Investments in Rural Air Transportation Networks in Developing Countries

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Rural airfields provide vital access to many remote regions of the world, thus enabling their socioeconomic development. While these facilities are usually very simple, their construction and maintenance can be very difficult. Thus, governments must balance the need to provide access with the cost of providing access. In this paper, we present a quantitative methodology for evaluating investment decisions in rural air transportation networks. The intended purpose of the methodology is to provide policymakers with enough understanding so that they can develop strategies that meet the accessibility needs of remote locations while making the best use of available resources. The first step in the methodology is to determine the importance of air links to the different points in the network. Next, the existing and desired infrastructure are evaluated in terms of their ability to support the expected traffic. These evaluations are followed by a gap analysis to determine the infrastructure deficit and provide the basis for the formulation of different investment strategies. In this paper we consider the case of Costa Rica and provide useful insights for policymakers interested in supporting rural air transportation networks.

I. Introduction

Rural air transportation networks provide fast and reliable access to remote regions in developed and developing nations and, thereby, support their socioeconomic growth. The aviation infrastructure in these places is usually very simple, but their construction and maintenance can be difficult. Regional and national governments must therefore balance the need to communicate and trade with these regions with the cost of providing these connections.

In this paper, we present a quantitative methodology for evaluating and prioritizing investments in rural air transportation infrastructure in developing countries. This work is illustrated by examining the network of government-owned rural airfields in Costa Rica, a small country in Central America.

The structure of the paper is as follows. First, the research objective and the theoretical framework of this methodology are presented. Next, the methodology is applied in full detail to the case of the Costa Rican airfields. Finally, conclusions and recommendations for future work are presented.

II. Research Objective

The goal of this research is to provide decision-makers with the means to evaluate the impact and the cost of bringing air transportation to remote locations. Our objective in writing this paper is to demonstrate how

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the proposed methodology allows policymakers to gain enough understanding of the need for aviation services, the state of existing infrastructure and the required improvements to develop strategies for effective and safe air transportation. This methodology is a quantitative approach to making decisions that are often based on the judgment of "experts" because there is insufficient data. The methodology is illustrated by considering the network of local airfields serving domestic passengers in Costa Rica.

III. Theoretical Framework

The main steps in the methodology suggested in this paper are presented below. Even though these steps are shown in a linear order, iterations are possible (See
Figure 1):

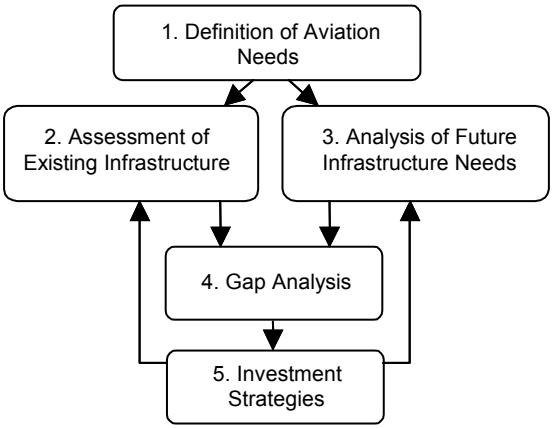

Figure 1: Main steps in the methodology suggested in this study. ***Source: The authors.***

1) Definition of Aviation Needs: The importance of air service to the different points in the network is evaluated based on a series of commercial, socioeconomic, geo-political, environmental and aeronautical factors.

2) Assessment of Existing Infrastructure: Conditions of the existing infrastructure are evaluated.

3) Analysis of Future Infrastructure Needs: The required infrastructure at each of the points in the network to serve future aviation activity is identified.

4) Gap Analysis: Infrastructure requirements identified in 3) are compared to existing facilities found in 2) to determine the margin of opportunity for improvement.

5) Investment Strategies: Results from the gap analysis are used to determine strategies to meet needed improvements and/or changes to the air transportation network.

IV. Applying the Methodology to the Case of Costa Rica's Rural Airfields

A. Overview of Costa Rica's Airfields

Costa Rica is a small and mountainous country of 51,000 km^2 and 4 million people located in Central America. The most important urban centers, including the capital city San José, are located in a valley in the middle of the country. The rest of the population is distributed outside of this Central Valley, mostly along the coasts and in the northern low-lands. Consequently, the main airports for international and domestic passengers are located in the Central Valley: the San José airport is the main international and

domestic gateway, while Pavas is the second domestic gateway (see Figure 2). Liberia, in the Pacific Northwest, is the second major international airport, serving mostly tourists.

There are more than 100 local airfields scattered around the country. Prior to the 1970s, air transportation was a primary means of communication for many communities outside of the Central Valley. During the 1970s, the expansion of the road network reduced and, in many cases, eliminated the prominence of aviation to access many of these places.[1] Thus, today, only a few dozen airfields are used regularly for commercial operations. The Costa Rican government maintains and operates 25 of these local airfields (shown in Figure 2) while the rest are privately owned.

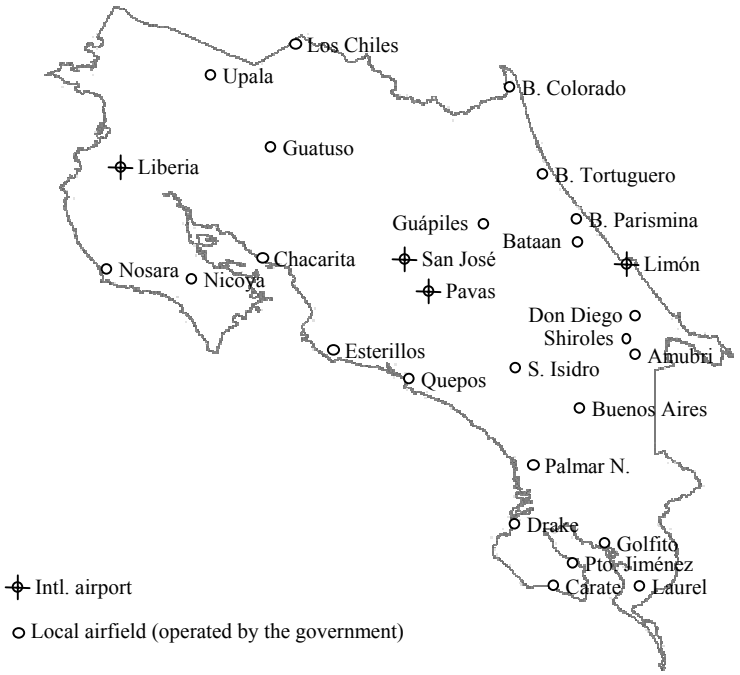

Figure 2: Costa Rica's main international and domestic aviation gateway is San José, followed by Pavas as the second domestic gateway. Liberia is the second major international airport. It is used primarily for tourism to the Pacific Northwest. The Costa Rican government currently maintains and operates 25 local airfields. ***Source: The authors with information from the Costa Rican Public Works Ministry.***[2]

B. Applying the Methodology

1) Definition of Aviation Needs

The importance of aviation services was determined by evaluating the following factors at each location served by an airfield:

a) Commercial factors:
- *Travel time reduction* by air compared to ground from San José.
- *Tourism potential* measured as number of hotel rooms/passenger at the destination.
- *Passenger purchasing power* measured in terms of average hotel room price at the destination.
- *Prominence of destination in the strategic plan of the Costa Rican Tourism Board.*

b) Socioeconomic factors:

These include the contributions of aviation to employment, income, population growth and other metrics of socioeconomic development; however, there was no data available at the local level to carry this study and,

therefore, they have not been included here. If the data is available, the inclusion of these factors is strongly recommended in subsequent studies.

c) Geo-political factors:
   - *Difficulty of access by surface transportation.*
   - *Support of response to natural disasters.*
   - *Importance for national security* (e.g., border patrol).

d) Environmental factors:
   - *Aircraft noise and emissions.*
   - *Environmental protection* (e.g., by allowing eco-tourism to take place in remote locations, aviation provides an incentive for environmental preservation)

e) Aeronautical factors:
   - *Average yearly passenger* traffic between 1998 and 2002.
   - *Average yearly traffic growth* between 1998 and 2002.
   - *Need of infrastructure repair.*

A value of 1 (least important), 2 (important) or 3 (very important) was given to each factor for a particular location served by one or more airfields. Thus, locations with a higher score have a greater need of aviation services. The ranking of the 25 public airfields using this procedure is given in Table 1.

Table 1: Ranking of the government-owned airfields in Costa Rica by aviation need and traffic. Traffic is measured in terms of average originating passengers per year between 1998 and 2002. ***Source: Authors with data from the Costa Rican General Directorate of Civil Aviation.***[3-6]

Airfield	Rank (Aviation need)	Rank (Traffic)	Traffic Aver. Pax/Yr
Pto. Jiménez	1	3	5,738
B. Colorado	2	6	2,093
B. Tortuguero	3	4	5,174
Drake	4	8	1,162
B. Parismina	5	10	260
Nosara	6	7	1,365
Golfito	7	2	8,737
Quepos	8	1	17,716
Carate	9	9	374
Palmar Sur	10	5	4,906
Amubri	11	23	0
Shiroles	12	23	0
Don Diego	13	23	0
Los Chiles	14	20	6
Upala	15	17	14
Laurel	16	22	2
Nicoya	17	13	142
Guatuso	18	18	11
San Vito	19	16	35
Esterillos	20	21	5
Chacarita	21	15	65
San Isidro	22	11	193
Guápiles	23	12	162
Bataan	24	19	9
Buenos Aires	25	14	94

There are two interesting observations from Table 1. First, among the top five airports in terms of aviation need, all except Puerto Jiménez[‡], are not accesible by road. This highlights the importance of air

[‡] Year-round road access to Drake was just recently opened.

transportation as a communication link. Second, traffic levels are not necessarily correlated with aviation need. For example, the top two airports in terms of traffic, Quepos and Golfito, are in positions 8 and 7, respectively, in the ranking by aviation need. Thus, traffic should not be used as the only parameter to justify investments in air transportation infrastructure. In many circumstances, especially when information regarding other factors is not readily available, traffic levels tend to be used by decision-makers to prioritize such expenditures; however, as Table 1 shows, it is important to consider other factors to make an informed decision of where investments are more prioritary.

2) Assessment of Existing Infrastructure

The conditions of several infrastructure elements were evaluated at each airfield via site visits. The selection of these elements is based on ICAO's Airport Planning Manual[7] with some modifications by the authors.

The infrastructure components were divided in two groups:

a) Landside:
   - *Passenger building*: waiting areas, restrooms, food vendors.
   - *Airfield personnel.*
   - *Access to surface transportation.*
   - *Nearby development:* includes land use in the vicinity of the airfield.
   - *Environmental impact (noise and emissions).*
   - *Public services:* electricity, drinking water, telephone.

b) Airside:
   - *Topography (mountains, rivers, etc).*
   - *Obstacles (trees, power lines, mountains, etc).*
   - *Runway and taxi ways.*
   - *Apron and aircraft stands.*
   - *Runway strip.*
   - *Fences.*
   - *Gates.*
   - *Drainage.*
   - *Land for future airport expansion.*

Each infrastructure component was assigned a qualification of *poor*, *good* or *excellent*. *Poor* indicates that the infrastructure element does not meet minimum ICAO standards as indicated in ICAO's Annex 14[8] and/or is not able to perform its intended function. *Good* denotes that the infrastructure element meets or is very close to meeting minimum ICAO standards. *Excellent* means that the infrastructure meets and/or exceeds ICAO standards. A summary of infrastructure conditions across the entire network is shown in Figure 3.

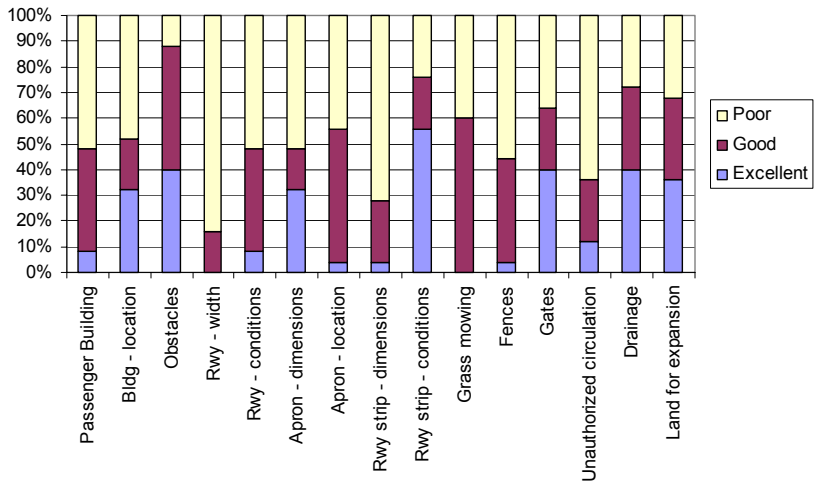

Figure 3: Summary of infrastructure conditions across the network of rural airfields.

From Figure 3, it is possible to identify the infrastructure components in best/worst conditions across the network. Obstacles, Conditions of the Runway Strip, Drainages and Land for Future Expansion are the elements that, by and large, are in better conditions on the network.

The infrastructure components that require the most attention are Runway Width, Runway Strip Dimensions, Runway Conditions, Fences and Unauthorized Circulation. Many of the Costa Rican airfields do not meet current ICAO's standards for runway width or runway strip dimensions as stated in ICAO's Annex 14. There are historical reasons for this, as the current Costa Rican Airfield's code, which dates from 1974, has smaller minima than Annex 14; however, Costa Rica will soon review its code to bring it in agreement with ICAO's standards so that some action will have to be taken with respect to runway width and runway strip dimensions in most airfields to meet the new standards.

Poor Runway Surface Conditions can be traced back to deficiencies in preventive maintenance. Harsh meteorological conditions, difficult ground access and budget restrictions make airfield maintenance a tall order. In addition, bureaucratic processes are very slow and lengthy, which further exacerbates the ability to provide timely preventive maintenance. A problem caused directly by the delay in maintenance contracts is the outgrowth of grass on the runway strip and/or on grass runways. Grass needs to be cut an average of four times per year, but delays in the approval of maintenance contracts result oftentimes in the contracts not been authorized until mid-year.

The poor state of the Fences and the Unauthorized Circulation of people, animals and vehicles through the airfields is a perennial problem with no easy answer. On top of the maintenance difficulties mentioned above, the Costa Rican government does not have the resources to assign staff at each of the local airfields under its supervision. Thus, even if the fences can be repaired and maintained, with nobody present to look after the airfield, people quickly open new holes in the fences. An interesting observation is that, oftentimes, the runway may be the only paved road in the area and, thus, it becomes the preferred route to circulate. Additionally, there appears to be the perception that living close to the airport is desirable. Therefore, it is not unusual to find a number of homes built very close to or even on the grounds of the airfield. An attenuating circumstance to this problem is that most airfields do not have heavy traffic loads and that an over-flight of the runway prior to landing is part of the standard operating procedure.

Passenger Buildings and other facilities are not adequate at approximately 50% of the local airfields. In many cases, not even a simple roof for protection from the sun or rain is available. While this does not directly compromise aviation safety, it can have a significant impact on the passenger's experience and, by extension, on travel demand.

3) Analysis of Future Infrastructure Needs

Future infrastructure requirements for each of the local airfields were determined based on current and potential future traffic growth. Where possible, historical data was used to project future traffic. The same elements selected in Step 2 were analyzed here.

Analysis of traffic trends indicate that Drake, Nosara and Puerto Jiménez are experiencing the strongest growth in air travel. This growth is expected to continue in the near future given the difficulty of access by surface and the high tourism potential of these places. The runways of Drake and Puerto Jiménez should be extended to allow a higher maximum take-off weight for current aircraft types in operation, especially in Drake, and to allow airlines to use larger aircraft. The runway at Tortuguero should also be lengthened because it current length of 780m poses some limitations on aircraft operations.

Quepos and Golfito, the two airfields with highest traffic, have not experienced significant increases in the number of passengers in the last five years. Existing infrastructure at both places appears sufficient to meet traffic demand and there are no indications that expansion of either airfield will be necessary in the foreseeable future. Similarly, most of the other airfields in the country appear to have runways long enough to serve current and expected future traffic. Nevertheless, the vast majority of them require extension of runway width and or the runway strip to bring them in compliance with ICAO standards.

4) Gap Analysis

The current conditions identified in Step 2 were compared to the future requirements obtained in Step 3 to determine the necessary improvements in the network. As it was already mentioned above, most of the infrastructure shortfalls are related to non-compliance with dimensions stipulated by ICAO and lack of preventive maintenance. Only in three cases (Drake, Puerto Jiménez and Tortuguero) is it suggested that the current infrastructure be significantly expanded. Thus, in this study, the gap analysis is primarily an examination of the improvements needed at each airfield in each infrastructure element to be in *good* or in *excellent* condition.

5) Investment Strategies

The last step in the methodology is to determine the recommended investment strategy for the government to upgrade the network of airfields. Different strategies were analyzed according to two important parameters: Desired Conditions and Airfield Priority (see Figure 4). Desired Conditions refer to the conditions that the investor wants the infrastructure at each airfield to have through the investment strategy. Similar to the evaluation of the existing infrastructure, the desired conditions can be *poor*, *good* or *excellent*. Depending on the state of the Existing Conditions and the Desired Conditions, the Required Improvements were identified in the Gap Analysis. Required Improvements along with Capital and Maintenance Cost and Lifetime Data are used to calculate Construction and Maintenance Costs. Through Airfield priority, the investor can specify the order in which airports should be improved. The outputs of these calculations are the expected capital and yearly maintenance expenditures for each investment strategy.

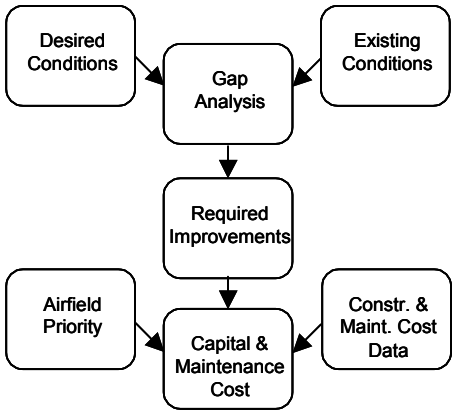

Figure 4: Steps for the calculation of capital and maintenance costs for the different investment strategies considered. ***Source: The authors.***

The information about the Existing and Desired conditions comes from Steps 2 and 3 of the methodology, respectively. Airfield priority was determined by the user based on the Aviation Needs identified in Step 1. The Construction and Maintenance Cost and Lifetime data were obtained from the Costa Rican General Directorate of Civil Aviation[§] (see Table 2 and Table 3, respectively). The calculation of the Capital and Maintenance Cost assume a project lifespan of 20 years and a discount rate of 6%.

Table 2: Estimated average infrastructure construction and maintenance costs for rural airfields in Costa Rica. ***Source: The authors with data from the Costa Rican General Directorate of Civil Aviation.***

Item		Unit	Cost
Passenger building		$/m^2	900
Simple shelter		$/m^2	150
Taxiways, runways and aprons	Asphalt	$/m^2	45
	Concrete	$/m^2	80
	Asphalt seal*	$/m^2	0.5
	Superficial asphalt layer	$/m^2	2
	Gravel (includes base layers)	$/m^2	18
	Re-shape (for gravel runways)	$/m^2	0.2
	Grass (includes base layers)	$/m^2	18
Fences	Barbed wire	$/m	3
	Chain-link	$/m	30
Gates	Barbed wire	$/m	3
	Chain-link	$/m	250
Grass mowing		$/m^2	0.01

Notes: Asphalt seal: tar solution used to seal cracks in the asphalt.

[§] Infrastructure Department, General Directorate of Civil Aviation, Costa Rica, April 2004. Personal communication.

Table 3: Estimated average lifetime of different infrastructure components for rural airfields in Costa Rica. ***Source: The authors with data from the Costa Rican General Directorate of Civil Aviation.***

Item		Unit	Cost
Passenger building		Years	20
Simple shelter		Years	20
Taxiways, runways and aprons	Asphalt	Years	20
	Concrete	Years	20
	Asphalt seal	Years	10
	Superficial asphalt layer	Years	10
	Gravel (includes base layers)	Years	20
	Re-shape (for gravel runways)	Years	1
	Grass (includes base layers)	Years	20
Fences	Barbed wire	Years	10
	Chain-link	Years	15
Gates	Barbed wire	Years	10
	Chain-link	Years	15
Grass mowing		Years	0.25

Note: An asphalt runway has an estimated lifetime of 20 years but requires a superficial asphalt layer every 10 years.

Three different investment strategies were considered in this study. The first includes improving all infrastructure elements in all airfields to be in *excellent* condition. The second strategy involves bringing all infrastructure components in all airfields to at least in *good* condition. The third strategy considers improving the infrastructure in the top 5 airfields to *excellent*, improving the infrastructure in airfields ranked 6 to 15 (except Don Diego) plus Nicoya and Chacarita to *good*, and leaving the other airfields in their current state. No investments are recommended for Don Diego primarily because it is in very poor conditions (a nearby river has already eroded 300m of the runway) and because the Shiroles airfield can service the Don Diego area. No investments are recommended for Guatuso, either, because of its great state of disrepair and the lack of any significant current or expected demand. Chacarita and Nicoya are being upgraded to at least *good* because of their strategic importance for the attention of natural disasters. Finally, the third strategy also includes runway extensions in Drake, Barra de Tortuguero and Puerto Jiménez.

An important cost object that could not be calculated because the data was not available is the expenditure associated with acquiring land for airfield expansion; however, the amount of land required is indicated.

The numerical results for all strategies are shown in Table 4:

Table 4: Numerical results for the different network improvement strategies considered here.

Strategy	Capital costs	Yearly maintenance costs	Land expansion required
	US$ million	**US$ million**	**Ha**
1 (*excellent)*	18.67	0.171	114.31
2 (*good)*	8.40	0.098	22.25
3 (by airfield rank)	5.89	0.106	78.26

Before discussing these results, it is helpful to point out that the total annual budget of the Costa Rican General Directorate of Civil Aviation is on the order of US$14 million.[**] In addition, the Capital

[**] Alfaro, Erika, Director of Procurement, General Directorate of Civil Aviation, Costa Rica, April 2004. Personal communication.

Improvements Program spanning 2003-2006 is estimated to cost US$5.34.[9] Maintenance expenditures are estimated at US$60,000 per year.[††]

In light of the budgetary limitations, the possibilities of improving the entire network of airfields to *excellent* or even at least *good* conditions seem very difficult. Investment costs for Strategy 1 are more than triple the budgeted amount for capital improvements. Similarly, Strategy 2 requires 1.5 times the amount in the Capital Improvements Program. The extra expenditures implied by Strategies 1 or 2 would be very difficult for the General Directorate of Civil Aviation to fund and, thus, where these strategies to be chosen, the probability that they would be implemented is very low.

Strategy 3, which prioritizes investments by the importance of the airfield, appears to be within the budget of the government. With this strategy, the government can bring 16 airfields to *good* or *excellent* conditions without considerably exceeding its Capital Improvements Program. The 16 airports benefited with this strategy serve approximately 98% of all air passengers that travel through government owned airfields, thus, Strategy 3 balances the cost of providing air access with the need to provide this access.

Strategy 3 requires more land for expansion than Strategy 2. This is primarily due to the fact that, unlike Strategy 2, Strategy 3 considers three runway expansions and bringing five airports to *excellent* conditions. In order to bring these airfields in accordance to ICAO's standards, especially the runway strips, it would be necessary to purchase significantly more land than if they were to be left in *good* conditions. It is important to extend these runways and to enlarge these airfields now in view of the expected increase in traffic at these locations. In some cases, for example Puerto Jiménez and Drake, these expansions need to occur soon before the vacant lands surrounding the airfields get developed and, thus, compromising their future growth.

The current maintenance budget of approximately US$60,000 per year is considered low even by top government officials.[‡‡] Lack of preventive maintenance was identified as a major contributor to the deterioration of runways, fences and other important infrastructure. Therefore, it is strongly recommended that a larger budget be assigned to maintenance activities. Notice that the expected yearly maintenance expenditures for Strategy 3 are slightly higher than for Strategy 2 because the maintenance burden to keep an airport in *excellent* condition is higher than that for keeping an airfield in *good* conditions. Nevertheless, the difference is not very significant and by keeping the top five airports in *excellent* conditions, the government will not compromise their expected future growth.

V. Conclusions

Air transportation can be an effective tool to promote social and economic development in rural areas. Investment decisions in aviation infrastructure must balance the need of providing service to these areas with the cost of doing so. These decisions should be based on multiple factors in addition to historical traffic levels. In this paper, a series of commercial, geo-political and aeronautical parameters were identified. Socioeconomic elements should also be apart of the decision-making process but, unfortunately, available data was not sufficient to identify the socioeconomic impact of air transportation in remote areas of Costa Rica.

Capital expenditures in air transportation infrastructure need not be exorbitant. The network of 25 government-owned airfields in Costa Rica could be improved to *excellent* conditions with a budget of approximately US$18 million; however, these outlays must be considered in relation to the government's budget. For example, the Costa Rican Civil Aviation Directorate has an annual budget of US$14 million, thus, US$18 million is not a trivial sum.

[††] Maintenance Department, General Directorate of Civil Aviation, Costa Rica (2004). Personal communication.
[‡‡] Civil Aviation Technical Council, April 2004. Personal communication.

The strategy for infrastructure improvements suggested here would cost on the order of US$6 million, which is more realistic given the country's budgetary constraints. This strategy prioritizes investments according to the importance of air transportation for each location served by the corresponding airfield.

Another element of great importance for the long-term functionality of the air transportation infrastructure is maintenance. Many of the deficiencies in the current facilities, such as poor runway conditions and long grass in the runway strips, can be traced back to insufficient preventive maintenance. Thus, adequate funding for maintenance should be part of any investment strategy.

An enduring situation in many airfields is the unauthorized circulation of people, vehicles and animals on the runway. Construction and/or repair of fences and gates has not been an effective answer because people constantly find other ways of trespassing. The solution to this problem is certainly complex, because it must go beyond the edification of physical barriers and into people's minds. Active community involvement is required to find a compromise that satisfies aviation safety and operational requirements with the community's needs.

VI. Next Steps

More research should be conducted to establish the links between aviation and its socioeconomic impact in Costa Rica. This knowledge would greatly enhance the effectiveness of this methodology as a means for the government to promote social and economic growth throughout the country by investing in air transportation. Furthermore, this methodology could be applied to other geographical areas to determine similarities and differences to the Costa Rican example. Cross-regional and/or cross-country comparisons of aviation needs and infrastructure requirements could indicate general trends and particular traits that would be very useful for policymaking by governments, international lending institutions and air service providers.

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