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A METHOD FOR IDENTIFYING GENERAL AVIATION AIRPORTS THAT ARE CANDIDATES FOR RUNWAY EXTENSIONS: A PLANNING MODEL FOR STATE AVIATION SYSTEMS

Randall G. Holcombe and Henry B. Burdg

ABSTRACT

One of the most important characteristics of an airport is the length of its longest runway: that length determines the types of aircraft that can use the airport and provides a margin of safety for users. A runway extension, therefore, would enhance the utility of many airports. But resources are scarce, and if funds are to be allocated at the state level, state officials need a method for determining which airports could best use a longer runway. Consideration of demographic factors enhances the traditional engineering analysis approach to runway evaluation. This combined approach is more consistent with the goals of comprehensive airport planning. This paper describes a model that uses regression analysis to compare airports in Alabama, taking into account a number of different demographic factors and airport related factors. A linear regression model was used to evaluate how an airport's runway length compared to others around the state with similar characteristics. The residuals from the regressions were used to identify those airports with relatively short runways, considering their other characteristics. The regression analysis identified 22 of the 106 public-use airports in Alabama as having runways substantially shorter than their other characteristics would predict.

One of the most important characteristics of an airport is the length of its longest runway, because it will determine the types of aircraft that can use the airport and because longer runways provide a margin of safety for any aircraft using the airport (Ashford & Wright, 1979). A short runway limits the usefulness of an airport and restricts the ability to accommodate the current corporate fleet. Many of the general aviation airports were designed and constructed 35 or more years ago, meeting the aircraft requirements of that day. For the most part the smaller community airport has not developed as fast as the population it is to serve. A runway extension, therefore, would enhance the utility of many airports.

There are some 5,598 general aviation airports and 568 general aviation and commercial airports in the United States. A recent study (National Association of State Aviation Officials [NASAO], 1988) estimated that $285 million (1988-1989) in state funds were spent on state airport development projects. In many situations it appears that these funds are politically directed rather than proactively planned.

Resources are scarce and if state airport development funds are to be allocated effectively, state officials need a method for evaluating candidate airports that could best use longer runways. This paper describes a model that uses regression analysis to compare airports in Alabama, taking into account a number of different factors. The work described here is included in a larger study of general aviation airports in Alabama conducted for the State of Alabama, Department of Aeronautics, March 1987. With the results from this model, state officials can better evaluate proposals for runway extensions.

Factors determining the appropriate runway length can be divided into two general categories: demographic factors (Federal Aviation Administration [FAA], 1972) and airport related factors (Horonjeff & McKelvy, 1983). In this paper 10 demographic factors are considered, including the population of the county where the airport is located, population in the immediate vicinity of the airport, population growth in the area, population density, and the number of nearby businesses, employees, and payroll. The paper also considers 23 airport factors, including the number of based aircraft and operations at the airport, services offered, and the locations of other airports. In certain geographical settings, it is important to consider the variation in airport elevations, runway gradient, and design reference temperatures. These factors do affect runway length. In Alabama the variation is represented by a narrow range and thus excluded from the analysis. For example, the design reference temperatures range from

89-94 degrees F. Another consideration can be the initial design function of the airport. For example, a few Alabama airports were initially built as military airfields and converted to public general aviation facilities. These tend to have longer runways than airports specifically designed and constructed for general aviation use. Additional variables can be added to the regression models as needed to accommodate a region's unique features.

A linear regression model was used to compare the lengths of the runways at general aviation airports around the state. Several regression equations were estimated with runway length as the dependent variable. One regression used all 32 independent variables; others used only demographic factors, airport data, or number of operations at the airport. The residuals from the regressions were used to identify those airports with relatively short runways, considering their other characteristics. The regression analysis identified 22 of the 106 public-use airports in Alabama as having runways substantially shorter than their other characteristics would predict.

After the regression analysis is explained, the airports are examined in detail to determine why their runways are shorter than expected and to explain how the regression results can be applied to make a recommendation to lengthen a runway.

RUNWAY LENGTH AND AIRPORT UTILITY

The usefulness of an airport is determined in large part by the length of its longest runway. A light, single-engine airplane can operate from a runway 2,000 feet long, but a heavy single-engine or multi-engine craft needs a runway of at least 3,000 feet. Although small jets can take off and land on 4,000 foot runways, larger jets require 5,000 feet or more. Runways of 10,000 feet are common at the major commercial service airports (FAA, 1983).

These runway lengths are approximations. Under many circumstances, the aircraft described above could operate from shorter runways, even though a margin of safety would be lost. An experienced pilot, for example, would have no trouble landing a typical civilian training aircraft in 2,000 feet of runway, but the runway would probably be too short for a student pilot or a pilot who flies infrequently. The trade-off is clear. A longer runway will make an airport safer and more useful, but runway extensions are expensive. If runway extension projects are eligible for state airport development funds, state airport officials need a means of identifying those airports that would benefit most from longer runways. Examining length alone is insufficient: a 3,500-foot runway adequate for an infrequently used airport catering to single-engine traffic, would be a significant constraint for a community that has the potential for many operations involving larger aircraft, including jets. Any determination of the adequacy of a runway must take into account the economic and demographic characteristics of the community or region served by the airport and the use to which the airport is put (FAA, 1975). These factors are taken into account in conjunction with the runway engineering specifications required by the airport's past designated Critical Aircraft.

Ideally, a state would compare its airports, taking into account the differences in their environments, and compile a list of those that could benefit most from runway extensions. Many airports could benefit from longer runways, but this paper presents the results of a regression model that identifies those with relatively short runways, taking other factors into account. The remainder of this paper explains how the analysis was undertaken for Alabama's airports.

METHOD - DATA USED IN THE STUDY

Alabama has 106 public-use airports, as identified by Federal Aviation Administration (FAA) 1986 records. The FAA maintains a Form 5010-1, Airport Master Record, for each federally registered airport in the United States. This study analyzes all public-use airports in the state, including those that are privately owned, for which the FAA maintains a 5010-1 form. The study excludes military airports, heliports, and seaplane bases. **Table 1** presents a list of the variables collected for each airport and used in the analysis. The first 10 are demographic variables that characterize the population that would use the airport.

The variable County is the population of the county in which the airport is located. Most counties in Alabama have only one airport, but a significant number (22 of 67) have more than one. City is the population of the primary city served by the airport. These data were

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obtained from the 1980 Census. PopSrv is the population served by the airport, which was determined by examining a map and matching small districts within a county to the nearest airport.

The percent county population growth (%pop) was also taken from the 1980 U.S. Census.

The variable manufacturing employment (MfgEmp) was obtained from the Alabama 1985-86 Directory of Mining and Manufacturing. Every manufacturer was associated with the nearest airport, and the number representing employment was the sum of all employees in firms with over 100 employees. Firms with more than 100 employees are more likely than smaller firms to use aircraft in the course of their business. The number of employees thus determined provides one indication of manufacturing activity in an area.

The next three variables, county employment (CouEmp), the number of businesses (#Bus), and county payroll (Payroll), are additional indicators of business activity near the airport. These were taken from County Business Patterns, 1983, Alabama.

Manufacturing percent (MfgPct) is an indication of the percentage of county employment that is made up of manufacturers near an airport. Population density (PopDen), taken from the 1980 U.S. Census, is useful because an airport in a less densely populated area might be expected to have better facilities than one in a more densely populated area, where other airports would tend to be closer.

Taken together, these first 10 variables describe the population served by the airport and the type of business activity supported by that population. A larger population with more income would warrant better facilities to support aviation activity, so any study of runway length should take these two factors into account.

Variable 11 is RwyLen (runway length), which is the dependent variable in the study.

Variables 12 through 17, taken from the airport's FAA 5010-1 forms, describe the services available. An airport supporting air charter services, instruction, etc., will utilize a longer runway better than one without these services.

The next four variables, 18-21, list by type the aircraft based at the airport. Again, more aircraft based at the field would indicate the demand for a longer runway. Multiengine and jet aircraft warrant greater runway length, so they are listed separately.

Variables 22-27 give the number of aircraft operations at a field, broken down by type of flight. The next two variables indicate whether the field has lighting for night operations and whether a control tower is located on the field. Variables 18-29 are also from the FAA 5010-1 forms.

An instrument approach helps a pilot land an aircraft in poor weather. A localizer or an instrument landing system (ILS) approach are two specific types of instrument approaches. Because of the inherent inaccuracy of the landing systems and the vast amount of pilot navigational inputs, these systems tend to be the most accurate and, therefore, the most desirable at a typical general aviation airport. These variables (Appch and LOC) are included because an airport equipped for operations in poor weather is a better candidate for a longer runway, other things being equal. Information for these variables is from NOS Approach Plates--the set of maps a pilot would use to fly the approach.

The final two variables indicate conditions that would tend to lessen the demand for a longer runway. The first (Nearby) indicates that another airport is nearby; the second (SecArpt), that the facility being analyzed is a secondary airport for a nearby primary airport.

Variables indicating a certain condition are binary variables, taking on the value of "1" if the condition exists and "0" otherwise. The binary variables are 12-17 and 28-33 in **Table 1.** For example, if flight instruction is available at an airport, the value of that variable would be given 1; if flight instruction is unavailable, the value of the variable would be 0.

Each variable should be taken into account in determining the appropriate runway length for an airport. In the regression analysis these various factors interact to predict the airport's runway length, given its other characteristics. A comparison of actual to predicted runway length will identify those airports with shorter than expected runways, given the characteristics of the communities they serve and the air traffic that uses the airport.

THE REGRESSION ANALYSIS

The regression analysis uses runway length as the dependent variable and combinations of the other variables as independent variables. A regression analysis

Table 1
Variables Used in the Regression Analysis

Number	Name	Description
1.	County	County population
2.	City	City population
3.	PopSrv	Population served by airport
4.	%pop	Percent county population growth 1970 to 1980
5.	MfgEmp	Employment in manufacturing firms with more than 100 employees
6.	CouEmp	County employment
7.	#Bus	Number of business establishments in the county
8.	Payroll	County payroll
9.	MfgPct	Variable 5 divided by variable 6
10.	PopDen	Population density of the county
11.	RwyLen	Airport runway length
12.	100LL	Aviation gasoline available at airport
13.	Repairs	Airframe or engine repairs done at the field
14.	Agri	Agricultural services available
15.	Charter	Aircraft charter available
16.	Inst	Flight instruction available
17.	Rent	Aircraft rental available
18.	SEBase	Number of single engine aircraft based at field
19.	MEBase	Number of multiengine aircraft based at field
20.	JtBase	Number of jet aircraft based at field
21.	HBase	Number of helicopters based at field
22.	OpCar	Number of annual air carrier operations
23.	OpTaxi	Number of annual air taxi operations
24.	OpGA	Number of general aviation local operations
25.	OpItin	Number of general aviation itinerant operations
26.	OpMil	Number of military operations
27.	OpTot	Total annual operations
28.	Light	Lighting on field
29.	Twr	Control tower on field
30.	Appch	Instrument approach
31.	LOC	Localizer or ILS approach
32.	Nearby	Nearby airport serves much of the same population area
33.	SecArpt	Another airport is the primary airport in the area

determines how the factors listed in **Table 1** are associated with different runway lengths at Alabama airports. Once this information is generated, the residuals can be used to identify airports that have shorter than expected runways.

Taking into account the variables from **Table 1**, the regression analysis identifies only airports that would be expected to have a runway of a certain length. An element of judgment, however, is missing in such an analytical comparison. Although the expected length of the runway is not by itself a recommendation for a longer runway, as will be discussed later, the comparison provides valuable information. If a runway is being considered for extension, it would be useful to know, for example, that other airports with similar characteristics would be expected to have longer runways. The regression analysis supplies this type of information. **Table 2** gives the results of

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several regression equations. Five equations use runway length as the dependent variable. The results of the tests of significance (F-test) of each model indicate that the equations are found to be useful for estimating runway length. The F ratio in the first estimation is significant, but lower than the others. This indicates a poorer fit due to the large number of insignificant variables.

The first, the full model, used all other variables as independent variables, and the coefficients are reported under the column labeled All Variables.

Running a regression analysis with all independent variables will explain the greatest amount of variation in runway lengths. Multicollinearity does exit in the full model. However, if one is primarily interested in the prediction of runway length rather than interpretation of the individual effects of the independent variables, multicollinearity should present no problem (Mendenhall, et al., 1986). Therefore, despite the model's multicollinearity, the result of the All Variables regression model is a source of useful information.

The next column, Selected Variables, in **Table 2** presents the results of a stepwise regression procedure starting with all 32 independent variables to simplify the full model. Eliminating variables that contain similar information (highly interrelated variables, e.g., the multiple population variables) and those exhibiting low levels of significance emphasizes the more important variables. Twenty-six variables were dropped from the full model to produce the simplified model. **Table 2** shows that the demographic variable included in the Selected Variables model is (%Pop) the percent population growth of the county in which the airport is located. Although %Pop was significant at the $p<.05$ level in the All regression, its significance fell as indicated by a lower t-value. The %Pop variable's sign is negative, which could be interpreted as meaning that counties experiencing lower population growth were associated with longer runways (typically rural low population density regions).

Three variables describing airport services were included in the equation: availability of charter services (Charter), flight instruction (Inst), and the existence of a control tower (Twr). An airport that provides charter services is associated with a runway 620 feet longer than one without such a service; the existence of flight instruction suggests a runway 760 feet longer than one without such a service; the existence of a control tower, however, is associated with a runway more than 1,725 feet longer.

The Inst variable is good for illustrating that correlation does not mean that one variable necessarily causes another. For example, having a fixed base operation (FBO) on the field to supply flight instruction might encourage the airport owner to lengthen the runway, so flight instruction could affect runway length; but the causation could run the other way, too. FBOs might choose to locate at airports with longer runways. The causation could run either way, or another variable might be the main factor causing the correlation. Fixing causation is important when trying to draw policy implications.

Note that the estimated coefficients tend to be more accurate in the Selected regression than in the All regression because of the probability of multicollinearity among the variables. For example, an airport that supports a repair facility also tends to have fuel available, and air charter is often associated with a firm that supplies rental and instructional services.

The multicollinearity is true with based aircraft; if multiengine aircraft are based at a field, single-engine aircraft are likely to be based there also. The Selected regression includes only the multiengine category. This type of aircraft is most likely to utilize a longer runway. The MEBase variable indicates that a runway tends to be 55 feet longer for each multiengine aircraft based there, and the variable is significant at better than the $p<.01$ level.

The final variable included, SecArpt, indicates whether the airport is a secondary airport in the area. If it is the runway would be expected to be 1,249 feet shorter.

Dropping variables out of the initial equation to estimate the Selected regression lowered the explanatory power somewhat. The R Square in this equation is .627; in the initial All equation it was .813. While the Selected equation may be more desirable in some ways, the additional explanatory power of the initial equation suggests evaluating both equations to consider runway length.

Three other regression equa-

Table 2
Regression Results: Independent Variable - Runway Length

	Variables Included				
Independent	All	Selected	Demographic	Airport	Operational
County	0.054				
	(2.88)***				
City	-0.019				
	(2.48)**				
PopSrv	0.030		0.018		
	(4.93)***		(7.61)***		
%pop	-21.354	-17.691			
	(2.21)**	(2.09)**			
MfgEmp	-0.019				
	(0.16)				
CouEmp	-0.122				
	(2.49)**	#Bus	0.920		
	(1.98)*				
Payroll	-0.005		-1.052E-03		
	(2.71)***		(3.31)***		
MfgPct	4.117				
	(0.25)				
PopDen	-8.893				
	(1.70)*				
100LL	-219.020				
	(0.77)				
Repairs	449.46				
	(1.45)				
Agri	401.228			453.981	
	(1.83)*			(1.94)*	
Charter	765.934	619.563		838.581	
	(2.35)**	(1.91)*		(2.59)**	
Inst	878.757	760.359	667.260		
	(1.73)*	(2.94)***	(2.61)***		
Rent	-31.075				
	(0.06)				
SEBase	-16.979				
	(1.56)				
MEBase	104.785	55.398		52.667	
	(2.91)***	(3.32)***		(3.18)***	
JtBase	-282.353				
	(2.02)**				
HBase	-191.172				
	(1.89)*				
OpCar	-0.241				
	(0.55)				
OpTaxi	-0.014				
	(0.03)				

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Table 2, continued
Regression Results: Independent Variable - Runway Length

	Variables Included				
Independent	All	Selected	Demographic	Airport	Operational
OpGA	-0.217				
	(0.51)				
OpItin	-0.238				0.088
	(0.56)				(8.10)***
OpMil	-0.223				0.020
	(0.52)				(2.50)**
OpTot	0.216				
	(0.51)				
Light	647.939				
	(1.08)				
Twr	1,769.683	1,724.822		1,884.254	
	(1.96)*	(2.72)***		(2.98)***	
Appch	-259.459				
	(0.90)				
LOC	-1,334.000				
	(1.68)*				
Nearby	-442.546			-403.080	
	(2.00)**			(1.82)*	
SecArpt	-804.188	-1,248.963		-1,304.799	
	(1.62)	(2.42)*		(2.53)**	
Constant	2,744.780	3,601.062	3,758.181	3,445.848	3,586.393
R Square	0.813	0.627	0.436	0.634	0.458
F Ratio	9.930	27.775	39.764	24.246	43.546

* Significant at better than the .1 level.
** Significant at better than the .05 level.
*** Significant at better than the .01 level.

NOTE:
The t-values are shown in parentheses.
See **Table 1** for a description of the variables.

tions were also estimated, using a stepwise procedure to look at particular factors affecting runway length. The column headed Demographic Variables includes demographic factors only in estimating runway length, the column headed Airport Variables includes only airport characteristics, and the column headed Operational Variables includes only operations into and out of the field. These equations can be useful if one wants to isolate those particular characteristics. For example, how long would the airport's runway be, if only the demographic characteristics of the area or the number of operations at the field were considered? The coefficients are not discussed in detail here, but the reader can evaluate them in **Table 2**. The regressions were included in order to compare the predictions based on all factors with those based on demographic, airport, and operations factors. Even if an airport is expected to have a longer runway based on demographic considerations, but not on the operations at the field, a longer runway might not be warranted.

Of course, the airport might be under-utilized precisely because its runway is too short. Thus all factors should to be taken into account; obviously, the set of five regressions will supply more information than any one regression.

ANALYSIS

Using the Residuals for Predicted Runway Length

If actual runway length is compared to the runway length predicted in the regression equations, airports with shorter than predicted runways can be identified. Subtracting the predicted length from the actual length gives the residual in the regression; these are reported in **Table 3**. Negative residuals indicate a predicted runway length in excess of the actual runway length. Therefore, a negative residual is an indication that a longer runway would be expected at the airport.

The residuals in **Table 3** are reported to the nearest foot. Looking at airport number 6, for example, Wilson Field would be predicted to have a runway 753 feet longer than its actual length based on all of the variables, 319 feet shorter based on the selected variables, 1,547 feet longer based on the demographic variables, 92 feet longer based on the airport variables, and 1,548 feet longer based on the number of operations.

The residuals must be considered within the context of other information about the airport, but some discussion is warranted to see how they might be applied. Using a threshold of 500 feet on the residuals, three of the five equations in **Table 3** suggest a longer runway at Wilson Field. The longer runway would be expected on the basis of all variables, demographics, and the number of operations at the airport. The Airport residual, however, suggests the runway length is close to appropriate, and the Selected residual suggests that the runway is too long by more than 319 feet. The mixed evidence from the statistical analysis does not support a runway extension for Wilson Field.

Table 3 reports 22 airports in which the residual is above the threshold (that is, the residual is less than -500) in every regression equation or in every equation but one. Eight have residuals below -500 in all equations, and another 14 have residuals beyond the threshold in all but one of the regressions. These airports are candidates for further examination for possible runway extensions.

Another 16 airports exceeded the threshold in the demographic regression, and 11 more exceeded the -500 foot threshold in the selected variables equation. Further examination of these airports revealed that some are secondary airports, so that longer runways are readily available to aircraft requiring them. Although more detailed analysis is needed to actually recommend a runway extension, the statistics provide a guideline for identifying airports that have a shorter runway than would be expected, so warrant further examination. **Table 4** lists the 22 airports with residuals below -500 in all or all but one of the estimations. The numbers associated with the airports are the numbers from **Table 3**. The next section discusses a few of the airports named in **Table 4** to show the reader how the model results can be used.

Table 3
Residuals From the Regression Analysis

		Variables Included				
	Airport Name	All	Selected	Demographic	Airport	Operational
1.	Lucky Field	-95	-1,487	-1,932	-1,947	-2,080
2.	Flomaton	-1,202	-1,572	-1,859	-1,193	-1,754
3.	Grove Hill Municipal	-1,469	-1,611	-1,873	-1,118	-1,837
4.	Shields	202	219	-1,585	262	-1,586
5.	Roy E. Ray	-645	-2,152	-196	-1,763	-1,674
6.	Wilson Field	-753	319	-1,547	-92	-1,548
7.	Madison Sky Park	228	-2,082	-2,958	-1,530	-1,599
8.	Huntsville-Lacey's Sp.	-791	-1,941	-3,200	-1,583	-1,757
9.	Red Bay Municipal	-272	-974	-1,506	-743	-1,313
10.	Ware Island	-550	-819	-1,854	-643	-1,222
11.	North Mobile County	348	-1,046	263	-1,151	-1,212

(continued)

Table 3 - continued
Residuals From the Regression Analysis

		Variables Included				
	Airport Name	All	Selected	Demographic	Airport	Operational
12.	Sky Harbor	-1,473	-1,144	-1,552	-997	-1,246
13.	McMinn	128	-664	-807	-393	-1,551
14.	Hazel Green	44	-1,703	-1,137	-1,599	-1,267
15.	Ardmore	-161	-774	-938	-849	-948
16.	Abbeville Municipal	-282	-412	-939	-531	-708
17.	Valley	-1,337	-1,893	-772	-1,599	-814
18.	Camp Hill	-259	-398	-863	-496	-654
19.	Carl Folsom	293	-526	-828	-148	-756
20.	Jacksonville Municipal	-536	-556	-666	-349	-1,044
21.	Headland Municipal	-1,653	-1,475	-858	-1,533	-850
22.	Wetumpka Municipal	-884	-1,525	-1,472	-2,055	-1,904
23.	Dauphin Island	803	-336	943	-446	-850
24.	Perry County	-444	-644	-872	-497	-657
25.	Chatom Municipal	-937	-537	-997	-446	-639
26.	Brundige Municipal	-563	-389	-797	-900	-640
27.	Martin Field	-691	-724	-637	-398	-522
28.	Lanett Municipal	57	-313	-1,146	107	-875
29.	Florala Municipal	-549	-318	-516	-354	-472
30.	Mallard	-451	-464	-818	-298	-492
31.	Guntersville Municipal	-519	-685	-931	-403	-648
32.	Centre Municipal	-411	-715	-659	-1,272	-410
33.	Freddie Jones Field	-275	-109	-396	-46	-230
34.	Double Springs	159	351	-419	-54	-183
35.	Enterprise Municipal	-866	-1,119	-686	-631	-298
36.	Autauga County	636	277	-761	-250	-969
37.	Greensboro Municipal	-1,006	-299	-520	-558	-174
38.	Wheelless	1,075	463	-1,203	457	-352
39.	Russellville Municipal	587	236	-548	64	-954
40.	Fort Deposit	106	-17	-392	494	-33
41.	Jack Edwards	-123	-261	0	-233	-2,618
42.	Logan Field	666	186	-200	103	-334
43.	Eutaw Municipal	33	61	-341	154	-52
44.	Lamar County	461	261	-324	103	-74
45.	Roundtree Field	-134	-1,252	23	-1,107	-425
46.	Bay Minette Municipal	-922	494	-255	-368	-339
47.	Franklin Field	-569	-85	-229	-200	26
48.	Foley Municipal	-1,316	-589	-128	-484	-483
49.	Roanoke Municipal	128	267	-371	254	78
50.	Huntsville North	-568	-664	-2,342	-557	-304
51.	Greenville Municipal	74	162	-291	747	68
52.	Shelby County	618	199	-889	-437	-1,204
53.	Ashland/Lineville	-170	-213	25	-113	194
54.	Middleton Field	-163	-390	4	-620	-2,341
55.	Gragg-Wade Field	124	21	-254	290	-25

(continued)

Table 3 - continued
Residuals From the Regression Analysis

		Variables Included				
	Airport Name	All	Selected	Demographic	Airport	Operational
56.	Auburn-Opelika	-212	-1,102	-833	-1,478	-825
57.	Geneva Municipal	-865	-794	-58	-549	286
58.	St. Elmo	216	664	1,524	503	370
59.	Scottsboro Municipal	431	830	-301	443	276
60.	Butler-Choctaw County	-233	-259	118	-28	323
61.	Weedon Field	-180	-254	-36	-171	5
62.	Stevenson-Bridgeport	-20	314	302	12	186
63.	Robbins Field	-37	1,102	-184	629	418
64.	Blackwell Field	451	-259	180	430	-505
65.	Bibb County	473	843	189	754	429
66.	St. Clair County	102	289	-49	-282	330
67.	Camden Municipal	142	431	302	754	578
68.	Isbell Field	-711	-552	-302	-998	508
69.	Thomas C. Russell Field	-84	29	391	441	446
70.	Coosa County	1,677	968	636	1,407	864
71.	Pine Hill Municipal	264	731	591	1,054	896
72.	Frank Sikes	757	1,067	615	1,051	439
73.	Lee Merkle Field	-834	-472	496	-653	256
74.	Clayton Municipal	-315	446	1,001	75	1,159
75.	Albertville Municipal	337	-419	806	-328	828
76.	Walker County	-376	497	85	371	331
77.	Richard Arthur Field	599	711	738	684	1,132
78.	Atmore Municipal	518	742	938	761	808
79.	Jackson Municipal	1,297	1,374	906	1,870	1,186
80.	George Downer	967	1,414	1,078	1,018	1,208
81.	Troy Municipal	-4	-1,772	895	-2,101	32
82.	Andalusia-Opp	-733	52	700	-108	1,157
83.	Moton Field	231	780	927	887	1,150
84.	Demopolis Municipal	898	1,491	964	1,100	1,194
85.	Posey Field	352	869	1,069	571	1,194
86.	Pryor Field	-431	307	-81	353	-967
87.	Brewton Municipal	577	242	1,113	499	345
88.	North Pickens	1,365	1,650	1,280	1,704	1,528
89.	Fairhope Municipal	596	680	1,377	546	716
90.	Folsom Field	643	982	425	878	822
91.	Bessemer	-45	-95	355	309	271
92.	Monroe County	545	1,512	1,860	1,573	2,224
93.	Talladega Municipal	566	867	1,816	631	1,090
94.	Tuscaloosa Municipal	-527	337	778	63	1,060
95.	Muscle Shoals	37	1,054	443	497	100
96.	Gadsden Municipal	394	1,733	1,699	1,608	2,878
97.	Marion County	1,408	2,938	2,644	2,275	3,150
98.	Anniston-Calhoun County	548	1,593	1,726	1,775	2,263
99.	Huntsville-Madison Co.	349	-380	1,893	-118	1,151

(continued)

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Table 3 - continued
Residuals From the Regression Analysis

	Airport Name	Variables Included				
		All	Selected	Demographic	Airport	Operational
100.	Vaiden Field	3,331	3,596	4,128	3,836	4,273
101.	Craig Field	1,622	2,757	3,377	3,243	4,150
102.	Dothan	-452	1,180	3,982	1,222	1,276
103.	Bates Field	218	-185	10	-65	1,397
104.	Dannelly Field	426	-1,109	2,829	-1,364	1,398
105.	Brookley	374	1,885	2,491	1,956	2,555
106.	Birmingham Municipal	-384	43	-1,811	407	-1,783

Further Analysis

A closer examination of the airports listed in **Table 4** reveals that 12 of the 22 listed are privately owned airports. The privately owned airports are Lucky, Flomaton, Ray, Madison Sky Park, Huntsville-Lacey, Ware Island, Sky Harbor, Ardmore, Valley, Jacksonville, Martin, and Huntsville North. Extending the runway at any of these or at publicly owned airports in that area might be feasible unless a nearby airport has a longer runway. Any recommendation would require further analysis. For example, in Lanett the Valley Airport's runway is 2,950 feet, at least 772 feet shorter (and sometimes more than 1,893 feet shorter) than predicted in the regression equations. These statistics alone suggest a runway extension. But circumstances not reflected in the statistics must be considered. First, that the field is privately owned is not an argument against a runway extension, but it complicates the State's role. Second, because the runway is in a bend in the Chattahoochee River an extension would be almost impossible. Third, the publicly owned Lanett Municipal Airport is nearby and could be extended more easily.

Table 4
Airports with Short Runways According to Regression Results

Airport Name
1. Lucky Field
2. Flomaton
3. Grove Hill Municipal
5. Roy E. Ray
7. Madison Sky Park
8. Hunstville-Lacey's Spring
9. Red Bay Municipal
10. Ware Island
12. Sky Harbor
14. Hazel Green
15. Ardmore
17. Valley
20. Jacksonville Municipal
21. Headland Municipal
22. Wetumpka Municipal
25. Chatom Municipal
26. Brundige Municipal
27. Martin Field
31. Guntersville Municipal
35. Enterprise Municipal
50. Huntsville North
56. Auburn-Opelika

Although Lanett Municipal's (**Table 3**, airport number 28) runway of 3,150 feet exceeds the -500 foot threshold in two of the regressions, combining the statistical information on the two airports with other factors suggests that a runway extension would be more feasible at the Lanett airport than at the Valley airport. The point is that, to arrive at policy recommendations, other factors must be considered along with this statistical information. The analysis suggests where action might be desirable.

For some airports, the information from the statistical analysis can be used to confirm the desirability of extending a runway. For example, the management of the Auburn-Opelika airport (**Table 3**, airport number 56) would like to extend a 4,000-foot runway to accommodate larger aircraft. The statistical analysis shows that when the airport, operational, and demographic characteristics are taken into account, the runway is shorter than would be expected. One would not want to extend a runway solely because of this statistical analysis, but it is comforting to find out that the statistical analysis confirms that this airport which wants a longer runway appears to be a candidate when considering its demographic and airport characteristics relative to other airports around the state.

Likewise, data that suggests a runway is relatively long compared to others in the state need not preclude an extension. If an airport operator wants to extend a runway, state officials should consider the data but be able to identify special circumstances that might make an even longer runway desirable. In short, the statistical analysis is the basis for recommendations: it can only show how a particular airport compares to others around the state. Officials can use the comparison along with other information to decide whether to extend a runway.

In the complete technical report from which this paper is developed, the regression analysis and other information about Alabama airports were the basis of a recommendation to consider runway extension at nine airports. The Auburn-Opelika airport described above is representative of an airport for which the regression analysis confirms that a runway extension would be desirable.

Other Applications

The preceding sections have illustrated how a regression model can be used to identify airports with runways shorter than would be expected. In the larger report being made for the State, the same type of model was used to look at other factors as well. The availability of repairs at the airport was used as the dependent variable in similar analysis in order to identify airports without repair facilities where they would have been expected. Only one airport, Brewton (number 87 in **Table 3**) was identified as a strong candidate for a repair facility in this regard. Although the State may not be interested in taking an active role here, the analysis did identify a possibility for local development.

An instrument approach aids aircraft landing during poor weather conditions and at night. The existence of an instrument approach was also used as the dependent variable in a regression analysis to identify five airports that would have been expected to have instrument approaches. Many states fund, own, and operate, instrument approaches as well as other navigational aids (NASAO, 1988). Information from the analysis could aid in the identification of candidate airports for possible instrument approach installations.

In another regression, based aircraft was used as the dependent variable in similar analysis. Three airports were identified as having fewer aircraft than expected by two standard deviations, and two had more than expected. Airports with fewer aircraft than expected could be candidates for development. Those with more than expected could perhaps be used as models for expanding underdeveloped airports.

The previous sections of the paper described in detail how runway length can be analyzed with a regression model. Undoubtedly this type of analysis could be adapted to other transportation issues as well, such as channel depth of waterways and number of lanes of traffic in an urban beltway.

CONCLUSION

This paper has reported the method and results of a study evaluating the length of runways at airports in Alabama. Using runway length as the dependent variable, a collection of independent variables describing the airport characteristics and demographic characteristics of the area surrounding the airport was used to predict runway length. The residuals from the regressions were examined in order to identify airports with runways that were shorter than expected. The regression analysis identified 22 airports that could be candidates for longer runways. Of those 22, a further analysis, only partly described in the paper, led to a recommendation that 9 airports be considered for runway extensions.

Regression analysis was used to evaluate other airport characteristics as well, such as the existence of a repair facility at the airport and an instrument approach. The method used here can be applied to other types of transportation to identify facilities that are candidates for development, taking into account a large number of factors at similar facilities.

Aviation capital investment decisions are theoretically justified by some form of a benefit-cost analysis to support the project's feasibility. The Federal Aviation Administration published a model guide in 1982 (FAA, 1982) to provide a systematic approach to answering economic questions for federal aviation projects. An evaluation (McLeod, 1984) found that the guide is not generally used. The authors' experience also

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suggests that a large proportion of state aviation development projects are undertaken without the support of a benefit-cost evaluation.

One reason benefit-cost analysis may not be universally used is that a state's decision to spend money can depend more upon the availability of funds than upon an assessment of need. If no money is available for runway extensions, then none will be undertaken regardless of the desirability of extensions; conversely, if money is available, government will tend to spend it. Allocation of funds is often based on political pressures rather than on analytical findings. The analysis undertaken here can help identify airports that could benefit most from a runway extension.

Because the methodology simply compares airports and identifies those that have relatively short runways considering the populations they serve, no conclusions can be drawn about cost-effectiveness of extending a runway. This analysis simply identifies airports with relatively short runways when taking into account the air traffic and community characteristics they serve. However, if state or federal funds are available for runway extensions in a state, this type of analysis is very appropriate because it can help identify those airports with the greatest relative need. It is not a substitute for benefit-cost analysis, but rather a complement that can help identify those airports at which the net benefits from runway extension would be the greatest.

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