when fixed costs are included in a cost curve, the initial capital outlay is converted to an annualized value by means of the capital recovery factor.

Figure 3 shows a typical corridor description required to perform a cost analysis with the ANCOR model. Base payload quantities for each of the three corridors are presented in Table 1 and average trip

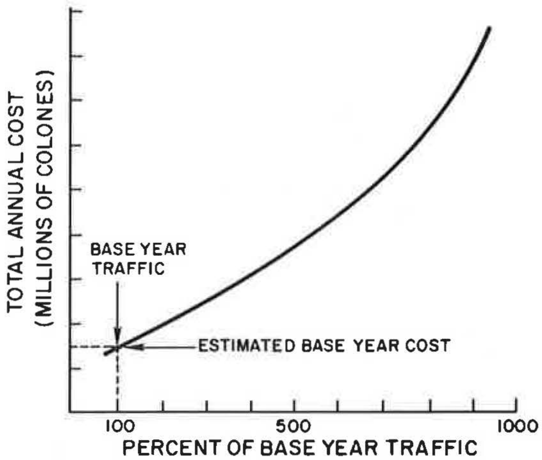

FIGURE 2 General form of total-cost curve.

lengths in Table 2. The quantities listed for the San José-Limón and San José-Puerto Caldera corridors are the 1981 reported rail volumes (2). The base volume for the Puerto Caldera-Liberia corridor was taken to be one-half of the 1981 volume between San José and Puerto Caldera.

Finally, Figure 4 shows the table of factor prices and construction productivities used to estimate all of the cost curves developed in this study. Note that factor prices and productivities are related to six different labor types and to eight major physical resources (energy sources and construction materials). These data represent 1982 prices and conditions in Costa Rica and were taken primarily from a University of Costa Rica study (3) supplemented through personal contacts.

The cost-estimation procedure and formulations of the various submodels involved in the estimation of cost for both vehicles and way are documented elsewhere (4,5).

TECHNICAL OBJECTIVES

The overall objective of the study was to develop a family of cost curves for different transportation technologies, including existing systems. All alternatives are serious candidates for implementation in the three selected corridors of Costa Rica. Among the cost curves developed for each technology are the following:

- Total annual cost (annualized fixed cost for vehicles and way plus total annual variable cost) as a function of annual payload,
- Annual vehicle operating cost as a function of annual payload,
- Vehicle energy consumption as a function of annual payload, and
- Total annual cost separated into domestic and foreign exchange components for selected alternatives.

```
##################################
Corridor:
SAN JOSE-BRASIL (NEW 4 LANE HWY)
##################################

==================================
      CORRIDOR DESCRIPTION
==================================

Number of Segments: 1
Number of Entry/Exit Points: 4

********** SEGMENT  1 **********
Length:     17 km

Topography:  ROLLING

Vegetation:  FOREST

Rainfall:    MEDIUM

Soil Type:    STABLE SOIL

Seismically Active Area

Primary Existing Land Use:
 URBAN FRINGE-LIGHT DEVELOPMENT

Span Length to Bridge Obstructions: 250 m

Beginning Elevation: 1142 m
End Elevation: 840 m

Design Speed: 100 km/hr

Representative Daily Volume of Other
  Vehicles: 6000 veh/day

Average Expected Delay from Other Than
  Congestion: .05 hrs/veh

**********************************

NO TRANSPORTATION SYSTEM IN PLACE
```

FIGURE 3 Corridor description.

TABLE 1 Base-Year Payload Volumes

Payload Type and Description	San José-Puerto Limón[a] Forward	San José-Puerto Limón[a] Reverse	San José-Puerto Caldera[a] Forward	San José-Puerto Caldera[a] Reverse	Puerto Caldera-Liberia[b] Forward	Puerto Caldera-Liberia[b] Reverse
5: Packaged food products (nonrefrigerated)	–	–	–	3,893	–	1,947
6: Bulk agricultural products (dry)	106,295	52,173	56,318	142,570	28,159	71,285
7: Bulk agricultural products (liquid)	–	16,922	–	539	–	269
8: Bulk industry products (dry)	149,391	12,352	28,928	97,229	14,464	48,615
9: Bulk industry products (liquid)	–	3,162	–	–	–	–
10: Wood and wood products	–	27,170	–	8,119	–	4,059
11: Heavy machinery	–	69,349	–	57,193	–	28,597
12: Packaged industrial and commercial products	1,058	26,833	287	3,123	144	1,561
13: Large fabricated structures or furniture	–	–	–	38	–	19
Total	256,744	207,961	85,533	312,704	42,767	156,352

Note: Values given in tons per year.
[a]Rail traffic reported in 1981, including bananas.
[b]Puerto Caldera-Liberia traffic arbitrarily set to 50 percent of that for San José-Puerto Caldera.

TABLE 2 Average Trip Length

Payload Type	San José-Puerto-Limon[a] Forward	San José-Puerto-Limon[a] Reverse	San José-Puerto Caldera[a] Forward	San José-Puerto Caldera[a] Reverse	Puerto Caldera-Liberia[b] Forward	Puerto Caldera-Liberia[b] Reverse
5-7, 9-13	66	63	70	73	70	73
8	66	76	70	99	70	99

Note: Values given in percentage of corridor length.

[a]Rail traffic reported in 1981, including bananas.

[b]Puerto Caldera-Liberia traffic arbitrarily set to 50 percent of that for San José-Puerto Caldera.

These results are available for use in future studies where different economic growth and transportation demand scenarios would be evaluated with respect to their total life-cycle transportation costs, energy use, and balance-of-payments implications.

RESULTS

Only the highlights of the results of this study for one corridor, that between San José and Puerto Caldera, are given here. A complete tabulation of results appears in the final report (1).

The total estimated economic costs for the existing electrified railway between San José and Puerto Caldera are shown in Figure 5. Three annualized cost curves are shown, each assuming that the entire payload being considered would be transported exclusively on trains of the stated size. In each case, the length of the train, in number of cars (wagons), is controlled by the available power of the single locomotive, based on the ruling grade of the existing railway.

Figure 6 contains a second family of cost curves for the electrified railway between San José and Puerto Caldera. In this case, the alignment of the railway is assumed to have been improved signifi-

FACTOR PRICES

Labor (colones/hr) — For Labor Type*	1	2	3	4	5	6
	12.96	17.80	225	62.50	900	30

Materials (colones/ton) — For Material Type**	1	2	3	4	5
Foreign Exchange Component:	466	13964	10660	1181	100
Domestic Expense Component:	233	3423.6	5330	319	32

Direct Propulsion (colones/)	gasoline (/liter)	diesel fuel (/liter)	electricity (/kw-hr)
Foreign Exchange Component:	21	16	1.36
Domestic Expense Component:	1.10	0.85	0.58

Land (colones/hectare) — For Land Use Category***	1	2	3	4
	30,000	40,000	2,500,000	10,000,000

Economic Discount Rate (%): 15

CONSTRUCTION PRODUCTIVITIES

Activities	Units	Labor by Type* (hours/unit) 1	2	3	4	5	6	Equipment & Supplies (colones/unit) Foreign Ex.	Domestic
Site Preparation	m^2	.0005	.0001		.00001		.000007	.223	.009
Earthwork (cut)	m^3	.050	.060		.006		.003	124.5	5.19
Earthwork (fill)	m^3	.111	0.133		.0133		.0067	252	10.51
Minor structures	lane -km	437	328		32.8		16.4	140	6
Bridge & Tunnels****	way -km	7200	3600		360		180	405,000	15,580
Surface Material Placement: Concrete	ton	0.139	0.062		.0062		.0031	100	4
Surface Material Placement: Steel	ton	0.230	0.460		.046		.0230	4,000	170
Surface Material Placement: Wood	ton	0.115	0.230		.230		.0115	2,100	85
Surface Material Placement: Asphalt	ton	0.100	0.075		.0075		.0038	125	5
Surface Material Placement: Gravel	ton	0.028	0.011		.0011		.00063	50	2
Final Site Details	m^3	.0834	0.035		.0035		.0017	25	1

*Labor Types: 1 = General (domestic) Labor; 2 = Skilled Crafts (domestic); 3 = Skilled Crafts (foreign); 4 = Professional (domestic); 5 = Professional (foreign); 6 = Administrative (domestic)

**Material Types: 1 = Concrete; 2 = Steel; 3 = Wood; 4 = Asphalt; 5 = Gravel

***Land Use Categories: 1 = Underdeveloped or Public Reserve
2 = Agricultural
3 = Urban Fringe - Lightly Developed
4 = Urban Fringe - Heavily Developed

****Major Structures' Productivities Based on Two-Lane Highway

FIGURE 4 Price and productivities.

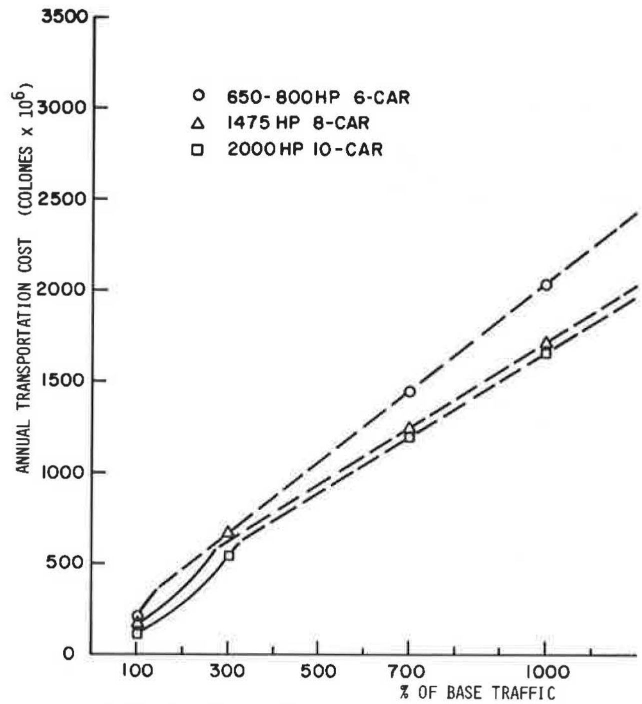

FIGURE 5 San José-Puerto Caldera rail electric technology on unimproved way.

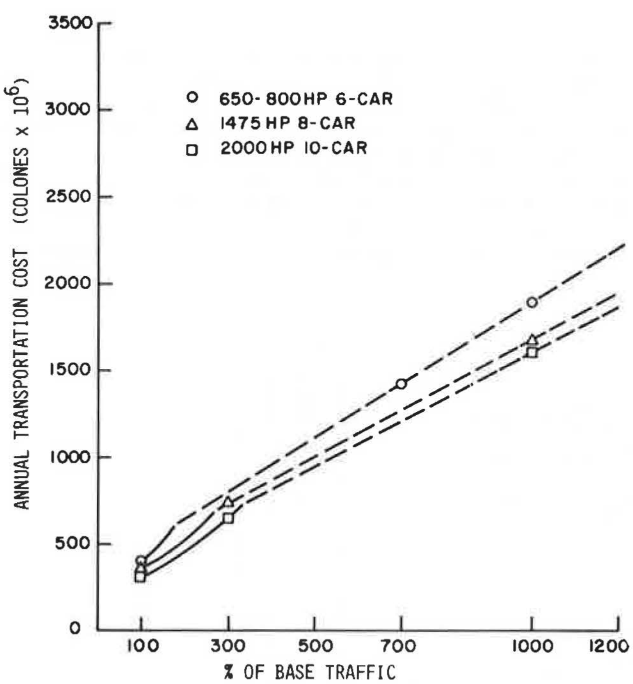

FIGURE 6 San José-Puerto Caldera rail electric technology on improved way.

cantly. The general shapes of these cost curves are similar to those of the unimproved railway; however, total costs for low traffic volumes are greater because of the construction cost of improving the way.

Other data for diesel-electric locomotives were developed for comparison only and show the logical result that the electric railway technology is more economical, particularly when the significant capital cost of electrification has already been incurred.

Figure 7 shows the family of total cost curves developed for three highway alternatives in the San José-Puerto Caldera corridor. In all cases, it is clear that the total annualized cost for highway transportation exceeds that for rail. Reconstruction of the current low-standard sections appears justified at a traffic level 5.0 times the base traffic.

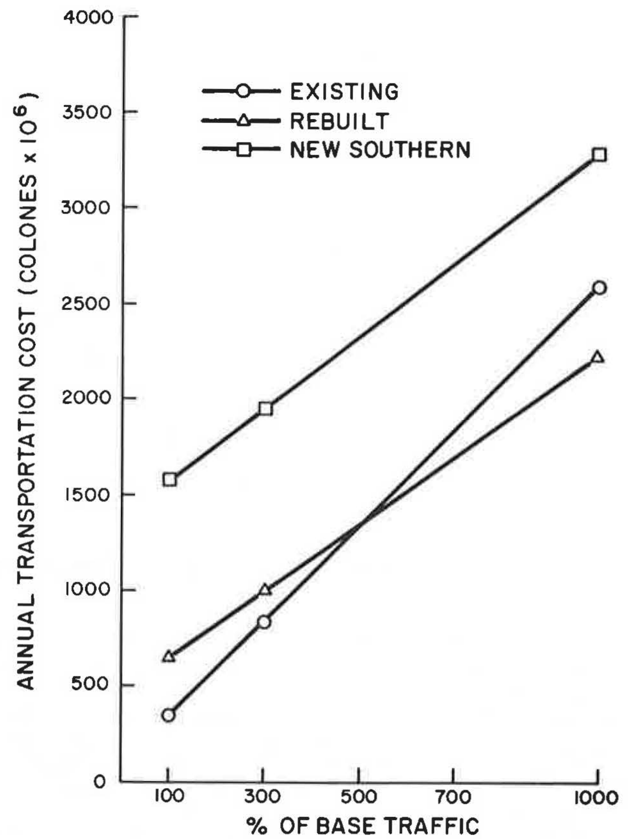

FIGURE 7 San José-Puerto Caldera highway.

Figure 8 is a composite total-cost curve showing the least-cost alternatives for freight movement in the corridor. The analysis indicates that the current electrified railway is optimum up to about 3.0 times current (1981) traffic, at which point double-tracking is economically justified. At approximately 7.5 times current traffic, substantial alignment improvements are justified.

Figure 8 includes two fiscal break-even points in addition to the economic break-even points of principal interest in this study. These fiscal break-even points indicate the traffic levels at which upgrading would be justified on the basis of capital cost savings alone. The fiscal break-even points are of particular significance to the capital expenditure side of transportation planning.

Figure 9 presents the energy intensities of the alternative technologies. The rates shown indicate only direct vehicle energy consumption. They illustrate the relative energy savings in reduced consumption per ton-kilometer of transportation that can be accomplished by various technological improvements. Improving the alignment yields approximately 10 percent energy savings, although this benefit overlooks the direct energy cost of the construction itself. Note that the energy intensities for electric and diesel propulsion alternatives have different scales and are not directly comparable.

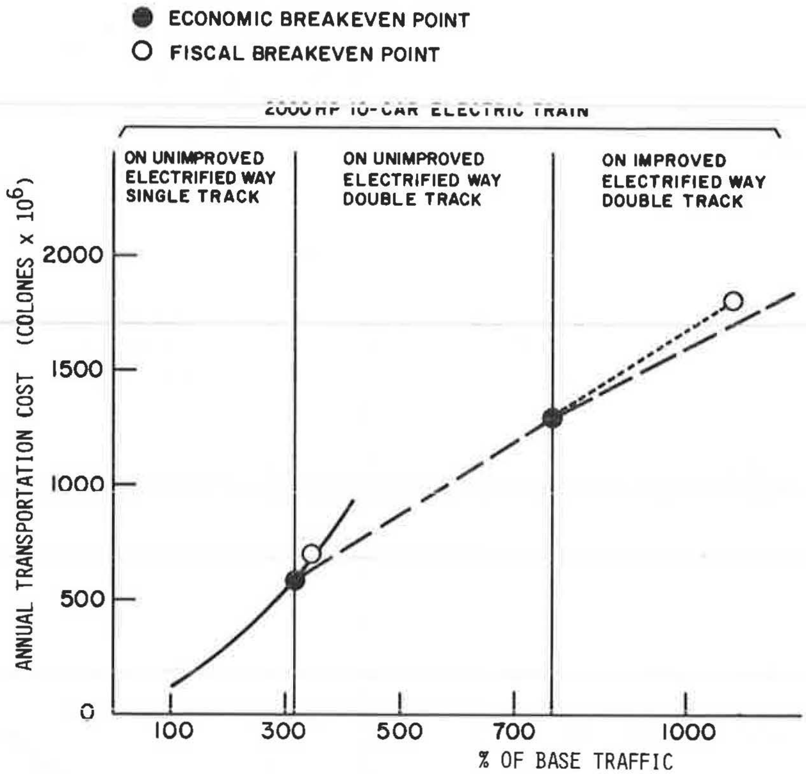

FIGURE 8 San José-Puerto Caldera corridor lowest-cost alternative.

Figures 10 and 11 show a more detailed breakdown of costs associated with a selected vehicle technology operating on the electrified railway between San José and Puerto Caldera. Figure 10 shows total lifetime fixed costs of the alternative, representing primarily the capital costs of vehicle acquisition. Note that the lifetime fixed costs include the present value of obsolete-vehicle replacement costs, which make up a significant portion of the fixed costs of all alternatives being considered. Figure 11 shows vehicle operating costs and the variable costs of railway maintenance and operations. For the alternative illustrated here, most variable costs are domestic expenditures, with the principal exceptions being the foreign expenditures for replacement parts of vehicles and other maintenance supplies.

Figures 12 and 13 show the lifetime fixed costs and annual variable costs (foreign and domestic) of

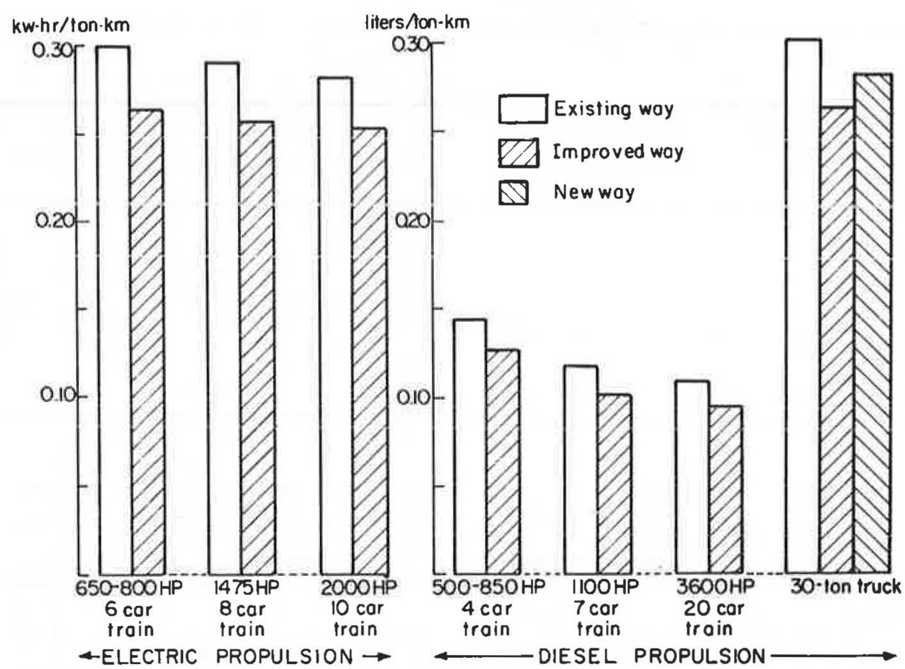

FIGURE 9 Energy intensities of alternative technologies: San José-Puerto Caldera.

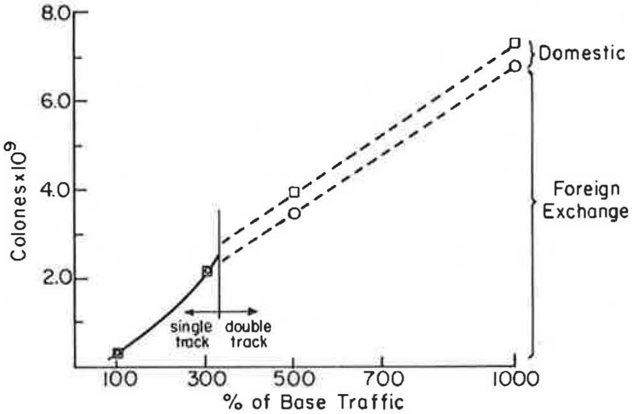

FIGURE 10 Cost breakdown (vehicles and way) for 2,000-hp, 10-car electric train on unimproved way, San José-Puerto Caldera: lifetime fixed cost.

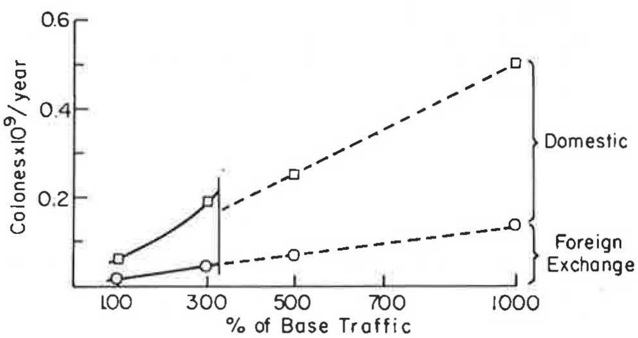

FIGURE 11 Cost breakdown (vehicles and way) for 2,000-hp, 10-car electric train on unimproved way, San José-Puerto Caldera: annual variable cost.

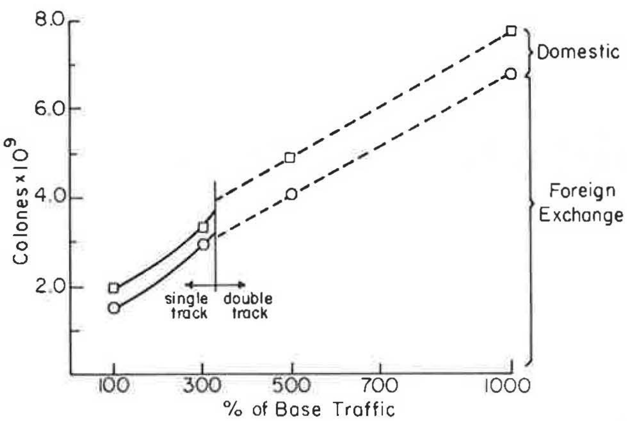

FIGURE 12 Cost breakdown (vehicles and way) for 2,000-hp, 10-car electric train on improved way, San José-Puerto Caldera: lifetime fixed cost.

significantly improving the alignment of the electrified way between San José and Puerto Caldera. Of interest is the fact that the increased fixed domestic expenditure due to railway reconstruction is relatively small compared with the foreign capital expenditure on vehicles. The operating-cost advantage of the improved way shows up as expected in both the domestic (mostly labor) and foreign exchange components of variable costs.

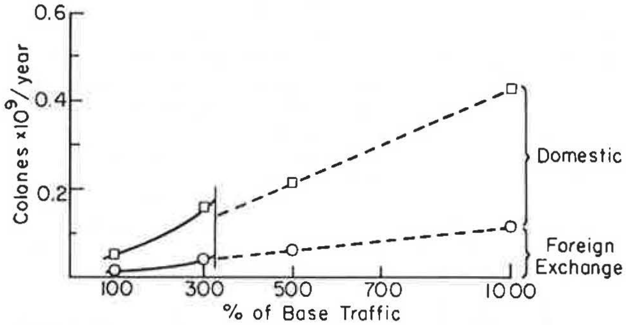

FIGURE 13 Cost breakdown (vehicles and way) for 2,000-hp, 10-car electric train on improved way, San José-Puerto Caldera: annual variable cost.

CONCLUSION

This research utilized an innovative transportation corridor cost model to explore the costs and resource consequences of several transportation technology alternatives for three major transportation corridors of Costa Rica. The output of the analysis is a collection of economic cost curves that were used to draw some initial conclusions regarding desirable directions for future transportation investment in Costa Rica. This study considered only conventional technological options that were believed to be strong candidates for adoption within the upcoming decades.

The cost curves developed in this study are valid for broad comparisons among technological options at the level of national transportation planning. They are not sufficiently accurate to be used as the basis of final decision making. These results are intended to show broad trends and comparisons, indicating the general direction in which the transportation technologies of Costa Rica should develop.

The study provided a number of specific recommendations with respect to the different technological alternatives considered in the three corridors of interest. These are documented in the final report (1).

As in all studies of this type, it is not possible to do everything that could be done. There always remain questions and opportunities for discovery that simply cannot be accommodated within the scope and resources of the study. The following are areas of additional work that would be useful extensions of these investigations:

- Because of the need to address the practical problems of immediate concern to Costa Rica, the novel transportation technologies discussed in an initial working paper (6) were not subjected to quantitative analysis. These include such options as electrified highways and hybrid locomotives able to function in both the pure electric and diesel-electric modes. The ANCOR model is capable of analyzing novel technologies in the same manner as existing technologies, and analyses of this nature would be a worthwhile extension of the work.
- This study was restricted to three corridors of Costa Rica to the exclusion of other potentially interesting transportation corridors, such as the proposed dry canal route connecting the Pacific with the Caribbean Sea through the underdeveloped northern part of the country. A combined analysis of transportation technology options and economic development opportunities for this and perhaps other corridors would be very interesting indeed.
- The ANCOR model was developed several years ago as part of a research program for the government

of Venezuela, but the current study is its first large-scale practical application. Although most relationships embodied in the model have been validated in their original form, there has never been a full validation of the complete ANCOR model with a comprehensive empirical data base. To the extent that reliable and disaggregate construction and operating-cost data can be obtained for the rail or highway modes in Costa Rica, this presents a valuable opportunity to evaluate comprehensively the strengths and weaknesses of the current model and to suggest directions for possible improvements.

In addition to the ANCOR model used in this research, two other corridor cost models have been developed: ANCOR-AGUA, which performs cost and resource use analysis for water transportation systems, and ANCOR-AIR, which analyzes air transportation technology alternatives. It would be of interest to utilize these models to explore non-land-transportation options in suitable settings.

ACKNOWLEDGMENTS

The author would like to express his appreciation to a number of fifth-year students in civil engineering at the University of Costa Rica and to their faculty advisors, without whose excellent thesis work the analysis reported in this paper would have been impossible. Thanks also to Ann Stevens and C.-K. Kong, both graduate students at Berkeley, who patiently produced the many computer runs required to develop these results, and to Juan Manuel Guell and Leonardo Castro, also Berkeley graduate students, whose personal knowledge of Costa Rican conditions made valuable contributions during the data acquisition phase of this research.

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Research on Appropriate Planning Methodology in Developing Countries

C. JOTIN KHISTY

ABSTRACT

Developing countries have generally adopted the planning methodology conventionally practiced by developed countries. The results have not been encouraging. There is a dire need to evolve inexpensive appropriate methodology especially applicable to developing countries, which will help policymakers reduce the inefficiencies in transport, correct misguided priorities, promote equity, and enhance the quality of life. The following topics connected with appropriate planning methodology are examined in this paper: development and diffusion of planning methods, basic problems of land use and transportation planning, the meaning of need as compared with demand, distributional effects of current planning methods, appropriate planning methodology, and the ethics of methodology assessment. The issues concerning appropriate planning methodology are clarified and areas where further research is needed to improve the planning process are identified. An agenda for action is included.