

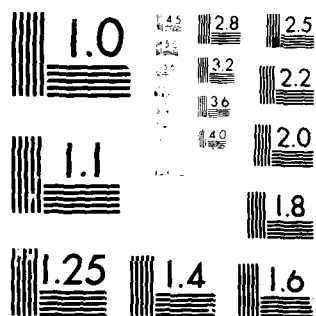
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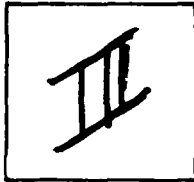


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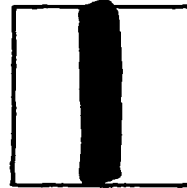
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General Aviation: Hours Flown & Avionics Purchase Decisions

by
Stephen G. Vahovich, Ph. D



May 1978

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U.S. DEPARTMENT OF TRANSPORTATION
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16. Abstract Using data from the Federal Aviation Administration's (FAA) national sample of general aviation (GA) aircraft owners, this staff study explores separately the factors that influence aircraft owners' hours flown decisions and factors influencing avionics equipage. Five different hours flown measures are utilized. Chapter 2 concentrates on the importance of aircraft owners' income and operating cost in the hours flown decisions of noncompany owners. Chapter 3 broadens the scope of the hours flown analysis by including company and noncompany owners, and discusses the importance of factors other than income and cost. Chapter 4 presents the factors that differentiate avionics equipped from nonequipped aircraft. Based on these factors a "system" is developed to predict avionics equipage for each of eight different types of avionics.					
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EXECUTIVE SUMMARY

This report marks the first time that reliable statistical sample data are used to explore the preference structure or decisionmaking process of general aviation (GA) aircraft owners. By concentrating on the underlying relationships between owners' characteristics and their hours flown and to their avionics equipage, and by utilizing representative data, the validity of the results presented in this report should be sustained for the foreseeable future in the absence of significant structural change in the GA community.

The need for such a structural assessment utilizing data specific to the GA community was identified in an earlier companion volume--General Aviation: Aircraft Owner & Utilization Characteristics (FAA-AVP-76-9)--which demonstrated the uniqueness of the GA community as compared to the general population. The latter volume also summarizes numerous statistical information collected by the Bureau of the Census from a nationally representative sample of GA aircraft owners. The present report uses this representative sample data but eschews rote, numerical emphasis. Rather, it seeks to explain the reasons why and the extent to which GA aircraft owners' characteristics determine hours flown and avionics purchases. The presentation of the results, following the intent of the President's Executive Order, is geared to common parlance, substituting easy to understand explanations and graphic presentations for the technical terminology. Thus, the report provides the individual aircraft owner with understanding of and insight into the "big picture," while simultaneously providing valuable information on the hierarchical ordering of key indicators to both the Federal Aviation Administration (FAA) and industry. Since FAA manpower staffing and facility planning are related to GA hours flown and avionics utilization, and since GA manufacturing industries' (aircraft and avionics) sales and production schedules are closely tied to GA aircraft owners' preferences, the practical value of the results presented in this report should not be underrated.

Chapter 1 is the introduction to the report, detailing the scope and the approach taken in the report.

Chapter 2 focuses almost exclusively on the importance of noncompany aircraft owners' income and operating cost in hours flown decisions. The results show that while both cost and income are important in explaining the number of hours flown, noncompany owners give more weight to costs than

income in their hours flown decisions. However, the extent to which cost exceeds income in importance varies with the type of hours flown--from almost equal importance for instrument hours flown to eleven times more important for local hours. This result implies that to properly ascertain the impact of cost and income on hour flown, each of the five types of hours flown (total, itinerant, local, instrument, and visual) must be analyzed separately. Investigating the sensitivity of hours flown to income and cost changes, leads to the conclusion that GA aircraft owners appear to act as if they were renting their airplanes to themselves, thus considering both the annualized initial purchase price of the aircraft and its operating cost in deciding at what point price has become high enough to curtail hours flown. Support for this type of consumption behavior has been found in areas other than general aviation. Further, this study found strong evidence that GA aircraft owners are firmly committed to their flying activities. Contrarily, other studies, which did not use data specific to the GA community, conclude that GA flying is a luxury good--nonessential and quickly sacrificed. Using GA specific data, this report finds strong evidence that GA aircraft owners consider their flying activities a necessity--hours flown are given up only grudgingly in response to changes in price and income.

Chapter 3 of this report broadens the purview of the hours flown investigation in two ways. First, it considers company as well as noncompany owners of GA aircraft. Second, while including a revised income-cost measure (based on Chapter 2 results), it examines in detail the importance of such other factors as aircraft productivity, age of aircraft, owners' type of use, and avionics equipage on GA hours flown. The results show that no single characteristic can be considered dominant in importance in explaining either company or noncompany owner hours flown decisions across all categories of hours flown. Thus, the results provide the necessary information on the relative importance of the various owner characteristics in each hours flown category. Further, the much broader scale results obtained in Chapter 3 concur with those obtained in Chapter 2--separate analysis must be conducted for each hours flown category. With respect to comparisons of the company and noncompany owners' hierarchical ordering of their hours flown decision criteria, discrepancies between the two owner group rankings are the rule, not the exception, across all categories of hours flown. Apparently, company and noncompany owners assess their hours flown decisions differently and consequently the two owner groups should be analyzed separately. Further, the decision structure for each owner group was reviewed for its level of decisiveness--i.e., the strength with which each owner group differentiated among the factors

in making their hours flown decisions. In two hours flown categories, total and instrument hours, the company owner ordering was more clearly defined. However, noncompany owners were more decisive in their itinerant and visual hours decisions.

The purpose and methodological approach taken in Chapter 4 is quite different from that of the preceding chapters. The focal point of Chapter 4 is to determine which GA aircraft owner characteristics account for avionics purchases, and to develop a system (based on those characteristics) that maximizes the number of correct predictions of avionics equipage and nonequipage. Eight different types of avionics are considered. In general, the results show that type of aircraft and age of aircraft are the two most powerful factors determining GA aircraft avionics equipage. Incidences of the system's "total" correct predictions--i.e., for both equipage and nonequipage--range from 46.2 percent for area navigation equipment to 86.6 percent for OMNI-directional receivers. Measured against the stringent maximum pure chance criterion, the system's correct prediction rate exceeds that which could be expected by this "educated guess" criterion in all but two of the eight avionics categories. Even for the latter two avionics categories, the percentage of the system's correct predictions exceed the criterion percentage when the avionics equipped owners are considered alone. Thus, the system developed in Chapter 4 is judged to be an effective discriminator between avionics equipped and nonequipped GA aircraft owners.

ACKNOWLEDGEMENT

Special note for cooperation and dedication is due to Ms Barbara Turner and Ms Geraldine Bolden whose patient and conscientious efforts expedited the typing of this report through its many stages of revisions.

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CHAPTER 1 INTRODUCTION

This staff report is divided into two major parts. The purpose of Part I is to examine the factors that are significant in determining the number of hours flown by general aviation (GA) aircraft owners. The first chapter in Part I presents a fairly detailed analysis of the relative importance of operating cost and owners' income in the number of hours flown decision of GA aircraft owners. In addition, the responsiveness (amount of increase or decrease) of hours flown to changes in GA owners income and operating cost is examined. This analysis is conducted using data for non-company owners of GA aircraft. The next chapter in Part I investigates both company and noncompany owners of GA aircraft. This second study should be viewed as relatively independent of the first. That is, although it deals with the same topic, hours flown, its perspective is different. The change in perspective is based partly on the results obtained in the first study, and partly on the need to thoroughly examine the influence of factors, other than cost and income, on hours flown decisions. The details of each of these studies are discussed more fully in the individual chapters in Part I.

The analytical technique and objectives of Part II are entirely different than those of Part I. The objective of Part II is to

identify aircraft owner characteristics that are important in determining whether or not an aircraft is equipped with avionics. Eight different types of communication and navigation instrumentation are considered. Once the characteristics are selected, they are combined to form a "system" which in turn is used to predict avionics equipage and nonequipage. The predictions are tested against a criterion value, formulated from known data, to assess their accuracy. Thus, the effectiveness of the system to differentiate between the avionics "haves" and "have-nots" is ascertained.

The advantages to the Federal Aviation Administration (FAA) and to industry of having information about which characteristics, as well as the relative importance of each, influence hours flown and avionics equipage are numerous. Given that GA aircraft represent approximately 98 percent of all civil aircraft and account for about 80 percent of all aircraft operations at FAA towered airports, FAA manpower staffing at its facilities is strongly influenced by GA. More particularly, certain types of flying, especially instrument flight, requires specified types of communications and navigation instrumentation and draws heavily on FAA ground facility manpower and equipment services. Currently GA accounts for almost one-third of all instrument flights handled at FAA Control Centers and well over one-half of all FAA tower instrument operations. Thus, in order to facilitate its planning for future manpower needs

as well as for the ground aid systems per se, knowledge of the factors that influence GA avionics equipage is critical to the FAA.

As may be expected, factors influencing the purchase of communication and navigation instrumentation is also of intense interest to the avionics producing industry. GA's commanding share of the civil aircraft fleet together with recent advances in microprocessors and consequent lower cost production technology target GA as a prime market. Thus, identifying the characteristics of GA aircraft and their owners that purchase the various types of avionics as well as the relative importance of those characteristics in the avionics equipage decision forms a basis for defining market demand, planning future sales/marketing strategies and arranging production schedules.

The data utilized in the analysis are from the 1975 sample of GA aircraft owners. This nationally representative sample of 9,860 GA aircraft owners was conducted by the Bureau of the Census for the FAA. Complete details of the sampling procedure and numerous statistics on GA ownership characteristics are presented in General Aviation: Aircraft, Owner & Utilization Characteristics (Report No. FAA-AVP-76-9). Whereas the latter report simply presented the information on GA characteristics, the present study examines the reasons why and to what extent GA aircraft owners behave as they do. Since the results are

based on representative data, and since the structure of aircraft owner preferences are not likely to change rapidly (similar to other consumer units), the results presented in this report may be considered relevant for some time to come. In addition, although the present study utilizes the sophisticated techniques of multiple regression analysis (Part I) and multiple discriminant analysis (Part II) to obtain the results, the complex terminology and catch phrases of these techniques have not been used. This report is written so that no prior knowledge of these techniques is necessary to understand the results presented herein. Graphic presentation and simplified explanations have been heavily utilized so that the important findings presented can be understood by both researchers and by GA aircraft owners.* This does not mean that the report reduces to light reading. The style retains the slightly more formal third person, and the substance focuses on describing serious research efforts and their results in a nontechnical manner. It is especially important that research results be comprehensible to the individual GA aircraft owner. Understanding what characteristics, and the extent to which each of these characteristics, motivate the GA community as a whole cannot be obtained from individual experience. Thus, the information

* Technical versions of the studies, presenting the equations, estimated coefficients, and supporting statistical tests are available through the Office of Aviation Policy.

presented in this report assists in making the individual aircraft owner vastly more knowledgeable about the larger community of which he is a member.

The analyses and conclusions presented in this study are those of the author and do not necessarily reflect the views of the FAA.

PART I

ANALYSIS OF GENERAL AVIATION

HOURS FLOWN

CHAPTER 2 IMPACT OF COST AND INCOME ON HOURS FLOWN BY NONCOMPANY OWNERS

2.1 NEED FOR STUDY

Based on the author's earlier research [5], the GA community may be characterized as a large and heterogeneous grouping, encompassing diverse types of aircraft, user groups, and utilization rates. Further, this earlier research also supports the uniqueness of the GA community as compared to the U.S. population. When the U.S. is divided into 11 distinct geographical areas (FAA regions), both the median (50 percent have incomes higher than this value and 50 percent are lower) and average incomes for aircraft owners are substantially higher than those of the U.S. population, and the distribution of aircraft owners across the United States is less skewed toward the East Coast than that for the general population.

Given their uniqueness and their importance in the National Airspace System (GA represents about 98 percent of all civil aircraft, and accounts for about 80 percent of all aircraft operations at FAA towered airports; [2]), an urgent need exists to conduct and present analysis on hours flown decisions utilizing GA specific data. Although the question of the impact of cost and income changes has been addressed in other studies, none of these have used data collected from the GA community. That is, for convenience, two implicit assumptions are usually made. First, that changes in the

general price level in the economy (e.g., as measured by gross national product deflator or some regional price index) represent an adequate measure of the change in prices of GA flying. Second, that GA aircraft owners react to changes in aircraft hours flown in the same manner and degree that they react to changes in the general price level. A similar set of assumptions are made concerning income. However given the uniqueness of the GA community, the validity of this assumption is questioned, and is further scrutinized by the results presented below.

2.2 FACTORS INFLUENCING GA HOURS FLOWN

Economists tell us that there are two main factors which direct buying habits. The price of the goods to be purchased and the income earned by the potential purchaser. GA aircraft owners may be thought of as a consumer of a good called hours flown. But hours flown, as with almost all goods, can only be purchased at a certain price. Excluding the initial purchase price of the aircraft, the important cost to the consumer/GA aircraft owner is the price that must be paid to operate his airplane say for one hour. The operating costs consist of fuel and oil costs, airframe and avionics costs, and engine overhaul and maintenance costs. (Hourly operating cost data by type of aircraft [3] was added onto the data obtain on the sample survey.) If hourly operating

cost increases, and excluding the influence of any other factor, the aircraft owner may be expected to fly fewer hours. The basic and simple economic principle is that as anything becomes more expensive, less of it is purchased.

In the early stages of the research the validity of this principle was tested using sophisticated multiple regression analysis techniques. Somewhat surprisingly, GA aircraft owners did not appear to consistently respond in the way the theory suggested. A second and more in-depth analysis was undertaken. The question to be answered was: what could cause GA aircraft owners to appear unresponsive to changes in operating cost? One factor, heretofore largely ignored, was the initial purchase price of the aircraft. This "initiation fee" into the club of GA owners, generally nontrivial for most owners, may exert a powerful influence on flying hours decisions. On this reasoning the basic economic principle put forth above was modified somewhat. That is, because of the high initial investment cost of purchasing an aircraft, hours flown are insensitive to increasing unit operating costs at low levels of operating cost; only at some high level of operating cost, will hours flown decrease. This theory is demonstrated in Figure 2-1. This figure shows hourly operating costs in dollars on one axis and hours flown on the other axis. The solid line from A to B, drawn on the plane formed by the

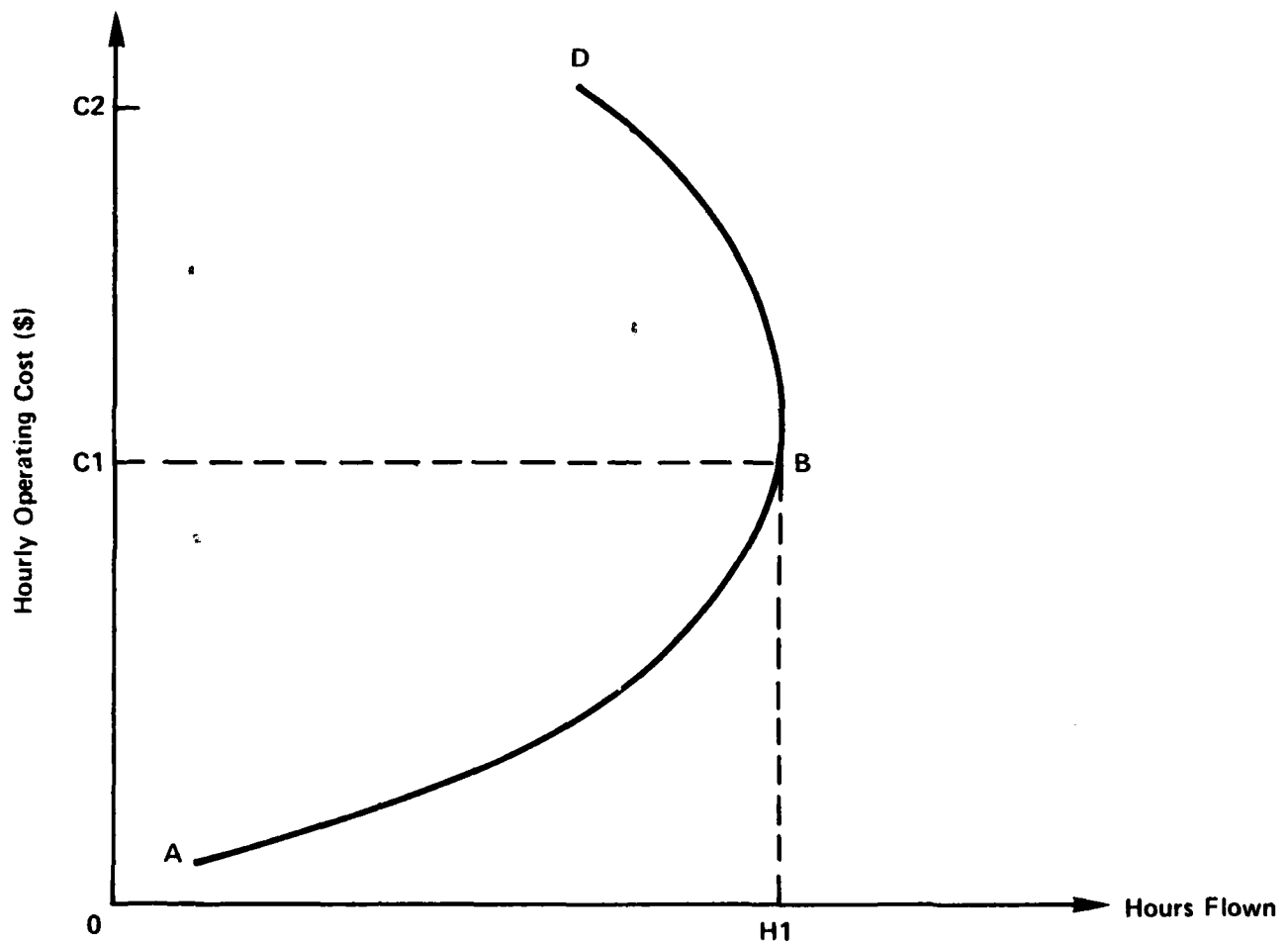


Figure 2-1

PROPOSED HOURS FLOWN RESPONSE TO INCREASES IN HOURLY OPERATING COST

axes, shows that at low levels of operating cost, hours flown continue to increase from zero to H1 hours despite the increase in operating costs from zero to C1 dollars. The portion of the line from B to D shows that only at operating costs higher than C1 do hours flown decline (from H1 toward zero) as costs increase from C1 to C2. Thus, the basic economic principle of decreases in quantity purchased with increases in price is not contradicted, but an emphasis is placed on the relevance of the magnitude of the change in operating costs. Due to the sophisticated techniques employed in this study (the mathematics and proofs we shall accept on faith) the validity of this theory can be tested for GA aircraft owners. But the investigation will not stop at this point. That is, should evidence be found to substantiate this interesting theory, mathematical extension of the results (via some basic calculus) will allow us to determine the point at which hours flown decrease in response to increases in operating cost (i.e., find point B as given in Figure 2-1).

Income is another factor often considered to be important in the purchase decision. Its relation to the quantity purchased is opposite to that of price. That is, as income increases, all other things remaining the same, we may be expected to buy more of a particular good. For aircraft owners, it may be expected that as their income increases, other things the same,

they will fly more hours. This theory is also tested in the present study. Further, the degree or magnitude of the responsiveness of hours flown to changes in owners' income is assessed.

While there are other factors which help to explain the number of hours flown by GA aircraft owners, a theoretical justification supporting the relevance of these factors and the results obtained is postponed until later. The intent of this chapter is to focus the reader's attention on the useful findings related to the impact of cost and income, rather than to get needlessly involved in the lengthy theoretical aspects. However, one digression is necessary before proceeding to the results. The purpose is to acquaint the reader with some of the particulars of the GA owners included in the study.

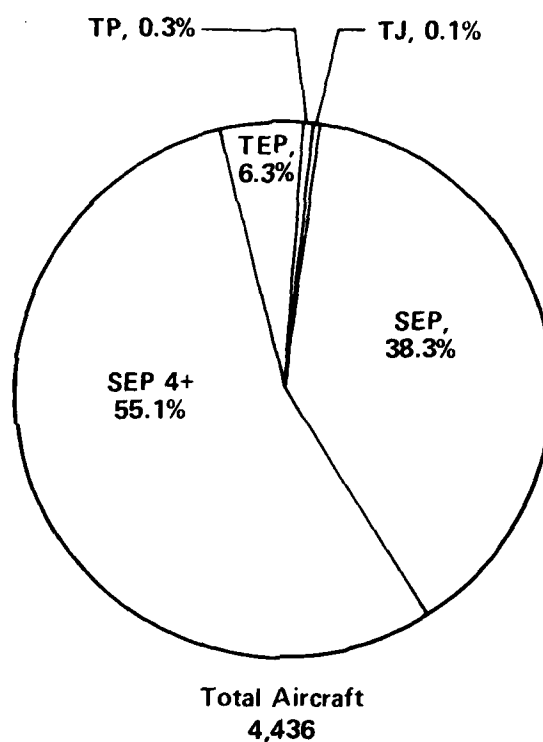
An important distinction to keep in mind for purpose of the present and following chapters is that between company and noncompany owners of GA aircraft. Company ownership means that the registered owner (FAA Form 8050-1) is some business entity such as a corporation, etc. Noncompany ownership means that the registered owner of the aircraft is an individual. However, this does not preclude the possibility that an individual will use his aircraft for business purposes. For example, an aircraft owned by an individual in a sole proprietorship business may use that aircraft for business purposes. (Figures 2-3 and 3-2 show the percent distribution

of use for noncompany and company owners, respectively.) However, it must be recognized that business entities realize special advantages such as tax write-offs for aircraft purchases and operating costs, some of which are not available to noncompany owners using their aircraft for business purposes. Further, Figure 2-3 shows that the personal use category accounts for 63.3 percent of total noncompany owners; however, Figure 3-2 (see Chapter 3) shows that the comparable percentage for noncompany owners is only 18.4 percent. Thus, even under the most liberal assumption--all use categories other than personal use are for business purposes and available for tax advantages--only 36.7 percent of the noncompany owners would realize some tax advantages; whereas 81.6 percent of the company owners would realize tax advantages. Because these advantages and other factors may be expected to result in differences between noncompany and company owners of aircraft in the magnitude of their hours flown response to price and income changes, these two groups of owners are considered separately. This chapter deals only with noncompany owners (Chapter 3 presents a comparison analysis for company and noncompany owners). Aircraft owned by noncompany owners represent 65.1 percent of the GA fleet.

For the purpose of eliminating suspected deviant members of the owners under study (i.e., individuals whose price and income responses may be atypical of the majority) only fixed wing aircraft, flying some positive number of hours are included. Twin/multiple-engine piston aircraft weighing

over 12,500 lbs. are excluded. That is, since the purpose of the study presented in this chapter is to estimate representative hours flown responses to changes in cost and income for a segment (noncompany owners) of the GA community, the latter were suspected of distorting this objective. Specifically, piston aircraft weighing over 12,500 lbs. were excluded because this class of aircraft has not been manufactured since 1960, and almost one-half of them could not be classified by any of eight user categories describing the other members of the GA community.

The following three figures are used to illustrate some of the characteristics of the GA owners upon whose responses the results are based. Remember that the "total" values (i.e., total aircraft in Figure 2-2 and total users in Figure 2-3) represent the number of observations in the sample used for analysis, not to the total number in the fleet. Figure 2-2 shows the composition of the GA noncompany owner fleet used in the study by type of aircraft. This figure shows that the noncompany owner is much more likely to own a single-engine piston (4 or more seats) aircraft (55.1 percent) than any other type of aircraft. The next most popular aircraft types are the small single-engine pistons (38.3 percent), twin-engine pistons (6.3 percent), turboprops (0.3 percent) and turbojets (0.1 percent). Figure 2-3 shows the composition of the noncompany owners according to primary use category. The largest concentration of noncompany owners is in the personal



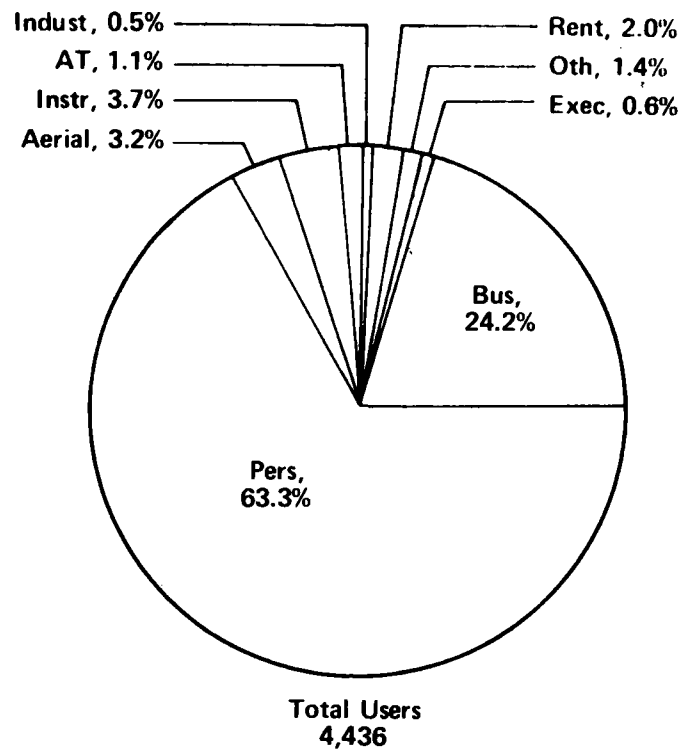
Legend:

SEP — Single-Engine Piston (1-3 seats)
SEP 4+ — Single-Engine Piston (4 or more seats)
TEP — Twin-Engine Piston (under 12,500 lbs.)

TP — Turboprop
TJ — Turbojet

Figure 2-2

PERCENT DISTRIBUTION OF AIRCRAFT BY TYPE OF AIRCRAFT



Legend:

Exec — Executive
Bus — Business
Pers — Personal
Aerial — Aerial Application
Instr — Instructional

AT — Air Taxi
Indust — Industrial
Rent — Rental
Oth — Other

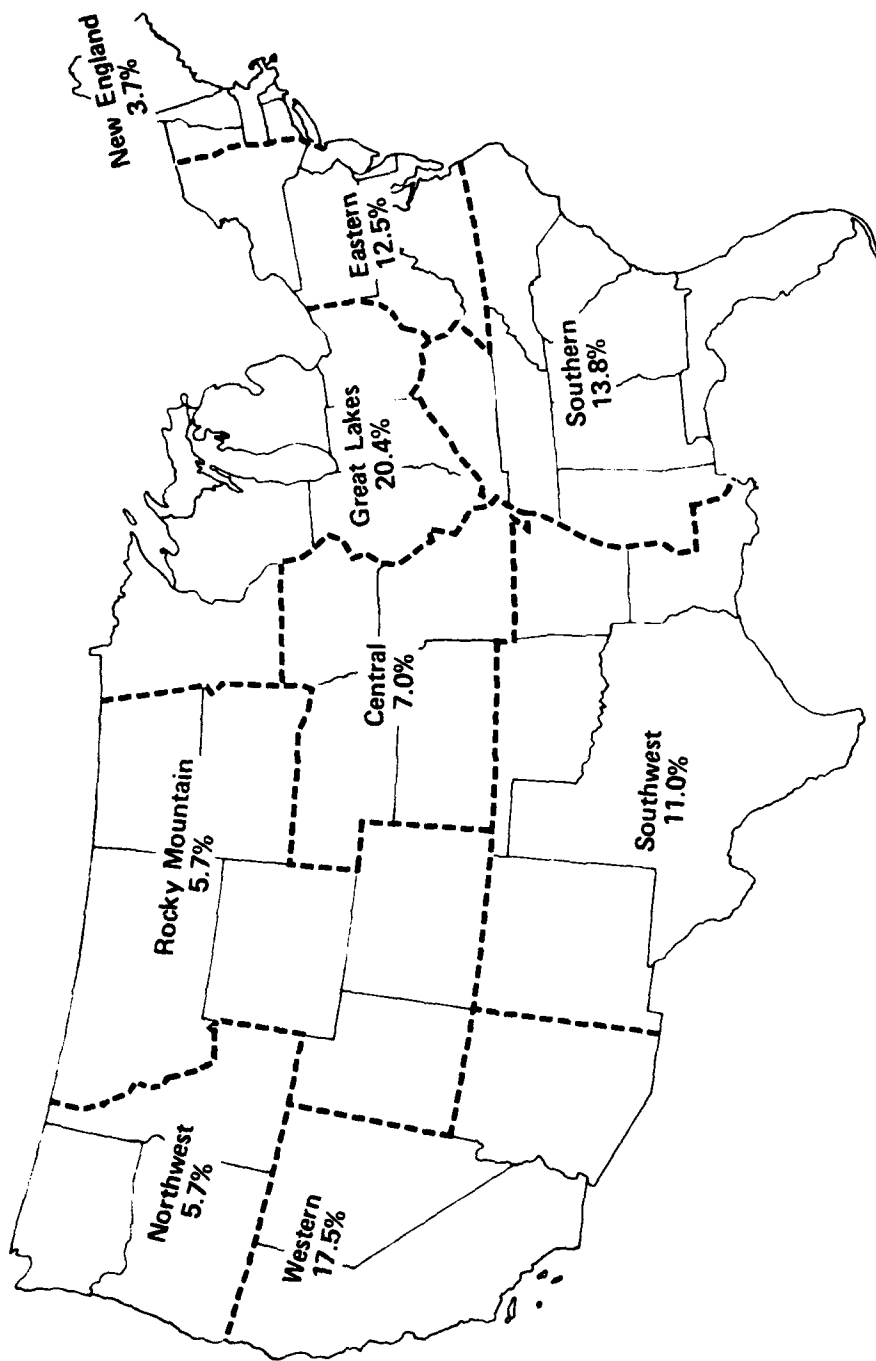
Figure 2-3

PERCENT DISTRIBUTION OF AIRCRAFT BY USER GROUP

use category (63.3 percent). Business use is the next largest category (24.2 percent), with the remainder of owners distributed among the other use categories. As for regional distribution, Figure 2-4 shows that the largest concentration of noncompany owners occurs in the Great Lakes Region (20.4 percent), followed closely by the Western Region (17.5 percent). If these figures are compared against those presented in General Aviation: Aircraft, Owner & Utilization Characteristics, it can be seen that the impact of including the screening criteria (i.e., fly some positive number of hours, etc.) does not significantly affect the characteristics of the sample. In the unscreened sample single-engine piston (4 or more seats) represent the largest proportion of the fleet, personal users are more prevalent than any other user category, and the Great Lakes Region has the largest concentration of owners. That is, the screening criteria have not changed the relative order of the components of the type of aircraft distribution, use distribution, or the regional distribution. Thus, the results obtained from the noncompany owners used in this study may be considered representative of all noncompany owners.

2.3 IMPORTANCE OF FACTORS IN THE HOURS FLOWN DECISION

Using multiple regression analysis, estimates of the relative impact of changes in cost, income and other factors were



Other Regional Headquarters

2.5% Alaskan Region (Anchorage, Alaska)

0.1% Pacific-Asia Region (Honolulu, Hawaii)

Legend

----- Regional Boundary

Figure 2-4

FAA REGIONAL DISTRIBUTION OF NON-COMPANY OWNERS OF AIRCRAFT

derived for each of five different measures of hours flown-- total hours flown, itinerant local, instrument, and visual flight hours. As used in this study, local and itinerant hours are the component parts of total hours. Instrument and visual hours comprise itinerant hours. Each of these hours flown measures will be considered separately.

It is critical at this time to alert the reader to the fact that the results presented in this chapter, and throughout much of this report, are presented in terms of the importance of each factor (e.g., income, operating costs, etc.) relative to the other factors. For the hours flown analysis, this means that the particular numerical value assigned to a factor is not important in and of itself, but rather that the relationship of that value to the values obtained by the other factors is the important point. For example, if there were only two factors, and if Factor A has a value of 4 and Factor B has a value of 2, then Factor A is two times more important or powerful than B in determining the number of hours flown. However, an identical statement is true if Factor A had a value of 8 and Factor B had a value of 4. The key point to remember is that the numerical value per se is not important for the purposes of this report, but the relative "position" of a factor is of crucial importance-- i.e., the rank assigned to a factor when all the factors are ordered from highest to lowest, based on their associated numerical values. Thus, the basis for the discussion throughout

much of this report is what econometricians call the "standardized beta," beta weight, or standardized estimating coefficient. Simply, it is a useful tool to assess the relative importance of say apples and oranges by standardizing them to common basis. Similarly, the reader must also be aware of the fact that certain factors impact hours flown in a positive manner (e.g., income and hours flown move in the same direction) while others have a negative impact (e.g., as cost increase, hours flown decrease). Economic theory explains the direction of impact. However, factors having equivalent numerical values associated with them are equally important in determining hours flown regardless of the direction of their impact.

Since this study focuses on assessing the importance of the factor's impact, the graphical presentation of the results includes only this dimension. For the interest of the reader, the direction (positive or negative) of the factor's impact, as it is used in this chapter for a specific hours flown category, is presented in the theoretical discussion in the text and is summarized in Table 2-A. This table may be used as a handy reference guide to the discussion and in conjunction with the results presented in the bar-charts (Figures 2-5 through 2-11).

The actual or absolute magnitude (i.e., impact relative to zero) of cost and income on hours flown for the various hours flown categories will be considered in Section 2-4 of this chapter.

For the benefit of the economists, it should be noted that all monetary variables used in the study have been deflated by a regional price index to control for distortions in the results that may arise simply from geographical variations in cost and income.

<u>FACTOR</u>	<u>DIRECTION OF IMPACT</u>
Annual Family Income	+
Hourly Operating Cost	-
Manufactured Pre-1960	-
Personal Use*	-
Instructional Use	+
Avionics	+
Air Carrier Service	-

* Personal use has a positive impact in the local hours decision only (see Section 2.3.3).

TABLE 2-A
DIRECTION OF IMPACT OF FACTORS
ON HOURS FLOWN

Finally, it should be noted that since the purpose of this chapter is to concentrate on the impact of cost and income on hours flown, the impact of other factors receive considerably less attention. Results for "key" factors are presented and discussed in this chapter. That is, results for income and cost are always presented, as are results for the most important (highest numerical value) and least important (lowest numerical value) factors. Further, if a factor achieves the highest or lowest rank in any one hours flown category, it is included in the presentation of the results for the other hours flown categories as well. Exceptions occur when a factor is irrelevant for a particular hours flown category--e.g., air carrier service, as an alternative to GA flying, is important to itinerant hours, but is irrelevant for consideration in local hours. Using this rule the discussion is able to focus attention on the income and cost impacts, simultaneously maintaining continuity with respect to the factors considered, and minimize unnecessary (for purposes of this chapter) distraction from the stated objective. The objectives of Chapter 3 are much broader and it presents results for each factor used in the analysis.

2.3.1 TOTAL HOURS FLOWN

Figure 2-5 shows the importance of key factors, relative to the others, in the owners' decisions about how many hours to fly.

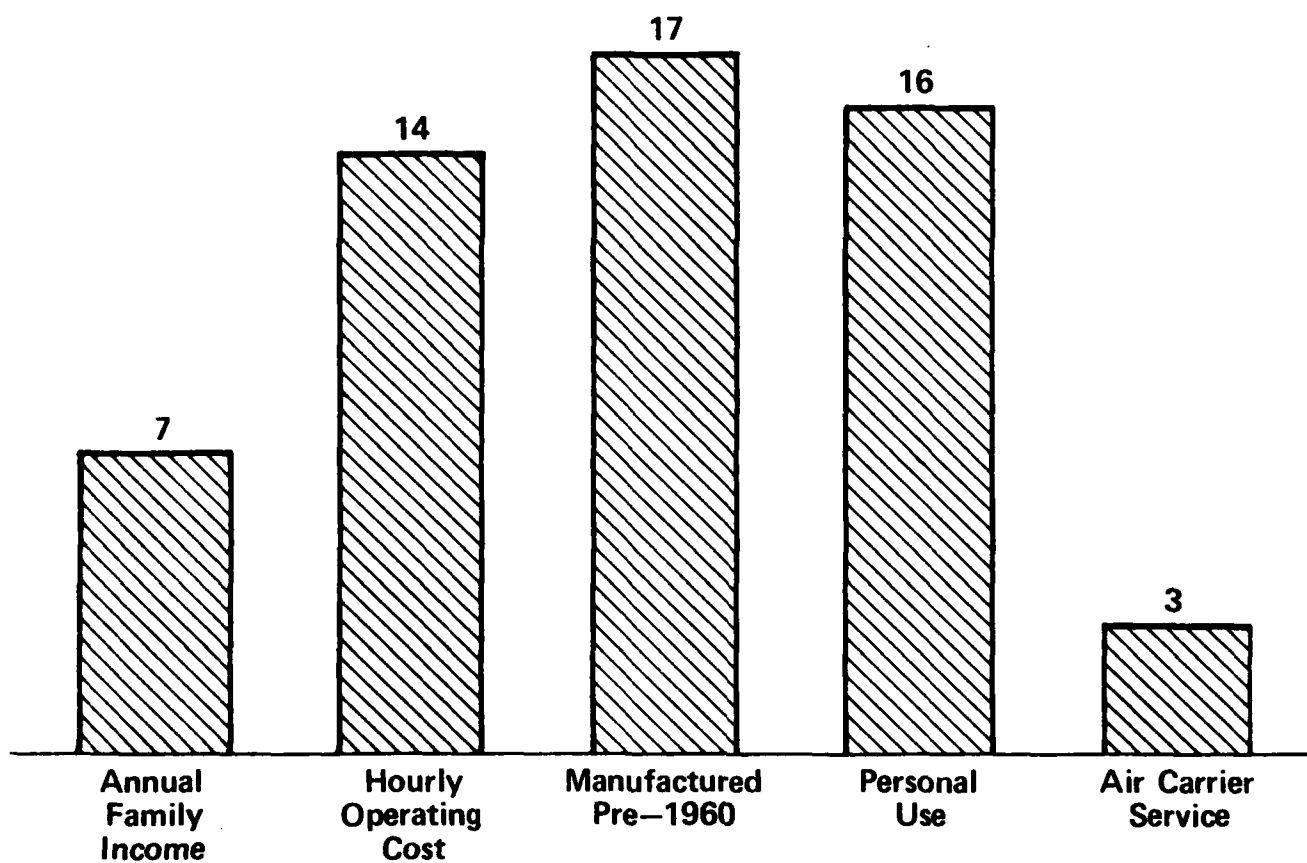


Figure 2-5

RELATIVE IMPORTANCE OF KEY FACTORS IN
TOTAL HOURS FLOWN DECISION

The figure shows that hourly operating costs are twice as important as annual family income in the total hours flown decision. The least important factor is the availability of air carrier service, while the most influential factor is age of the aircraft. The type of use, specifically personal use, is also very important in the hours flown decision. The theoretical justification supporting the use of the latter three factors in the hours flown equation and their expected direction of impact may be briefly stated as follows. Due to the deleterious effect of age/use on an aircraft's operating condition and performance, older aircraft may be expected to fly fewer hours. For the opposite reason, more recent vintage aircraft may be expected to fly more hours. The greater the availability of a substitute mode of transportation, specifically the number and frequency of air carrier service, the fewer the expected number of hours flown. Because of the way the study is structured, theoretical arguments for the user group factors are related to business users. An owner who flies his aircraft primarily for pleasure may be expected to fly fewer hours than an owner who flies for business reasons. That is, business users suffer a greater financial loss if they do not reduce nonproductive travel time. This rationale supports the use of these factors for all categories of hours flown except local hours (see Section 2.3.3).

As for the direction of the impact, the multiple regression results support all the contentions advanced thus far. That is, hours flown increase with income and decrease with increases in cost. Older aircraft fly fewer hours and newer aircraft fly more hours. Personal users fly fewer total hours than business users and the availability of air carrier service decreases total hours flown. While these findings may seem almost trivial, this study represents the first time that this reasoning has been scientifically tested and has been found true at a statistically significant level using actual sample data from aircraft owners. As is well known, many supposedly common sense notions have, under the close scrutiny of scientific testing, been proven erroneous, or at least not as simple as they first appeared.

2.3.2 ITINERANT HOURS FLOWN

Itinerant hours consist of the time elapsed during a flight having an origin different than its destination. Figure 2-6 shows the relative importance of key factors in the itinerant hours flown decision. The figure shows that hourly operating costs are almost three times as important as annual family income in the itinerant hours flown decision. Clearly, the most important factor is equipage with an automatic direction finder (ADF). The intent of introducing this variable in the itinerant hours equation is to capture the impact of the level of aeronautical sophistication on the hours flown decision.

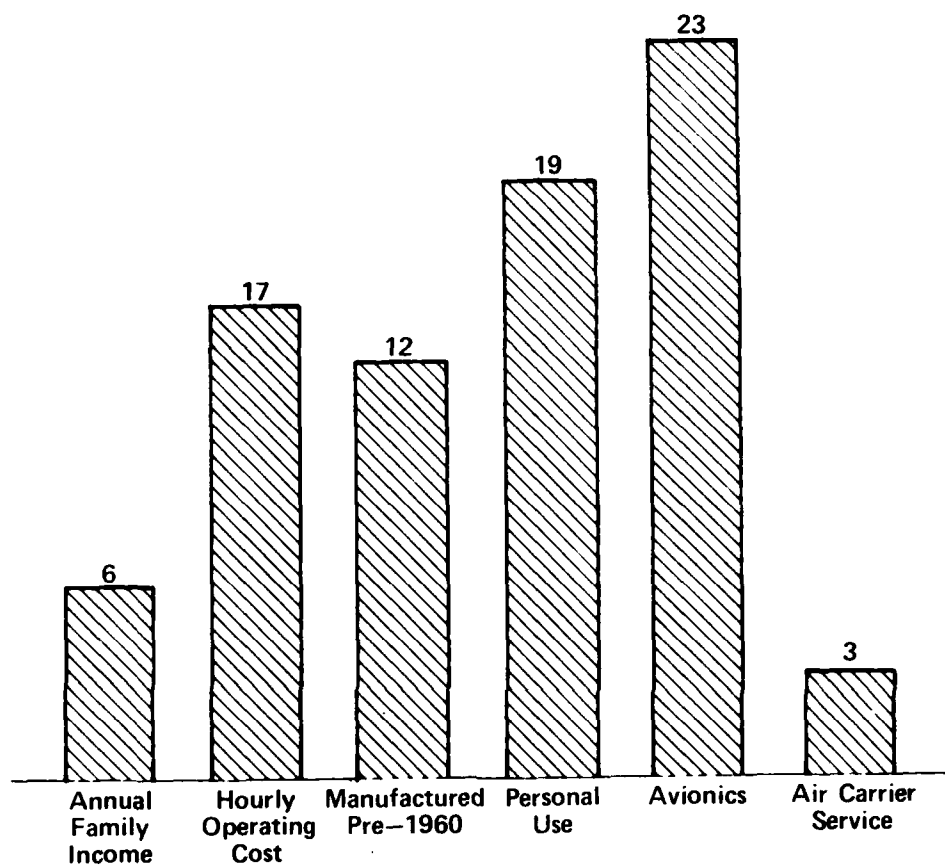


Figure 2-6

RELATIVE IMPORTANCE OF KEY FACTORS IN
ITINERANT HOURS FLOWN DECISION

This particular type of avionics (ADF) was selected because of its function--i.e., it is indicative of longer inter-city flights--and it did not cause distortions of the results when included with the other factors.

As for the other factors presented in Figure 2-6, the availability of air carrier transportation appears to have the least impact on the itinerant hours decision. Personal use appears to exert more influence than age of aircraft in the itinerant hours flown decision, whereas their relative positions were reversed in the results for total hours.

The direction of the impact of these factors is the same as that found for total hours. That is, increases in income and the level of aeronautical sophistication are associated with increase in itinerant hours flown, while increases in cost, age, personal use, and availability of air carrier service are associated with decreases in itinerant hours flown. Results for avionics shows that this factor has a positive influence on the number of hours flown.

2.3.3 LOCAL HOURS FLOWN

Local hours are defined as the time elapsed between a takeoff and landing, both of which occur at the same airport. Local hours, having the same origin and destination point, are generally associated with the pure pleasure of flight experience. Since, at best, local hours may be considered incidental to the business use of aircraft, personal users may be expected

to fly more local hours than business users. Similarly, since flight training involves a great deal of local flying, instructional users may be expected to fly more local hours than business users.

Figure 2-7 illustrates the relative importance of key factors in determining the number of local hours flown. This figure shows that owners' income is the least important factor in the local hours flown decision. Instructional use is by far the most important factor, followed by hourly operating costs. Age of aircraft is only about one-half as important as cost in its influence on the number of local hours flown decision. Comparing Figures 2-7 and 2-6 quickly shows the variation in the relative importance of the factors for each of the different types of hours flown. Hourly operating cost is significantly more important relative to family income (11 to 1 ratio) in the local hours decisions than it is in the itinerant hours decision (17 to 6 ratio). These differences in relative importance appear to reflect the distinguishing characteristics of each of the two types of hours flown. That is, the definition of local hours primarily suggests a pure pleasure flight of relatively short duration with highly discretionary trip costs. The definition of itinerant hours suggests a purposeful transportation flight of longer duration entailing a certain minimum trip cost. Since most local hours are primarily for pleasure flight, costs should be more important than for purposeful transportation. Alternatively, since the amount of time spent

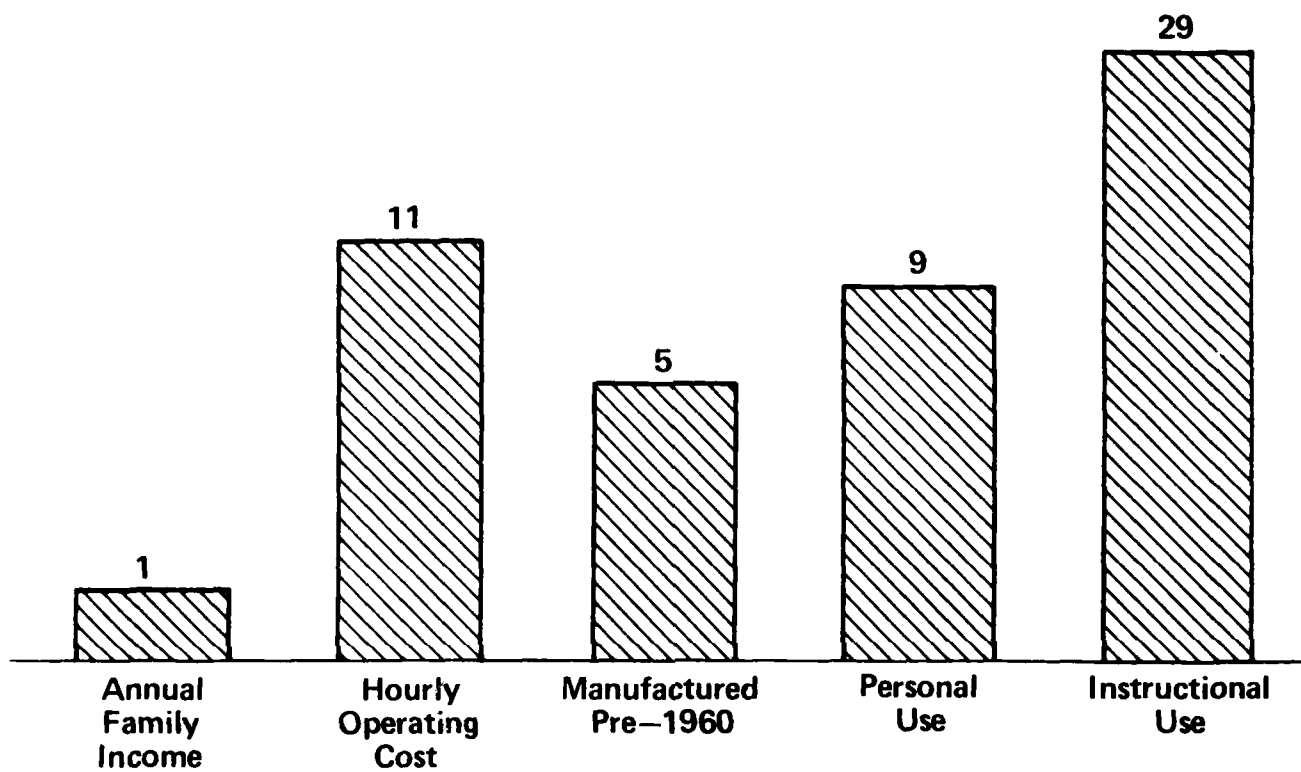


Figure 2-7

RELATIVE IMPORTANCE OF KEY FACTORS IN
LOCAL HOURS FLOWN DECISION

in local flying is more discretionary than it is for itinerant flying, the income ability to purchase larger discrete bundles of hours (time from origin to destination) becomes more important in the itinerant hours purchase decision.

2.3.4 INSTRUMENT HOURS FLOWN

As used in this study, instrument hours form one of the two components (the other is visual hours, see following section) of itinerant hours. In addition to satisfying the requirement for itinerant flight (origin different than its destination), instrument hours require that the time spent in flight be under the control (i.e., periodic reporting of altitude and location) of an FAA facility. This entails certain on-board avionics (e.g., two-way radio communications system and certain navigation equipment). Since instrument hours are the most sophisticated flight procedural level, equipage with an ADF did not serve well to differentiate among GA owners flying especially high or low numbers of instrument hours. Thus for instrument hours only, equipage with an altitude encoding transponder is used to differentiate among owners flying at the most sophisticated flight procedural level. Equipage with this type of avionics, required for high altitude flights (18,000 feet and above) and in airspace around most major cities, suggests a high number of instrument hours flown.

Figure 2-8 illustrates the relative importance of key factors in determining the number of instrument hours flown. This figure shows that family income, hourly operating cost, and avionics equipage are about equally important in the instrument hours flown decision. Age of aircraft and personal use are considerably less important than any of the other factors. Compared to the relative importance of cost to income for the other hours flown categories, the results for instrument hours are quite unique. That is, for itinerant hours operating cost is about three times more important than family income, for total hours it is twice as important, and for local hours it is eleven times more important in the hours flown decision. However, in the instrument hours flown decision cost and income are approximately of equal importance. The large weight obtained by income in the instrument hours decision may be due to the fact that the cost of instrument hours, given the minimum trip length cost requirement and the additional and not insignificant cost required for sophisticated avionics, are relatively more expensive than other types of hours flown. The average hourly operating costs, across all characteristics of the study subsample, for each type of hours flown are presented in Figure 2-9. This figure adds credence to the above contention, showing that, on average, instrument hours are significantly more expensive than any other type of hours flown. Further, the results presented in Figure 2-8 suggest that as the cost of flying takes a

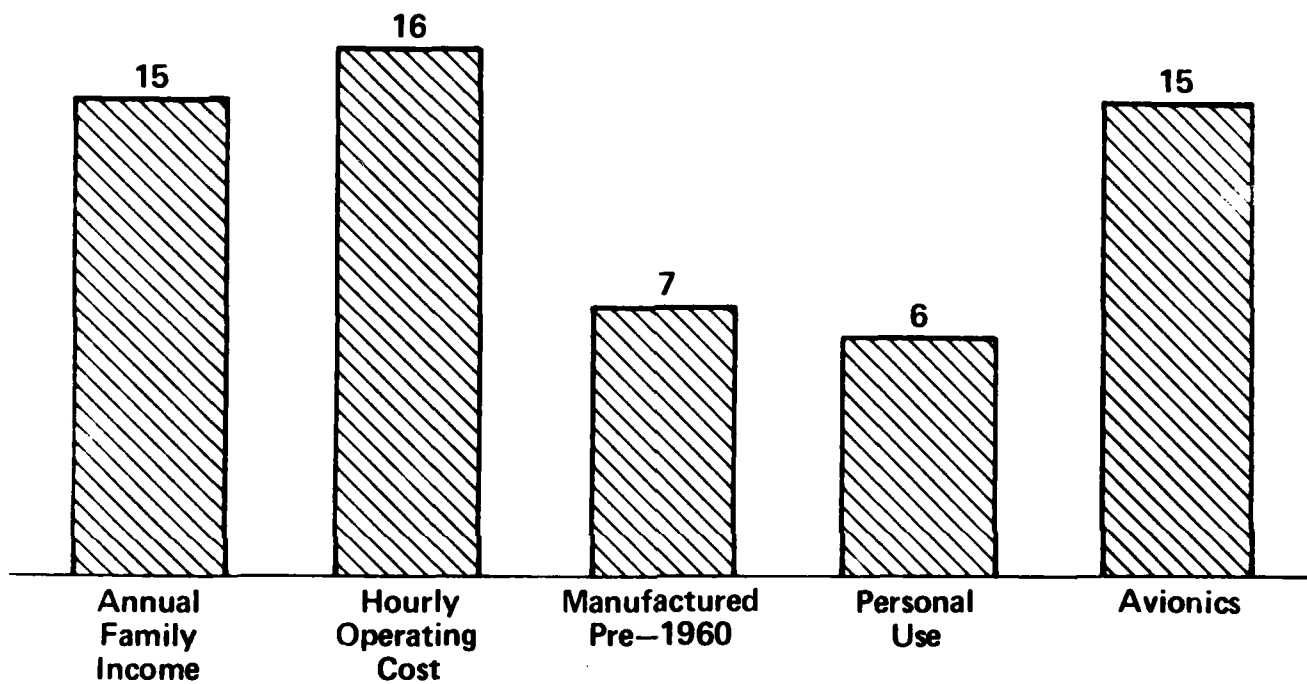


Figure 2-8

RELATIVE IMPORTANCE OF KEY FACTORS IN
INSTRUMENT HOURS FLOWN DECISION

Dollars

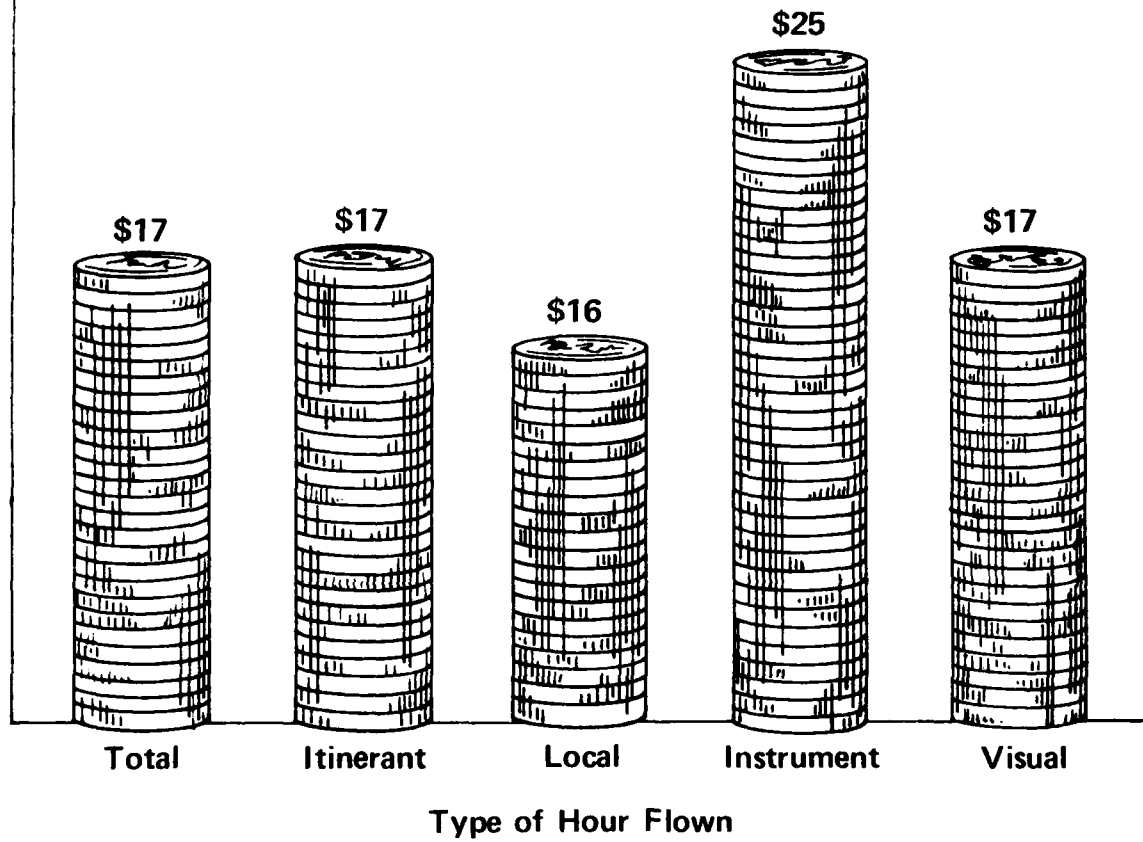


Figure 2-9

AVERAGE HOURLY OPERATING COST BY
TYPE OF HOURS FLOWN

larger and larger portion of the owner's income, the ability to purchase this type of good becomes not only more important in and of itself, but it also is given increasing weight in the purchase decision relative to the cost of that good.

That instrument hours may be characterized, relative to other types of hours flown, as a high income consumer (i.e., taking a larger proportion of income) is supported as follows. The average annual family income of GA owners, across all the other characteristics of the study subsample, for each hours flown category is presented in Figure 2-10. Clearly, the average family income for owners flying instrument hours is greater than that for other types of hours flown. Comparing the average cost estimates, presented in Figure 2-9, with the average income estimates, illustrated in Figure 2-10, suggests that of the five categories of hours flown, hourly operating costs for instrument hours take a greater share of family income than for any other hours flown category.

As for the direction of the impact of the factors presented in Figure 2-8, the results support the theoretical notions advanced earlier and are summarized in the last paragraph of Section 2.3.2.

2.3.5 VISUAL HOURS FLOWN

As used in this study, visual hours form one of the two components (the other is instrument hours, see Section 2.3.4) of

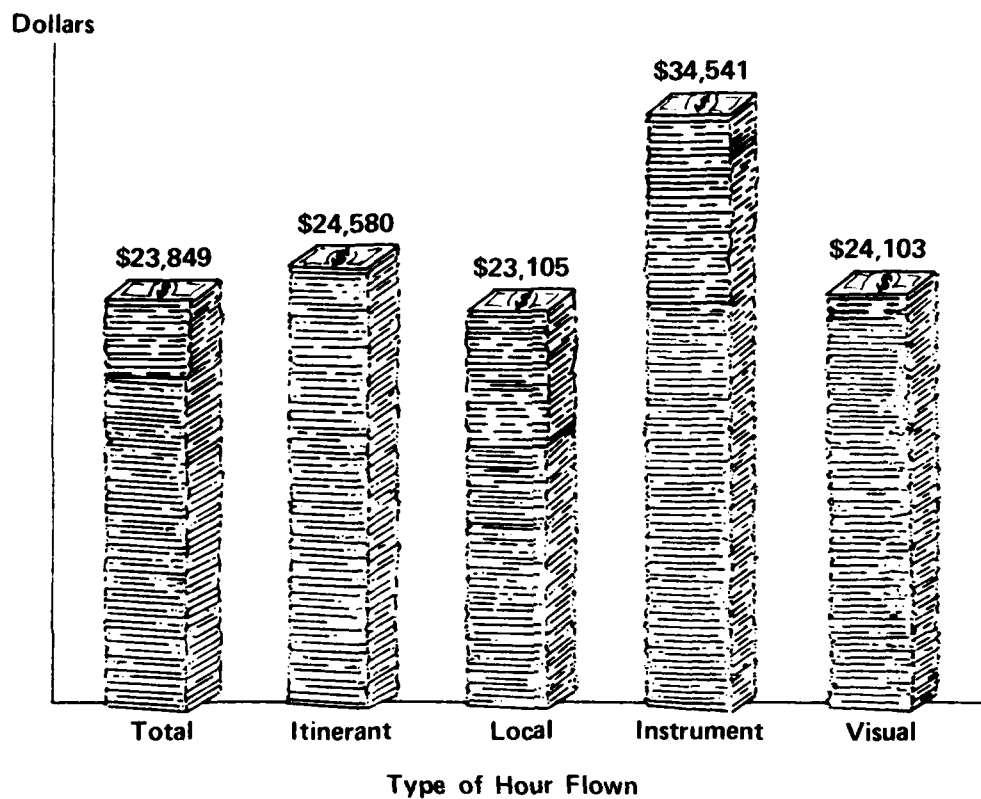


Figure 2-10

AVERAGE ANNUAL FAMILY INCOME
BY TYPE OF HOURS FLOWN

itinerant hours. In addition to satisfying the requirements for itinerant flight (origin different from its destination), visual hours do not require periodic reporting to an FAA facility. Although visual hours require certain minimum avionics equipage, the instrumentation requirements are less stringent than for instrument hours.

Figure 2-11 illustrates the relative importance of key factors in determining the number of visual hours flown. This figure shows that personal use and avionics (ADF) equipage share equally the most important place in the visual hours flown decision. The next most important factor is hourly operating cost, followed by age of the aircraft. Family income and availability of air carrier service are relatively less important than the other factors shown. The result that income is considerably less important, relative to operating cost, in the visual hours flown decision is similar to the results obtained for all other categories of hours flown except instrument hours. Results regarding the direction of the impact of the factors, presented in Figure 2-11, on visual hours flown are identical to those presented for itinerant hours and are adequately summarized in Section 2.3.2.

2.4 DEGREE OF SENSITIVITY

While the preceding sections have focused largely on pointing out which factors are important, and why, in the hours flown

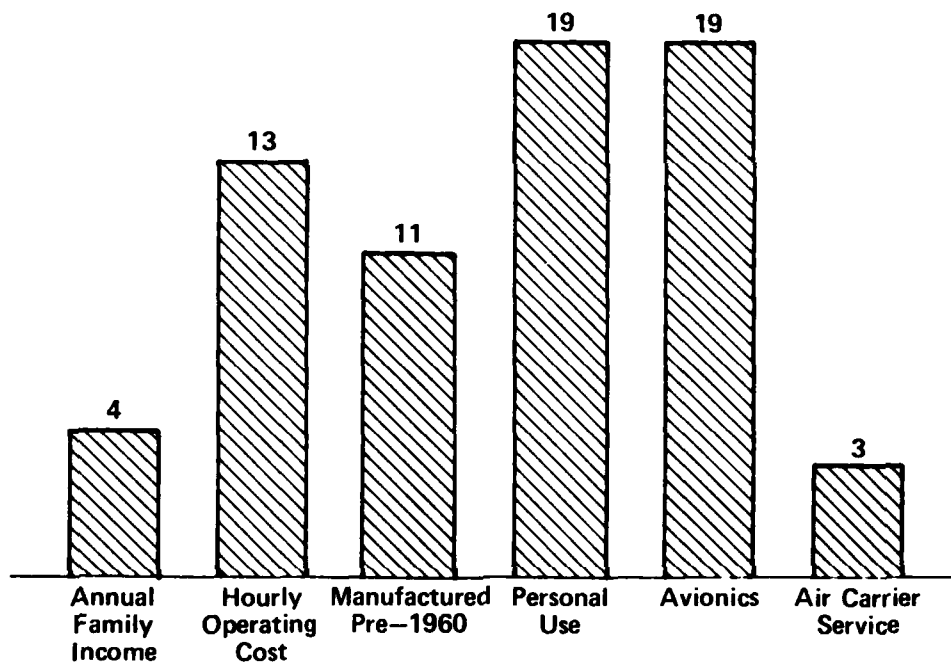


Figure 2-11

RELATIVE IMPORTANCE OF KEY FACTORS IN
VISUAL HOURS FLOWN DECISION

decision, this section emphasizes the degree of responsiveness (i.e., magnitude of impact relative to zero) of hours flown to price and income changes.

This study found statistically significant evidence that GA noncompany owners exhibit the behavior described by Figure 2-1 for total hours, itinerant hours, and visual hours. (Similar evidence was found for instrument hours, however, it was not statistically significant.) As may be recalled, this strongly supports the contention that hours flown are insensitive to increasing hourly operating costs at low operating cost levels; only at some high level of operating costs, will hours flown decrease. However, when the critical point, at which the curve begins to bend backward (point B in Figure 2-1), was investigated for these hours flown categories, its numerical value was found to be inordinately high. That is, less than 1.0 percent of the aircraft have hourly operating costs greater than or equal to that estimated from the results. One plausible explanation is that in their hours flown decisions aircraft owners consider not only the hourly operating costs but also the fixed cost of their aircraft. Investigating this scenario, representative investment/purchase price (spread over the life of the aircraft) data [3] for the various types of aircraft, divided by the number of hours flown, were added to the hourly operating cost data. The resultant figure may be viewed as an hourly use charge that the owner pays to himself for the use

of his aircraft. It is conceptually equivalent to the gain that he would realize if he had rented the plane rather than using it himself. The results of comparing the computed hourly use charge with the critical value showed a high degree of similarity for the three categories of hours flown where statistically significant evidence of backward bendingness occurred. This suggests that owners decrease hours flown approximately at the same point at which the price of an additional hour equals the total hourly cost (operating plus annualized fixed) of flying. This is illustrated in Figure 2-12. This figure shows the critical costs, above which hours flown begin to decrease (equivalent to point B in Figure 2-1), and the corresponding mean hourly use charge (in parenthesis). Support for this type of consumption behavior has been found in areas other than general aviation.

The results for local hours were considerably different. That is, local hours decreased as operating costs increased over all relevant levels of operating cost. The lack of a critical or threshold value for local hours, may reflect the pleasure use and highly discretionary nature of local hours.

Further investigations were conducted to determine the extent of the responsiveness of hours flown to cost and income changes. The customary way of measuring this "sensitivity" is to compute the percentage change in hours flown in response to a one percent change in price. A similar computation is performed for a

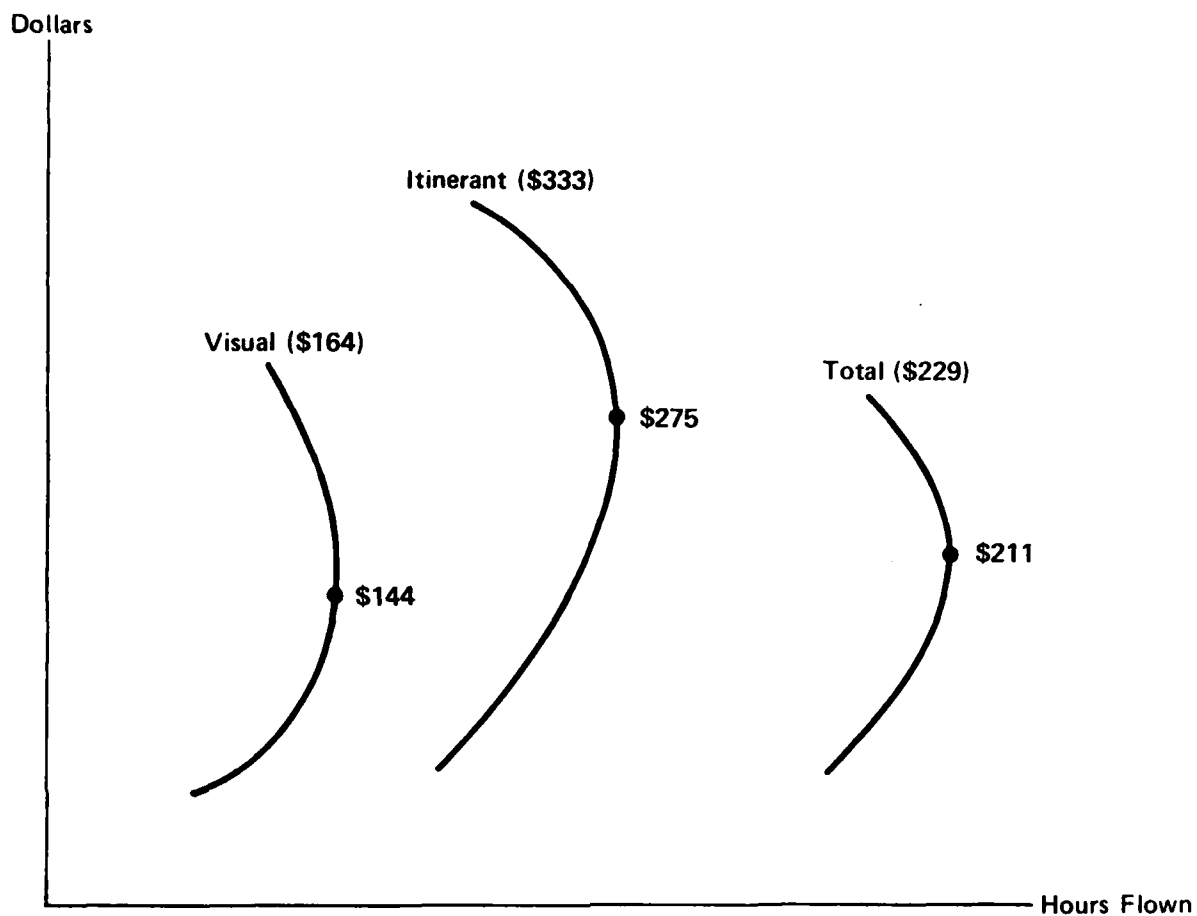


Figure 2-12

CRITICAL OPERATING COST (AVERAGE USE CHARGE IN PARENTHESIS)
ABOVE WHICH HOURS FLOWN DECREASE

one percent change in income. Economists call these estimates the "price elasticity" and "income elasticity" of demand, respectively. The results of these computations for the present study are very interesting, not only for the magnitude of the estimated elasticities themselves but also because of the relationship between the income and price elasticities. First, it should be pointed out that the computation for each category of hours flown showed that GA noncompany owners' hours flown decisions are not very sensitive to family income changes. That is, while hours flown increase as income increases, they do not increase in the same proportion. The results show that if income increases by 1.0 percent, hours flown increase by a significantly lesser amount (on average by about 0.10 percent). Second, similar results are obtained for the sensitivity of hours flown to hourly operating costs (on average, hours flown decrease by 0.29 percent in response to a 1.0 percent increase in costs). In contrast, two fairly recent studies, one using income of the population for a specific geographical area [1], another using income for the U.S. population [4], found that GA owners' activity increases by a greater percentage than the percentage change in income. The latter findings imply that GA flying would be classified as a luxury good. That is, a good consumed which is not considered essential and is therefore rather quickly sacrificed if income decreases. The principal difference between the two studies cited above and the research results presented in this chapter is that the present study is

based on data specific to the GA community. The lack of research based on GA specific data has been a conspicuous void until the present study. Thus, contrary to other studies, the results presented in this chapter imply that GA owners consider their flying hours a necessity good--a good which they are willing to give up grudgingly and only after large changes in income. Further evidence to support this result is obtained by comparing the magnitudes of the changes in flying hours in response to changes in income with the hours flown response to changes in prices. That is, this study found that for each category of hours flown, the hours flown response to changes in prices is significantly greater (on average at least twice as great) than the response to equivalent percentage changes in income. This is considered strong evidence by many economist [6] that the good in question (hours flown) is a necessity. If it were a luxury good, the opposite relationship would hold. Thus, in general, the results suggest that while the GA community acts in accordance with conventional economic theory (i.e., increasing hours flown in response to increases in income and decreasing hours flown as costs increase), they are strongly committed to their flying activities. Hours flown are curtailed only grudgingly in response to changes in price and income.

2.5 CONCLUSIONS

This chapter has focused almost exclusively on the impact of changes in noncompany owner's income and operating cost on

hours flown. The results shows that the importance of these factors in the hours flown decision varies with the type of hours flown. While both factors are useful in explaining hours flown decisions, operating cost appears to be more powerful than owner's income in the decision hierarchy. For total hours flown, operating cost is twice as important as income; for itinerant hours it is three times more important; and for local hours it is eleven times more important. However, disaggregating itinerant hours into its components show that income and operating cost are equally powerful in the instrument hours flown decision. In the other component of itinerant hours, visual hours, operating cost is over three times more important than income. An interesting point to note is that the impact of income and cost in the two aggregate hours flown categories (i.e., total and itinerant hours) is not simply a straightforward summation or average of their respective impacts in the components of these aggregate categories. This is because, when, for example, itinerant and local hours are added to form total hours, the two distributions are combined. To the extent that either or both of these distributions are excessively skewed and dissimilar, the results will correspondingly be unpredictable. That is, to properly ascertain the impact of cost and income on hours flown, the various hours flown categories must be considered separately. The impact of cost or income exhibited for total hours cannot be used as representative of their respective impacts for either local or itinerant hours.

Nor can their itinerant hours results be used to reduce their separate impacts in either instrument or visual hours.

Investigating the sensitivity of hours flown to income and operating cost revealed strong evidence supporting the contention that hours flown are insensitive to increasing hourly operating cost at low operating cost levels; only at some high level of operating cost will hours flown decrease. GA aircraft owners decrease hours flown approximately at the same point at which the price of an additional hour flown equals total hourly cost. That is, the GA aircraft owner appear to act as if he were renting the plane to himself, thus he considers both his initial purchase price of the aircraft and operating costs in deciding at what point prices have become high enough to curtail hours flown. Further, this study found strong evidence that GA aircraft owners are firmly committed to their flying activities. Contrarily, other studies, which did not use data specific to the GA community, conclude that GA flying is a luxury good--an extra or a good which is not considered essential and quickly sacrificed. This study, based on data specific to the GA community, finds that GA aircraft owners consider their flying activities a necessity--hours flown are given up only grudgingly in response to changes in price and income.

CHAPTER 2 REFERENCES

1. Baxter, N.D. and Howrey, E.P. "The Determinants of General Aviation Activity: A Cross-Sectional Analysis," Transportation Research, II (March 1968), 73-81.
2. Federal Aviation Administration, Office of Aviation Policy: Aviation Forecasts Fiscal Years 1978-1989. Springfield, Virginia: National Technical Information Service, 1977.
3. Federal Aviation Administration, Office of Aviation Policy, Selected Statistics United States General Aviation 1959-1975. Springfield, Virginia: National Technical Information Service, 1976.
4. Urban Systems Research & Engineering, Inc. Models for Aviation Activity Forecasting. Report prepared for Department of Transportation, Federal Aviation Administration, June 1975. Cambridge, Mass.: Urban Systems & Engineering, Inc., 1975.
5. Vahovich, S.G. General Aviation: Aircraft Owner & Utilization Characteristics. Springfield Virginia: National Technical Information Service, 1977.
6. Wold, H. Demand Analysis. New York: John Wiley & Sons, Inc., 1953.

CHAPTER 3 HOURS FLOWN BY COMPANY AND NONCOMPANY OWNERS

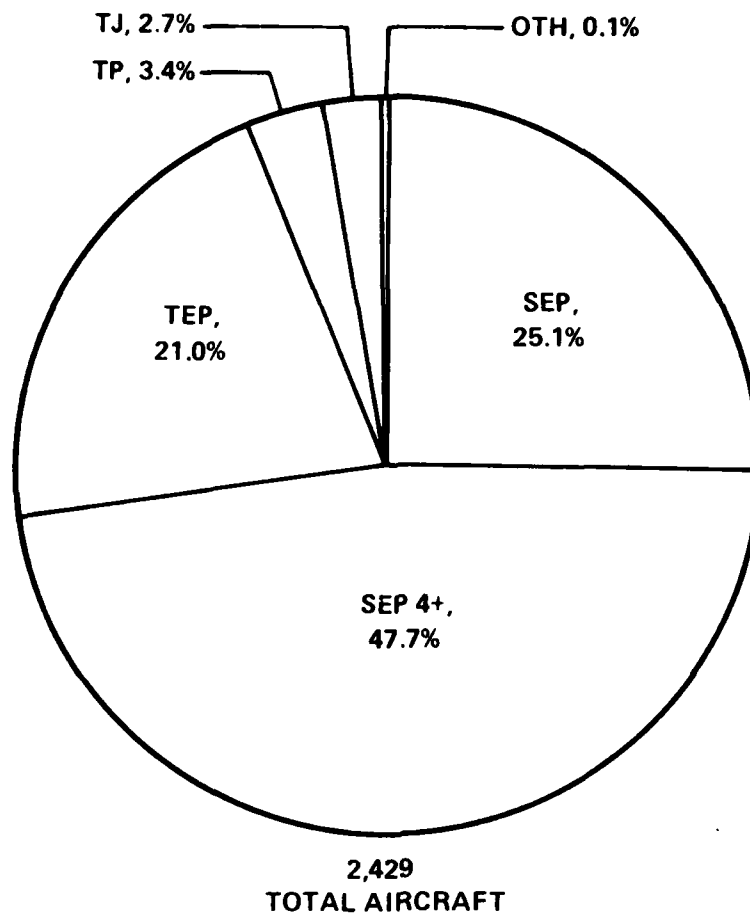
3.1 PURPOSE OF STUDY

While Chapter 2 focused almost exclusively on an analysis of the impact of cost and income changes on noncompany owners' hours flown, Chapter 3 takes a much broader approach. The broadened approach involves three areas--a detailed discussion of the importance of those factors considered only in a perfunctory fashion in Chapter 2; an alternative formulation of the hours flown problem based on Chapter 2 results; and expanding the scope of the hours flown analysis to include company as well as noncompany owners of GA aircraft. Thus while building on Chapter 2 results, the present study represents a major departure from the previous chapter in two important respects. First, a qualitative departure is noted in the formulation of the problem in that the cost and income factors for noncompany owners are replaced by an aircraft productivity factor and a relative income factor. Second, a quantitative departure is noted in that the scope of the present study includes both company and noncompany owners of GA aircraft. Thus, the purpose of Chapter 3 is to present additional information on hours flown decisions, via the alternative formulation of the problem and the detailed evaluation of the importance of each factor, and to assess and compare the structure of company and noncompany owners' hours flown decisions.

For the reasons stated in Chapter 2 (Section 2.2), the present study includes only fixed wing aircraft, flying some positive number of hours, and excludes twin/multiple-engine piston aircraft weighing over 12,500 lbs. The factors examined in this chapter may be grouped into four major categories: an income measure, an aircraft productivity indicator, age of aircraft, and owner's type of use of his aircraft. For noncompany owners, the income measure consists of annual family income divided by aircraft operating costs. The income measure for company owners is profits. As in Chapter 2, all monetary variables have been deflated by a regional price index. For both company and noncompany owners, aircraft productivity is measured in seat-miles per hour. Two separate factors are used to measure the importance of aircraft age in both the company and noncompany owners' hours flown decisions, and four primary use categories are employed to gauge the importance of owners' type of use in explaining changes in hours flown. Similar, to the previous chapter, an avionics factor is included to measure the impact of the level of aeronautical sophistication. Each of these factors will be discussed in detail in the following sections.

3.2 FACTORS INFLUENCING HOURS FLOWN

The following discussion serves to acquaint the reader with some of the characteristics of the noncompany owners included in the study. Figures 3-1 through 3-3 present some of the characteristics of the study sample utilized for the company



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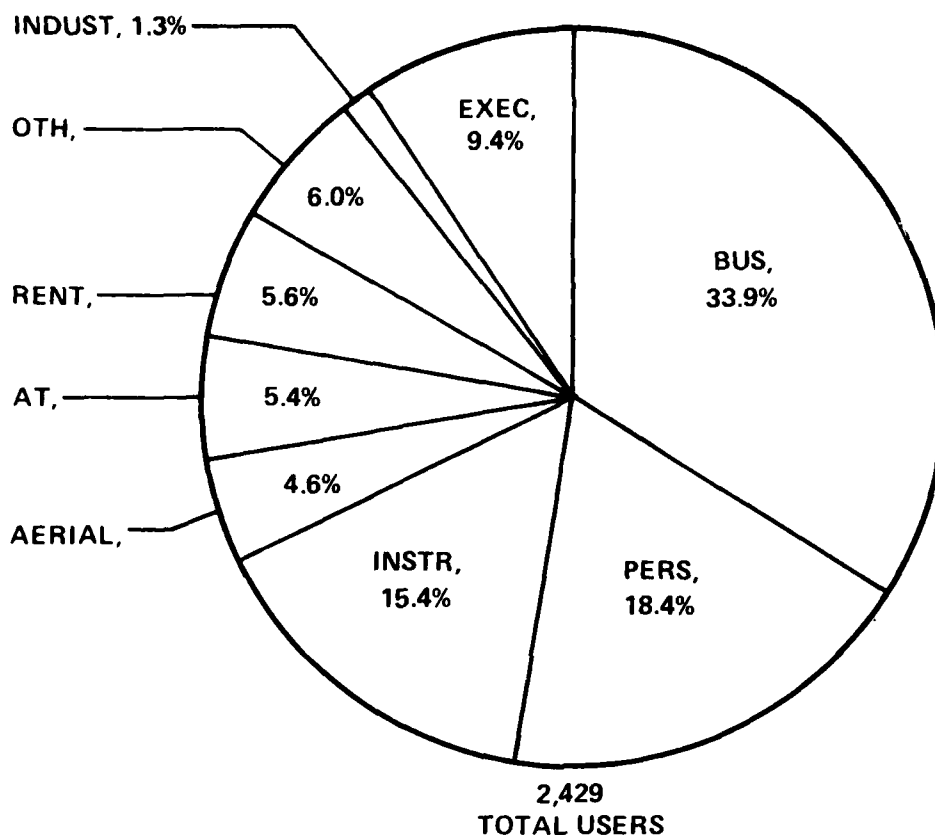
SEP - Single-Engine Piston (1-3 seats)
SEP 4+ - Single-Engine Piston (4 or more seats)
TEP - Twin-Engine Piston (under 12,500 lbs.)

TP - Turboprop
TJ - Turbojet
OTH - Other

Figure 3 -1

PERCENT DISTRIBUTION OF AIRCRAFT BY TYPE OF AIRCRAFT

owner analysis. The percentages exhibited in these figures may be compared with those given in the comparable figures for noncompany owners presented in Chapter 2. Remember that the total values presented in the pie-charts (total aircraft in Figure 3-1 and total users in Figure 3-2) represent the number of observations in the sample used in the analysis, not the number in the total fleet. Figure 3-1 shows the distribution of company owned aircraft by type of aircraft. This figure shows that the company owner is much more likely to own a single-engine piston (4 or more seats) aircraft (47.7 percent) than any other type of aircraft. The next most popular aircraft types are the small single-engine pistons (25.1 percent), twin-engine pistons (21.0 percent), turboprops (3.4 percent), and turbojets (2.7 percent). The "other" category, comprising a small percentage (0.1 percent) of company owned aircraft, represent jets with other than two engines. Compared with Figure 2-2 for noncompany owners, the most striking difference evident in Figure 3-1 is the much larger representation of turboprop and turbojet aircraft in the company owner fleet. Compared to noncompany owners, this difference probably reflects a multitude of influences. Among these may be included, the greater financial resources available to companies to purchase the more costly aircraft, companies' greater emphasis on reducing nonproductive travel time, and their desire to reach out further in order to broaden the potential market base. Figure 3-2 shows the composition of the company owners according to primary use category.



LEGEND:

EXEC - Executive

BUS - Business

PERS - Personal

AERIAL - Aerial Application

INSTR - Instructional

AT - Air Taxi

INDUST - Industrial

RENT - Rental

OTH - Other

Figure 3 - 2

PERCENT DISTRIBUTION OF AIRCRAFT BY USER GROUP

Whereas noncompany owners (see Figure 2-3) have the largest concentration of users in the personal use category (63.3 percent), Figure 3-2 shows that business use is by far the most popular company owner use category (33.9 percent), followed by personal use (18.4 percent). While the personal users' share of the total is lower for company owners, relative to noncompany owners, the share of total use accounted for by the "for-hire" user categories (instructional, rental, and air taxi) is significantly higher for company owners. Finally, Figure 3-3 shows the regional distribution of company owners of GA aircraft. This figure shows that the largest concentration of company owners occurs in the Great Lakes Region (18.2 percent), followed closely by the Southern Region (16.5 percent). Compared to noncompany owners (Figure 2-4), the distribution for company owners, presented in Figure 3-3, appears to have a slightly larger representation of owners in the three East Coast Regions. This probably reflects the large concentration of manufacturing and financial institutions in this area. Correspondingly, noncompany owners have a somewhat larger representation of owners in the two West Coast Regions.

The bulk of the remainder of this section deals with the reasoning that supports the inclusion of each of the factors in the company and noncompany owners hours flown analysis. Since this chapter undertakes a detailed examination of a relatively large number of factors, such discussion will help the reader to understand the results presented in Section 3.3.

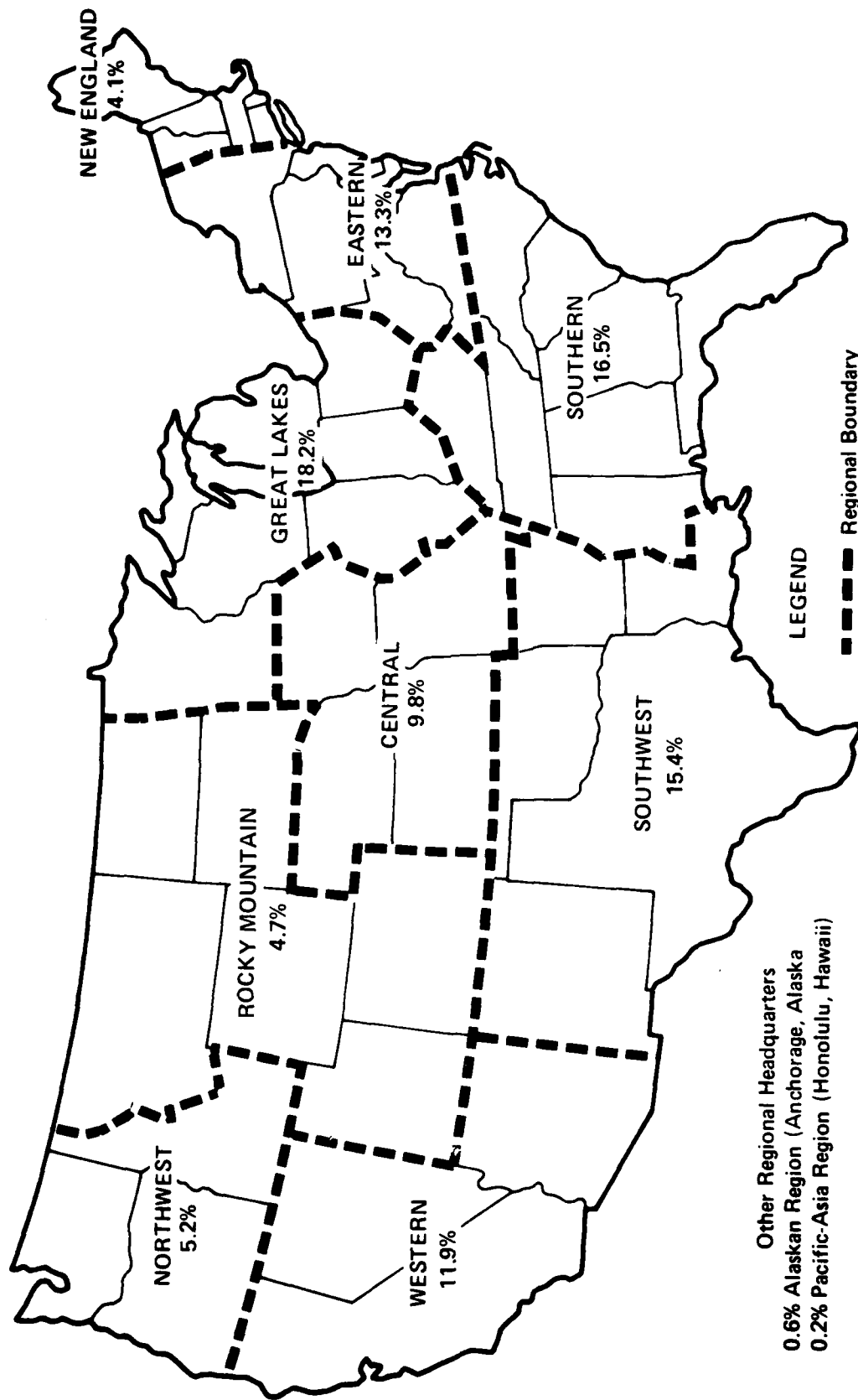


Figure 3 -3

FAA REGIONAL DISTRIBUTION OF COMPANY OWNERS OF AIRCRAFT

First, it provides the reader with an explanation of the researcher's logic; second, it gives the reader insights into the researcher's expectations as to the direction (positive or negative) of impact of the factors used in the analysis. In the actual research, this theoretical reasoning is carried out prior to the inclusion of each factor in the computerized multiple regression "run." Such theoretical reasoning or logic justification may be conducted for a larger group of factors than those which are included in the final analysis. The preliminary computer run of the regression model, and the resulting statistics which are generated from this process, represent a mathematical test of the theoretical reasoning set down by the researcher. (A more extensive but also simplified explanation of the modeling and testing process is presented in [4].) In this preliminary stage of model testing, results obtained for some factors, for one reason or another, may be contrary to the theoretical expectations (implying that the reasoning is oversimplified or otherwise faulty), or the results may confirm the theoretical expectations. From among the latter group, a set of factors is selected which cooperate well together to accomplish the overall objective of solving the problem at hand--i.e., explain GA owners' hours flown decisions.

Caution should be exercised should the reader choose to ignore the remainder of the discussion presented in this section because the results presented in Figures 3-4 through 3-8

emphasize the relative importance of the factor in hours flown decisions and not the direction (positive or negative) of the impact. However, a brief summary of the direction of impact is provided at the beginning of Section 3.3.

The income measure for company owners of GA aircraft is profits. As profits increase it may be expected that companies will attempt to expand the geographical scope of their markets. To sell more, companies must reach out further in order to broaden the potential market base. Since privately owned GA aircraft allow maximum flexibility in arranging travel schedules and provide access to relatively large market areas, some of which may not be easily accessible by commercial air transportation, increasing profits are expected to be associated with increasing hours flown. More specifically, this study uses the change in before tax corporate profits between 1974 and 1973 [3] to measure the impact of increased profits on hours flown. The results from several trial computer runs showed that the change in profits factor explained more about the number of hours flown by aircraft owners than profits per se, and further this factor explained aspects of the hours flown decision not explained by any of the other factors considered. Econometricians refer to the latter characteristic as the degree of independence of the predicting variable, and if not satisfied it leads to multicollinearity problems which cause spurious and misleading results to be obtained in either or both the direction and magnitude of impact of the variable.

The income measure used in the noncompany owner equation is the ratio of annual income to operating costs. The use of this relative income factor was suggested from the results obtained in Chapter 2. It is expected that as this ratio increases, hours flown will increase. That is, as costs consume a smaller and smaller proportion of income, the owner will be better able to afford to fly his aircraft and hence hours flown will increase.

Another factor considered in the hours flown analysis is aircraft productivity. This factor is measured in seat miles per hour, computed by type of aircraft as the product of average cruising speed [2] and the typical number of seats [1]. Aircraft owners are expected to get high utilization from those aircraft with higher productivity because such aircraft can carry a greater payload more rapidly than other aircraft, and they are expensive to own and thus cannot be allowed to stand idle.

While this argument is persuasive for itinerant hours flown, its corollary is equally convincing for local hours flown. That is, expensive, high productivity aircraft are likely to be inversely related to the number of local hours flown. For example, results from an earlier study [5] show that average turboprops fly eleven times more itinerant than local hours, and turbojets fly thirty-eight times more itinerant hours. Thus, as aircraft productivity increases, local hours flown are expected to decrease.

As pointed out in Section 3.1, two factors are used cooperatively to measure the impact of aircraft age on hours flown. The first factor accounts for the effect of ownership of older aircraft, those manufactured between 1901 through 1959, the other factor captures the impact of more recent vintage aircraft, those manufactured between 1970 and 1975. Both aircraft age groupings are compared against the category held constant (aircraft manufactured between 1960 through 1969). Ownership of the pre-1960 vintage aircraft, because of the deleterious effect of age/use on performance and operating condition, are expected to fly fewer hours. For the opposite reason, aircraft of the post-1969 vintage are expected to fly more hours.

In the study presented in Chapter 2, avionic equipage was introduced as a factor which influenced hours flown decisions in a positive direction. The present study also uses this factor and the hypothesis supporting its expected impact is the same as that proposed in Chapter 2--the GA owner has achieved a level of proficiency over and above the minimum level required or attained by other owners and has correspondingly equipped his aircraft with the appropriate avionics. Similar to Chapter 2, automatic direction finder equipage is the preferred measure, because its function is indicative of longer inter-city flights, for all but instrument hours flown.

For the latter hours flown category, equipage with altitude encoding transponder is the measure of the level of aeronautical sophistication (see Section 2.3.4).

The final group of factors relate to the manner in which the owner uses his aircraft. Originally the sample data collected information on owners classified by nine separate user groups. However, because of the relatively few number of observations in some user groups (see Figures 2-3 and 3-2) and based on similarities among their activities, the nine user groups were clustered into five categories.* Four different user groups are compared against the business use category (i.e., the combined business and executive users). Except for local hours, business users may be expected to fly more hours than personal and the combined aerial application and industrial/special category (hereafter referred to simply as the industrial category). This is because business users are likely to incur greater costs than either of these two user categories if they do not reduce their executives' travel time. The costs incurred are

* Both aerial application and industrial/special uses involve specialized application of aircraft. The former primarily for crop dusting, the latter for such uses as survey work, advertising, etc. Miscellaneous users were also included in this category. Business and executive uses share the function of transporting employees and/or property of the organization. The primary difference is that the latter employs a professional pilot. In air taxi and rental uses the owner places his aircraft up for hire, neither maintains a regular schedule, and charges are made on an hourly basis. The primary difference is that a rental may be either "wet" (with pilot) or "dry" (no pilot), whereas air taxi always includes a pilot.

direct--i.e., the length of time in travel--and indirect--i.e., the money which the executives could earn if they performed an alternative productive function rather than travel. The latter is referred to by economists as the opportunity cost. On the other hand, the instructional and combined air taxi and rental categories (hereafter referred to simply as the rental category) use their aircraft in direct revenue generating activities. Thus, compared to business users where reduced consumption of hours flown is only partially reflected (via the executive's contribution) in reduced revenues, the instructional and rental categories realize the full monetary impact of reduced utilization rates on their revenues. For this reason, and because the incentive for the latter two user groups to maintain higher utilization rates is not expected to change qualitatively (i.e., the direction of impact) with the type of hours flown, these user groups are expected to have a positive impact for all categories of hours flown.

Because of the nature of local hours, the rationale supporting the expected direction of impact for the personal and industrial users is different than that for the other types of hours flown. Local hours, having the same origin and destination, are generally associated with the "pure" pleasure of flight experience and with certain productive activities. Since, at best, local hours may be considered incidental to the business use of aircraft, personal users and industrial users are expected to fly more local hours than business users.

That is, personal users may at least derive a certain level of satisfaction from recreational flying, and most industrial uses (e.g., crop dusting, survey work, pipeline patrol) are compatible with local hours.

3.3 IMPORTANCE OF FACTORS IN THE HOURS FLOWN DECISION

The results obtained for the direction of impact of each factor on the five different hours flown measures are summarized in Table 3-A. In brief, the multiple regression results obtained in the hours flown analysis support the expectations advanced in the preceding section. That is, all categories of hours flown increase with increases in the income measure and productivity. The exception, if local hours where, as hypothesized, hours flown is inversely related to productivity. All user categories fly more local hours than business users. Thus, all user group factors have a positive impact on local hours flown. Personal use has a negative impact on total, itinerant, instrument, and visual hours--as hypothesized, this user group flies fewer of these type of hours than business users. On the other hand, the instructional and rental categories fly more of each of the latter type of hours than business users (i.e., positive impact). The industrial category has a negative impact on the itinerant, instrument, and visual hours flown decision, but a positive impact on total hours flown. The latter is attributed to the large positive impact of the local hours component of total hours flown--i.e., the activities of this user category are highly compatible with local flying.

TABLE 3-A DIRECTION OF IMPACT OF FACTORS
ON HOURS FLOWN

Factors	Hours Flown Measures				
	Total	Itinerant	Local	Instrument	Visual
Productivity	+	+	-	+	+
Income	+	+	+	+	+
Pre-1960	-	-	-	-	-
Post-1960	+	+	+	+	+
Rental	+	+	+	+	+
Industrial	+	-	+	-	-
Instructional	+	+	+	+	+
Personal	-	-	+	-	-
Avionics	+	+	N.A.	+	+

Key:

+ indicates that the direction of impact is positive.

- indicates that the direction of impact is negative.

N.A. indicates that the factor has been omitted because of irrelevance.

Results for the age related factors are as expected--older aircraft fly fewer and more recent vintage aircraft fly more of each type of hours than aircraft of the middle vintage (those manufactured between 1960 through 1969). Results for the avionics equipage factor indicate that owners who have attained a higher degree of aeronautical sophistication fly more hours.

The remainder of this section presented the importance of each of the various factors relative to the other factors (i.e., similar to Section 2.3, standardized beta weights are used) for the five different hours flown decisions for both company and noncompany owners. The results presented in Table 3-A, giving the direction of impact, may be used in conjunction with the relative magnitude of impact results presented in Figures 3-4 through 3-8.

3.3.1 TOTAL HOURS FLOWN

Figure 3-4 shows the relative importance of the factors considered in both the company and noncompany owners total hours flown decisions. Results for noncompany owners are presented to the left of the vertical line and are represented by a broken horizontal line; company owner results are on the right-hand side and are represented by a solid horizontal line. The length of each horizontal line indicates the relative importance of its associated factor, printed in *italics*, in the hours flown decision. Somewhat surprisingly,

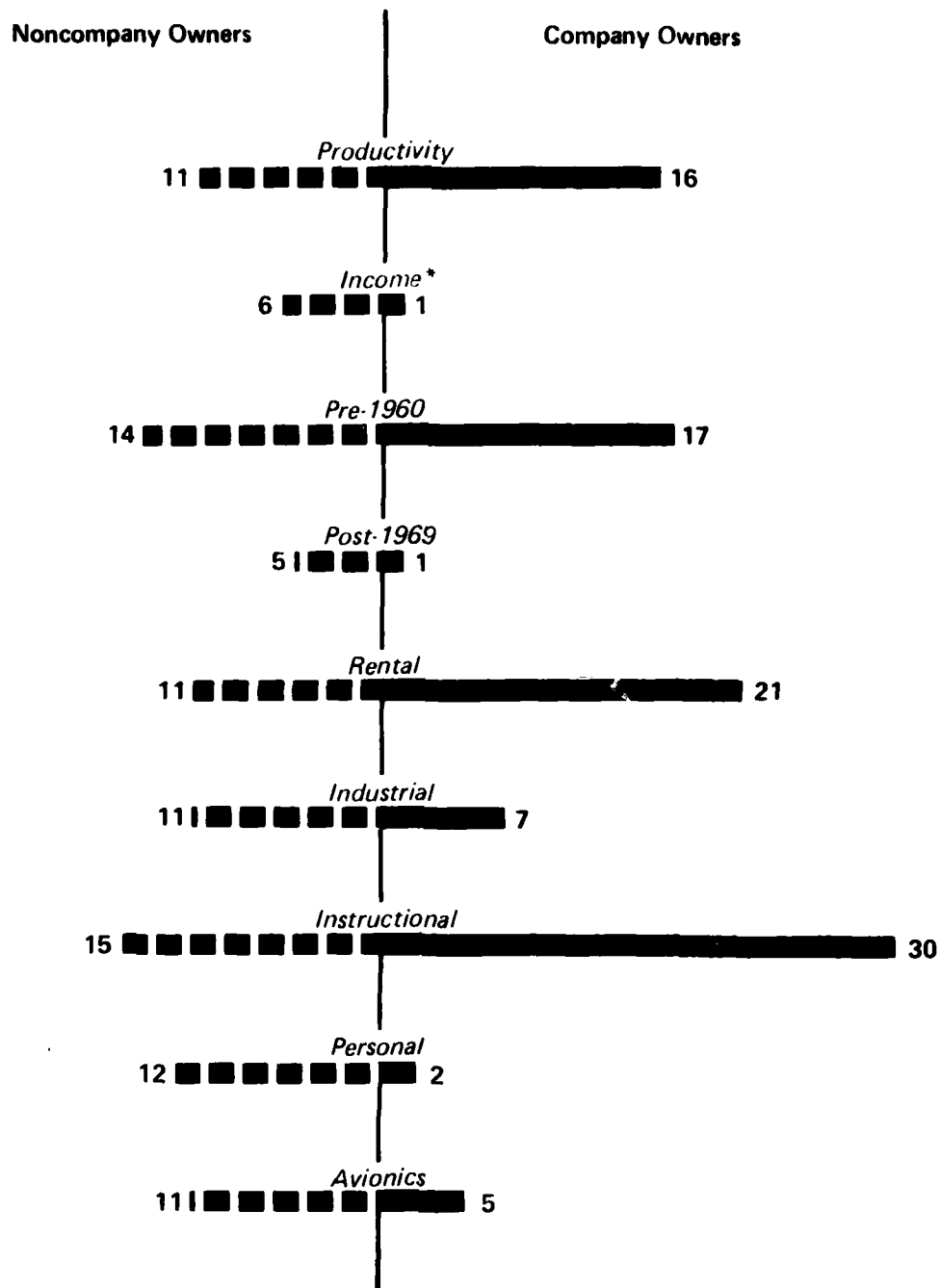


Figure 3 - 4

RELATIVE IMPORTANCE OF FACTORS IN TOTAL HOURS FLOWN DECISION

* Two different income measures are used. Change in profits is used for company owners; income relative to operating cost is used for noncompany owners.

Figure 3-4 shows that aircraft productivity is only the fourth most important factor for each group of owners. For company owners, it is superseded in importance by instructional use, by far the most important factor, rental use, and age of aircraft (pre-1960 vintage). For noncompany owners, it is preceded in importance by instructional use, age of aircraft (pre-1960 vintage), and personal use. Remembering that comparisons of the numerical values are valid only within each owner group (however, rank order comparisons are valid between owner groups), the results presented in Figure 3-4 suggests that company and noncompany owners evaluate the importance of productivity equally in their respective total hours flown decisions.

The importance of the income measure is also evaluated quite similarly in the company and noncompany owners' hours flown decisions. The change in corporate profits is one of the least important factors in the company owner total hours flown decision. Apparently, company owner decisions are guided to a much larger extent by factors such as owners' type of use, age of aircraft (pre-1960 vintages), and productivity. A similar statement applies to noncompany owners, where income relative to cost is ranked next to last in importance.

Despite these similarities at the extremes of the company and noncompany orderings, several differences between the respective priority ordering may be noted. Company owners rank rental use

as the second most important factor while noncompany owners relegate this factor to the fourth most important position. Another significant discrepancy between the orderings is the importance of the personal use factor. Noncompany owners consider this factor as third most important while it is next to last in importance in company owner hours flown decisions. Thus, in general, it may be stated that while certain similarities exist for the company and noncompany owner decision structure, several significant differences exist in the hierarchical ordering of the factors. Figure 3-4 also shows that the company owner ranking is more definitive than that for noncompany owners. For example, the most important factor in the company owner decision ordering is one and one-half times more important than the second, whereas only minor difference is noted for the corresponding ordering for noncompany owners. That is, noncompany owners tend not to differentiate as acutely among the factors.

Since total hours is comprised of two very different components--itinerant and local hours, the following sections examine each of these components separately. This analysis will focus on the origin of the differences in the orderings exhibited in and noncompany owners which may have been lost in the total hours aggregation will be clarified.

3.2.2 ITINERANT HOURS FLOWN

Figure 3-5 presents the results for itinerant hours.

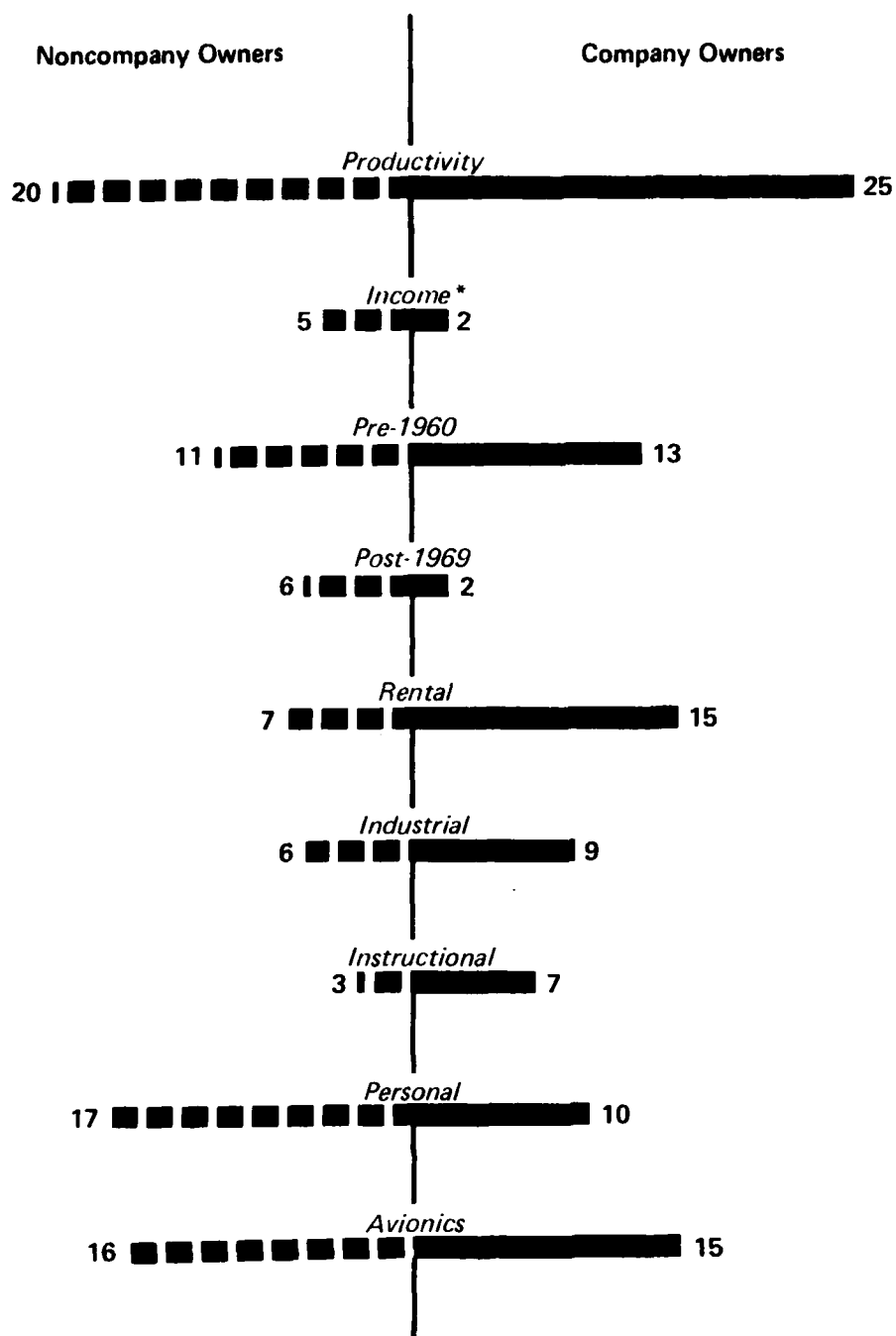


Figure 3 - 5

RELATIVE IMPORTANCE OF FACTORS IN ITINERANT HOURS FLOWN DECISION

* Two different income measures are used. Change in profits is used for company owners; income relative to operating cost is used for noncompany owners.

Clearly, aircraft productivity is by far the most important factor for both company and noncompany owners in their respective itinerant hours flown decisions. Thus, for GA flying of a more purposeful nature, productivity is a very important factor in the utilization decision. This result is considerably different than that obtained for total hours. At this point, it can be speculated that the mediocre level of importance achieved by productivity in the total hours equation can be attributed to its low level of importance in the local hours equation. (The following section presents results supporting this contention.) For company owners, avionics equipage and rental use are the next most important factors explaining itinerant hours flown decisions. In contrast, noncompany owners rank rental use considerably lower in importance than company owners. Further, the second most important factor in the noncompany owners' itinerant hours flown decision--the personal use factor--receives a much lower priority in the company owner ordering. Thus, some of the discrepancies between the orderings for the two owner groups noted in the total hours analysis is also clearly visible in the itinerant hours analysis.

Contrary to the results obtained for total hours, instructional use is not very important in explaining the number of itinerant hours flown by either owner category. This can probably be attributed to the fact that instructional activities are associated with both itinerant and local hours, although largely the latter, and hence do not serve well to explain differences in

itinerant hours flown. As in the results for total hours, the income measure for each owner group is considered very low in the hierarchy of factors explaining the number of itinerant hours flown. Apparently, either further research is required to determine a more appropriate factor to measure the income effect, or this factor may not have a large weight in hours flown decisions.

As in the case of total hours, company and noncompany owners exhibit some similarities in their itinerant hours rankings, primarily at the extreme ends of their respective orderings; otherwise, considerable differences exist in the preference orderings of company and noncompany owners. As noted above, at least some of these discrepancies are common to total and itinerant hours and hence appear to stem from itinerant rather than local hours (see the following section for additional supporting analysis). Alternatively, the itinerant hours ordering for company and noncompany owners does not explain the low level of importance accorded to instructional use in the total hours analysis, nor does it explain the mediocre level of importance achieved by aircraft productivity in the total hours equation. Thus, the following section turns to an examination of local hours in an attempt to account for these results.

Finally, it may be noted that the company owner ordering for itinerant hours does not, in general, exhibit the same degree of decisiveness as in apparent in the total hours decision.

That is, except for the two highest ranked factors, where company owner preferences are clearly more definitive, non-company owners differentiate more acutely between the factors.

3.3.3 LOCAL HOURS FLOWN

Figure 3-6 shows the relative importance of factors in the local hours flown decision. Since local hours are primarily associated with a pleasure flight of relatively short duration and highly discretionary trip costs, it may be expected that aircraft productivity and income are not likely to be the most important factors in this type of hours flown decision. That is shown in Figure 3-6. Aircraft productivity is ranked the third most important factor in noncompany owners' decisions and it is the fifth most important factor for company owners. Remembering, from Table 3-A, that the direction of impact of this factor is negative for local hours, the relatively greater emphasis placed on productivity by noncompany owners suggests that the latter group of owners are less likely than company owners to fly the more expensive aircraft in local hours. The fact that instructional use is by far the most important factor for both owner groups is not surprising, since much pilot training takes place with takeoffs and landings at the same airport. The great emphasis placed on instructional use and the low-emphasis placed on productivity by both owner groups in their local hours decisions helps to explain the degree of importance achieved by these factors in the total hours analysis.

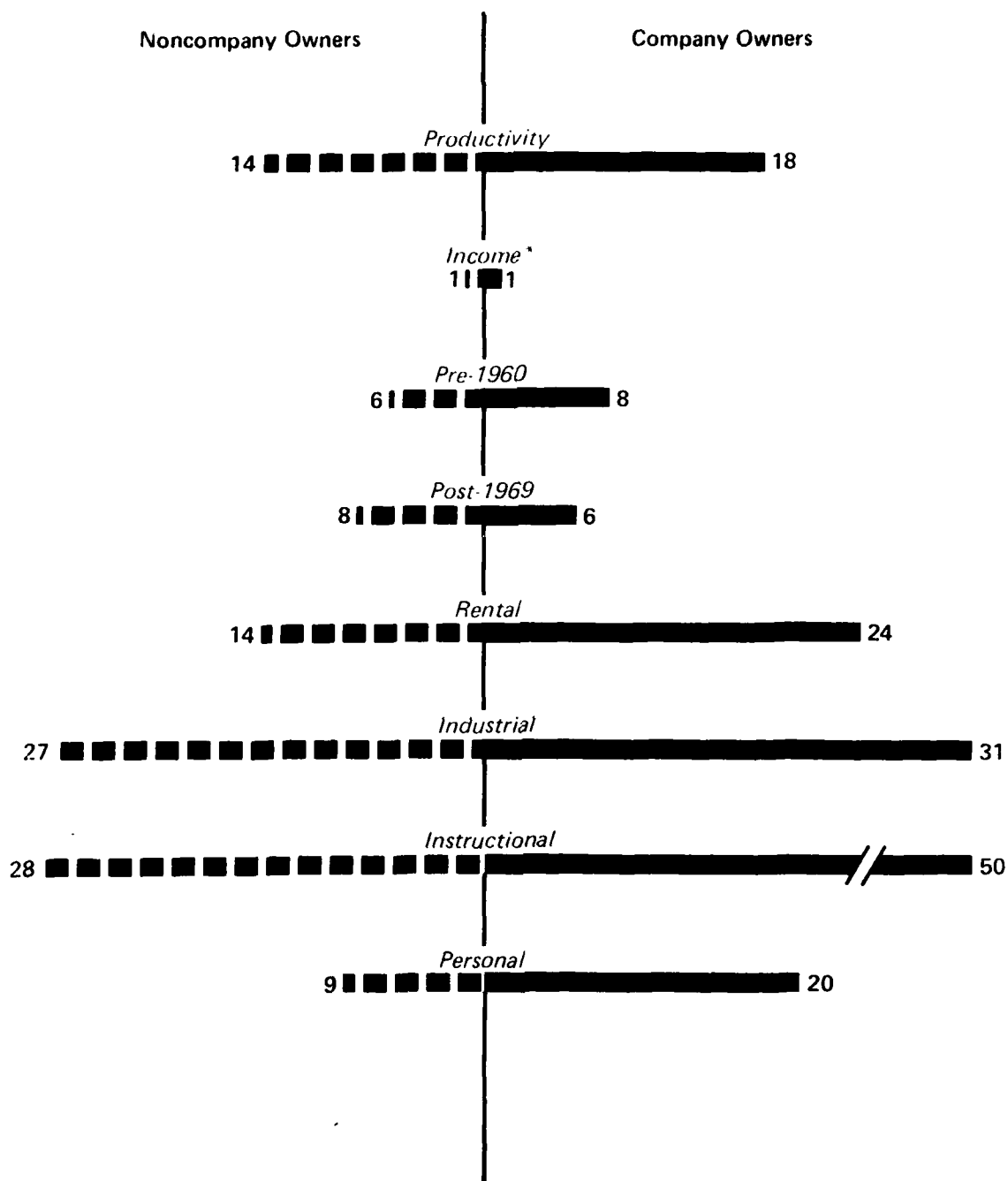


Figure 3 - 6

RELATIVE IMPORTANCE OF FACTORS IN LOCAL HOURS FLOWN DECISION

* Two different income measures are used. Change in profits is used for company owners; income relative to operating cost is used for noncompany owners.

Personal use is commonly taken as the basis for the classic image of GA as the one airport pure pleasure sport. However, the result, that personal use receives a relatively low priority in local hours flown decisions of both owner groups (lower or equal to its priority for itinerant hours), contradicts this classic image. The fact that personal users do not concentrate their hours flown in local hours (about 43 percent of total personal use hours are local hours [5]) helps to account for the resulting low priority of personal use. This result suggests a more mature image of GA, including at least equal emphasis on purposeful transportation. As may be expected, the pre-1960 vintage factor receives significantly less emphasis in the local hours decision than in itinerant hours. That is, since local flights are of relatively short duration, the effects of age/use do not weigh heavily in this decision (see Figure 3-6); however, for the relatively longer inter-city flights, the operating condition of the aircraft is an important consideration (see Figure 3-5).

In general, an overall comparison of the company and noncompany local hours factor orderings reveals fewer differences than noted in the itinerant hours analysis. The top three factors in the company owner hierarchy are the same as those for non-company owners, and an identical statement can be made for the three least important factors. Perhaps the greatest difference between the local hour company and noncompany orderings occurs

for the priority assigned to productivity. This implies that most of the differences exhibited in the company and noncompany comparison for total hours ranking stem from the itinerant hours decision structure. The following sections further analyze the origin of these difference exhibited in the itinerant hours analysis by disaggregating the latter hours category into its component parts--instrument and visual hours.

Contrary to the preceding hours analyses, the results presented in Figure 3-6 suggest no clear determination as to which owner group is more decisive in its local hours flown decisions. At the highest priority level company owner preferences are more explicit (the highest ranked factor is over one and one-half times more important than the second highest); at the next highest priority level noncompany owner preferences are more explicitly (the second highest ranked factor is almost twice as important as the third highest).

3.3.4 INSTRUMENT HOURS FLOWN

Instrument hours represent one of the two components (the other is visual hours) forming itinerant hours. Figure 3-7 shows the relative importance of the factors in the instrument hours flown decision. For both company and noncompany owners, aircraft productivity is the most important factor. This is especially true for company owners where productivity is over three times more important than the second most important factor, rental use. Since this type of flight

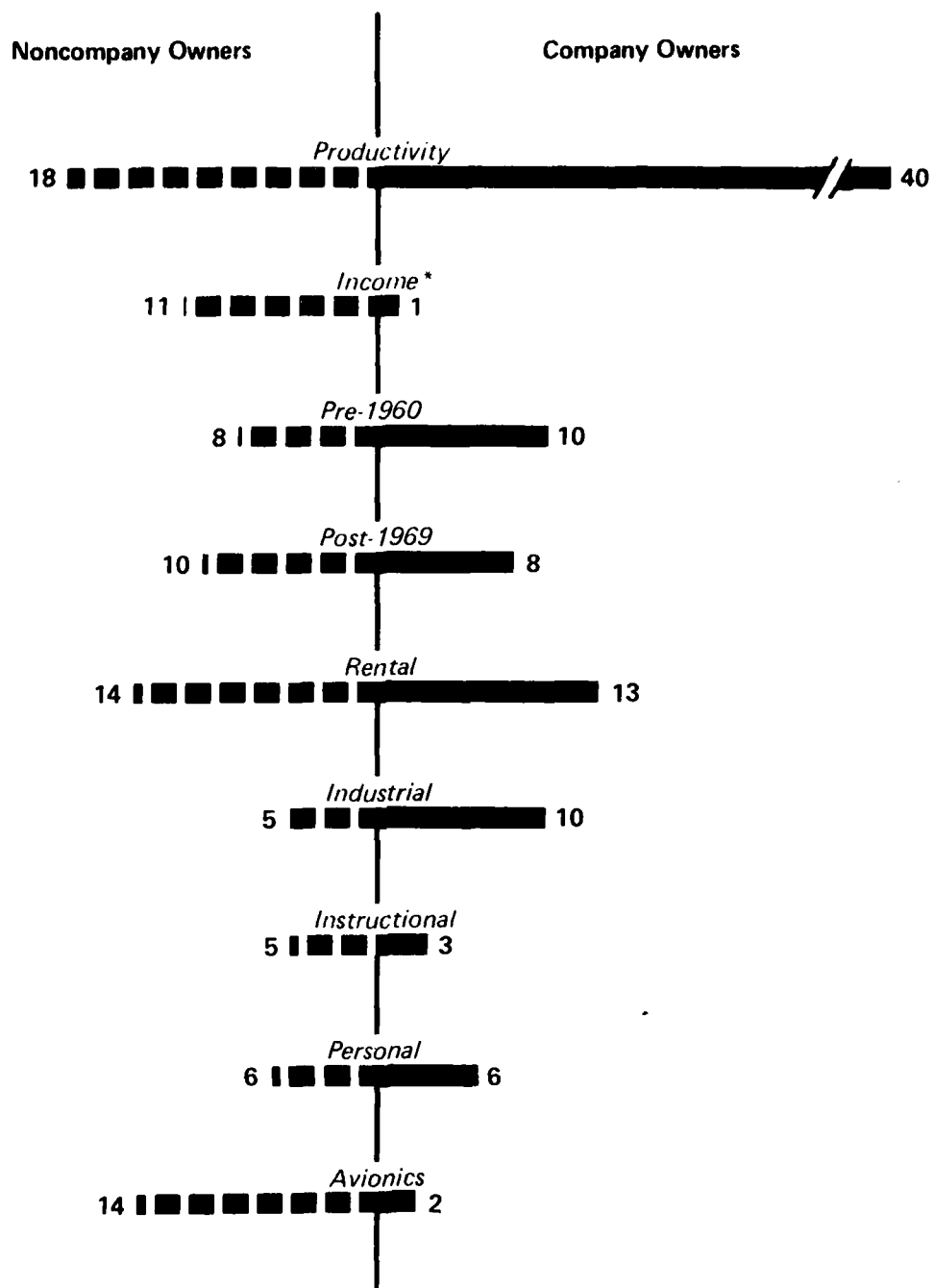


Figure 3 - 7

RELATIVE IMPORTANCE OF FACTORS IN INSTRUMENT HOURS FLOWN DECISION

* Two different income measures are used. Change in profits is used for company owners; income relative to operating cost is used for noncompany owners.

is generally at higher altitudes and of longer distances per trip, the higher rank accorded productivity for both owner groups is understandable. Jets and turboprops generally pressurized and providing speedy transportation over long distances are especially suited to this type of hours flown. Further, the fact that instrument hours are likely to entail flying in and around major cities--the centers of commercial and financial activities--helps to explain the dominant position of productivity relative to the other factors in the company owner results (business use is by far the largest single use category among company owners, see Figure 3-2). The great emphasis placed on productivity by both owner groups in their instrument hours decisions concurs with the results obtained for itinerant hours. As shown in the next section, the owners' evaluation of productivity for visual hours is somewhat more mixed. Thus, the high rank accorded to productivity in the itinerant hours analysis may be attributed primarily to its instrument hours component.

Figure 3-7 also shows that for noncompany owners, income relative to cost is the third most important factor in the instrument hours decision. In Chapter 2 the contention was advanced that as cost takes a larger and larger proportion of income, hours flown would decrease--i.e., a positive relationship between the income to cost ratio and hours flown because they move in the same direction. While the results presented in Table 3-A support this hypothesis for all categories of hours flown, the results presented

in Figure 3-7 imply that such considerations are of relatively greater importance for the instrument hours flown decision than for any other category of hours flown (observe the relative rank of this factor for noncompany owners in Figures 3-4 through 3-6). The fact that costs encroach more heavily on income (i.e., lower income to cost ratio) for itinerant hours than other hours flown categories helps to explain the greater sensitivity of noncompany owners for this category of hours flown. Further, the greater emphasis placed on the income measure by noncompany owners for instrument hours significantly differentiates their ranking structure from that of company owners. Another factor which serves to differentiate the noncompany and company owner decision structure is avionics. That this factor is significantly more important in the noncompany owners' decision may be attributed to the fact that avionics equipage rates are considerably higher for company owners than noncompany owners [5]. That is, since a large proportion of company owners, flying diverse types of hours, have avionics, this factor does not serve well to differentiate among those flying primarily instrument hours.

As for an overview of the company and noncompany owner rankings, the high degree of emphasis placed on the income measure and the avionics factors in the noncompany owner instrument hours flown decision represents a significant departure from the company owner decision hierarchy. As to the degree of decisiveness of the orderings, in general company owner preferences appear to be more pronounced and decisive.

3.3.5 VISUAL HOURS FLOWN

Visual hours represent one of the two components (the other is instrument hours) of itinerant hours. Figure 3-8 shows the relative importance of the factor for both company and noncompany owners in visual hours flown decisions. Of all the types of hours flown examined, Figure 3-8 exhibits the greatest disparity between company and noncompany owners' rankings. The difference in emphasis placed on the factors in visual hours flown decisions by the two groups of owners is at least partly attributable to vastly different levels of concentration of their itinerant hours in visual hours. The typical noncompany owner flies over seven times more visual hours than instrument hours, whereas the typical company owner flies only about three times as many visual hours [5]. Given this disparity in concentration levels between the two owner groups, it may be expected that the factor orderings will differ significantly for the two owner groups and that the preference ordering for the owner group which is most concentrated in visual hours will be more clearly defined. This is reflected in Figure 3-8. Noncompany owners consider personal use the most important factor and aircraft productivity a close second. Results for company owners show that rental use is the most important factor in visual hours flown decisions and three factors (avionics, personal use, and pre-1960 vintage) share equally the second most important place. For noncompany owners, avionics is the third most important factor. The income measure is the least important factor for both company and noncompany owners. As pointed out above, in general, the noncompany ordering is more decisive than that for company owners.

Noncompany Owners

Company Owners



Figure 3 - 8

RELATIVE IMPORTANCE OF FACTORS IN VISUAL HOURS FLOWN DECISION

* Two different income measures are used. Change in profits is used for company owners; income relative to operating cost is used for noncompany owners.

3.4 CONCLUSIONS

This chapter examined in detail the relative importance of various factors in company and noncompany owner decisions for five different hours flown categories. With respect of the factors per se, no single factor can be considered as dominant in explaining either the company or noncompany owner hours flown decisions across all categories of hours flown. The relative importance of the factors vary considerably with the type of hours flown. This implies that the results obtained for one category of hours flown cannot be generalized to other hours flown categories. This result supports the approach taken in this chapter--separate hours flown analysis must be conducted for each category of hours flown. This approach, while originally adopted largely on intuitive justification related to the diverse nature of each of the hours flown categories, is now supported by sophisticated econometric results.

With respect to comparisons of the owners' decision structure, for each category of hours flown, considerable discrepancies were noted when the company and noncompany owner rank orderings of the factors were compared. That is, although the two owner groups exhibited similarities in the extremes (highest and lowest) of their respective factor rankings both for total hours and itinerant hours, discrepancies between company and noncompany owner rankings were the rule, not the exception, across all

categories of hours flown. This result confirms earlier expectations that company and noncompany owners assess their hours flown decisions differently (i.e., in degree, but not in the direction of factor impact). Given these nontrivial differences, the two owner groups should be analyzed separately for each category of hours flown.

In order to determine the extent to which the differences between the company and noncompany owner orderings noted for the two aggregate hours flown categories could be attributable exclusively to one or the other of their components, an attempt was made to trace the origin of the differences. Since the greatest degree of similarity between the company and noncompany owner decision structure occurred in local hours (where the three highest and the three lowest ranked factors were the same for both owner groups), most of the discrepancies evident in total hours could be attributed to itinerant hours. However, when itinerant hours was disaggregated into its components--instrument and visual hours, the degree of discrepancy between the owner group rankings quickly intensified. Little similarity was found between company and noncompany owner rankings for instrument hours and even less was noted for their respective visual hours rankings. Thus, the differences between the respective owner group itinerant hour factor orderings is attributable to both of its components. As for the similarities between company and noncompany orderings for total and itinerant hours, when the rank of a factor was approximately the same for both owner

groups, some success was achieved in tracing the origin of the difference to its component hours category. The more the owner ranks diverged for a particular factor, the more difficult/complex the tracing process becomes.

The decision structure for each owner group was reviewed for its level of decisiveness--i.e., the strength with which each owner group differentiated among the factors in making their hours flown decisions. In two hours flown categories, total and instrument hours, company owners were more decisive. However, non-company owners were more decisive in their itinerant and visual hours decisions. In the case of local hours, no determination could be made as to which owner group preference structure was stronger.

As a final note, it must be reemphasized that this chapter represents one, among several possible ways, of viewing the hours flown problem. Although the factors selected for inclusion were pretested and were determined to be more effective than any other group of factors in explaining hours flown (and at least as effective as those used in Chapter 2), further research may reveal an even more powerful combination of factors. However, regardless of later findings, the results reported in this chapter are significant in that they provide each GA aircraft owner important insights into the hours flown decision as made by the entire GA community, and as viewed over a standardized (i.e., same group of factors over different categories of hours and different owner groups) and scientifically selected

group of factors. Further, the results point out basic structural differences among the various categories of hours flown and between the owner groups. These scientifically tested and proven heterogeneous properties are not likely to change (even if a different set of factors are used) unless the CA community undergoes substantial structural change.

CHAPTER 3 REFERENCES

1. Battelle-Columbus Laboratories. General Aviation Cost Impact Study, Volume IV: Data Base, prepared for the Federal Aviation Administration, June 1973.
2. Federal Aviation Administration, Aeronautical Center, Oklahoma City, Oklahoma, "Engine Manufacture and Model Reference File."
3. U.S. Department of Labor, Bureau of Labor Statistics, Survey of Current Business (July 1976 and July 1977).
4. Vahovich, S.G., "How to Forecast Aviation Activity Level," in Aviation Forecasts Fiscal Years 1978-1989. Springfield, Virginia: National Technical Information Service, 1977.
5. Vahovich, S.G., General Aviation: Aircraft, Owner & Utilization Characteristics: Springfield, Virginia: National Technical Information Service, 1977.

PART II

ANALYSIS OF PURCHASERS OF
GENERAL AVIATION AIRCRAFT
AVIONICS

CHAPTER 4 GENERAL AVIATION PURCHASERS OF AVIONICS

4.1 INTRODUCTION

This chapter explores the factors that account for GA purchases of aircraft communication and navigation instrumentation (avionics). While the results presented in this chapter are highly informative to the individual GA aircraft owner, they are at least of equal importance to the FAA and the avionics manufacturing industry. This is because FAA manpower staffing at Control Centers and Towers and facility planning are highly dependent on instrument operations, and the latter, in-turn, is dependent on aircraft avionics equipage. Similarly, the information presented in this chapter can be utilized to establish a market profile of the demand for avionics. Obviously, such information is valuable to avionics manufacturers in planning sales strategies and arranging production schedules. Eight separate types of avionics are considered in the present chapter.

Technically speaking, the analytical technique employed in this study--discriminant analysis--is quite different from that employed in the previous chapters. For informational purposes, discriminant analysis is the same technique that is frequently used to forecast national election results and assess your credit eligibility rating when you apply for

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GENERAL AVIATION: HOURS FLOWN AND AVIONICS PURCHASE DECISIONS.(U)

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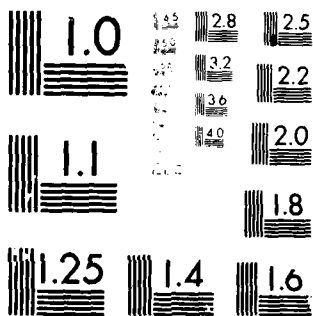
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credit cards. Since one of the objectives of this report is to present the results obtained from such sophisticated techniques in a manner that is understandable to all, the reader need not be concerned with the technical ramifications. Good technical explanations of the theoretical underpinnings of discriminant analysis are available elsewhere [1,3]. However, since this technique may be unfamiliar even to most researchers, and since a basic understanding of the way in which the results are derived will greatly enhance the meaningfulness of those results to the general reader, the following simplified explanation is provided.

In brief, developing a combination of factors (aircraft and owner characteristics) that differentiate or discriminate optimally between the "have" and the "have-nots" is the primary objective, virtue, and usefulness of discriminant analysis. Two components are involved here. First, in developing the final set of factors the researcher utilizes his knowledge to select candidate factors that are backed by sound reasoning (the methodology cannot manufacture gold from straw), and the methodology provides statistical tests which the researcher uses to evaluate the trial results. The unique aspect of the methodology, per se, is that given the factors it is asked to consider, it will develop the best possible "system" (i.e., an equation utilizing those factors) for discriminating between the have and have-not groups--the system's discriminating

power is optimized. Second, the methodology uses this system to make predictions about an individual's likely group membership based only on his values for these factors. The magnitude of the problem solved by the methodology is illustrated by the following hypothetical example.

Suppose a hat contains 100 balls, 90 of which are red balls and the rest are green balls. If the balls were drawn one-by-one (and not seen until all the balls were drawn) and each correct guess as to color drawn was worth \$100, the best strategy to get the most money would be to simply always guess red. That way one would get \$9,000. This is defined as the pure chance rule. But suppose each correct guess of a red ball is worth \$100, each correct guess of a green ball is worth \$500, and a certain number of the green balls had to be correctly guessed in order to collect any money. As applied to this problem, the discriminant analysis methodology would develop a red-green prediction system based on the characteristics of the balls--e.g., if they varied by size, texture, and weight--so that the maximum number of both green and red balls are correctly identified. This maximum would be limited by the extent to which color varied regularly with the above named characteristics of the balls. This example demonstrates the complex problem faced in the analysis undertaken in this chapter. That is, by analogy, there are two types of owners--avionics equipped and nonequipped--corresponding to the two

different colored balls. Based on owners' characteristics/factors (e.g., type of aircraft owned, aircraft's age, etc.), the system must correctly identify not only those aircraft owners who are equipped with avionics, but also the system must correctly identify their counterparts who are not so equipped. Further, since for many type of avionics the group equipped with avionics is considerably smaller than the nonequipped group (corresponding to the disproportionately low number of green balls), the magnitude of the problem of correctly identifying members of the smaller group increases exponentially. The system must defy the odds by identifying owners in the smaller group. How well the system achieves the objective of correctly identifying members of both groups is the very practical and acid test of its usefulness. Each of the eight systems, one for each type of avionics, developed in this chapter is judged against a nonarbitrary criterion in order to determine how well it meets this objective. The next section explains this criterion as well as the type of results obtained from the methodology.

4.2 APPROACH

The results in a study of this nature are usually reported in the form exhibited in Table 4-A. For the present study, "Group 0" means the nonequipped group and "Group 1" is the group equipped with the particular type of avionics in question. N_0 , the number of owners in Group 0, is known from the results obtained on the GA survey-sample questionnaire.

		PREDICTED		
		Group 0	Group 1	
ACTUAL	Group 0	n_{11}	n_{12}	N_0
	Group 1	n_{21}	n_{22}	N_1
		C_0	C_1	N

Table 4 - A
TYPICAL CLASSIFICATION MATRIX

N_1 is the number of owners in Group 1, and this number is known from the questionnaire results. The sum of N_0 and N_1 is N --the total number of owners considered. n_{11} and n_{22} each represent what can loosely be called the number of "correct guesses." If the have-not group (N_0) is larger than the have group (N_1), then by analogy from the preceding section, n_{11} represents correctly guessing a red ball and n_{22} represents correctly guessing a green ball. $(n_{11} + n_{12})/N$ is the overall proportion of correct guesses. The latter is a crucial number and will be utilized extensively as a key result in the following section.

As explained in the preceding section, the guesses are actually based on a system. Thus, the guesses might more appropriately be called predictions. Each system developed in the present study is based on the way the aircraft owner uses his aircraft, the age of the aircraft, the type of aircraft, and the number of itinerant hours flown. Results from extensive pre-testing suggest that the have and have-not groups differ substantially from one another by these characteristics or factors. However, no system is perfect. In Table 4-A, n_{12} and n_{21} represent the number of incorrect predictions. n_{12} represents the number of aircraft owners who actually do not have the avionics device but who are predicted by the system as having that device. n_{21} is the number of owners who are actually have but are predicted as have-nots. Then the column sums, represented by C_0 and

C_1 , represent the total number in each group predicted as have-nots and haves, respectively. The number of correct predictions in each column (i.e, n_{11} and n_{22}) divided by its respective column sum is the proportion of correct predictions for that group. This is the second key result that is extensively utilized in the following section. While Table 4-A is an extremely useful tool to explain the background for the results presented in the following section, it may be too cumbersome for many readers. Thus, further graphical simplification is undertaken in the presentation of the results. Given the background provided in this section, that graphical presentation will be meaningful to the reader.

A very important point to note in the approach taken in this study is that only noncompany owners were used to develop the system which differentiates between and predicts the equipped and nonequipped group members. Company owners were not considered in this development phase of the system. Once the system was developed, it was applied to the heretofore unconsidered company owner data. The theoretical necessity for conducting the analysis in this manner is discussed elsewhere [2]. Intuitively, the reasoning is that the data that has been used to develop the discriminating system cannot also be used to test that system as to how well it discriminates among member of

that same data. The predictions obtained by applying the system to the "fresh" company owner data are then evaluated in the manner described below.

As mentioned briefly in the previous section, how well the system distinguishes among the equipped and nonequipped groups is not evaluated in an arbitrary fashion. That is, the prediction results for the total (equipped and nonequipped groups) and the equipped group obtained for company owners are not simply compared against the corresponding results for noncompany owners to see if they are about the same or higher. The nonarbitrary test applied to judge if the system is an effective discriminator between the avionics equipped and nonequipped groups is the "pure chance" criterion. The pure chance criterion values are obtained as follows. The number of individuals actually having the avionics device is divided by the total number of individuals considered, yielding the pure chance expectation of correctly guessing a member of the avionics equipped group. This computation gives the appropriate pure chance criterion value against which to judge the company owner system generated prediction result for the avionics equipped group. This, however, is only a partial result, since it concerns only one component group of the total, and its usefulness by itself is discussed later (subsection 4.3.5). Dividing the number of nonequipped individuals by the total number of individuals yields the pure chance expectation of

correctly guessing a member of the nonequipped group. The appropriate pure chance criterion value against which to judge the system's company owner prediction result for the total is the maximum or highest of the above two pure chance expectations. That is, this maximum pure chance criterion value is compared against the percentage of the system's correct predictions for the total. If the system's percentage of correct predictions for the total exceeds the maximum pure chance criterion value, the system is judged to be an effective discriminator between the avionics equipped and nonequipped groups.

This is a very stringent test and many researchers argue that a less stringent test is applicable (e.g., see [4]). This is because the maximum pure chance criterion does not allow for the fact that the system must defy the odds by predicting individuals in the smaller group. While this is true, the more stringent maximum pure chance criterion is used in this chapter to satisfy even the hardest of critics. Table 4-B presents a schematic outline of the approach used to obtain the results presented in the following section.

Least the practical usefulness of all of the foregoing be lost, it is worth repeating that what has been advanced thus far is a way to identify aircraft owners who are likely to equip their aircraft with avionics. Representative sample

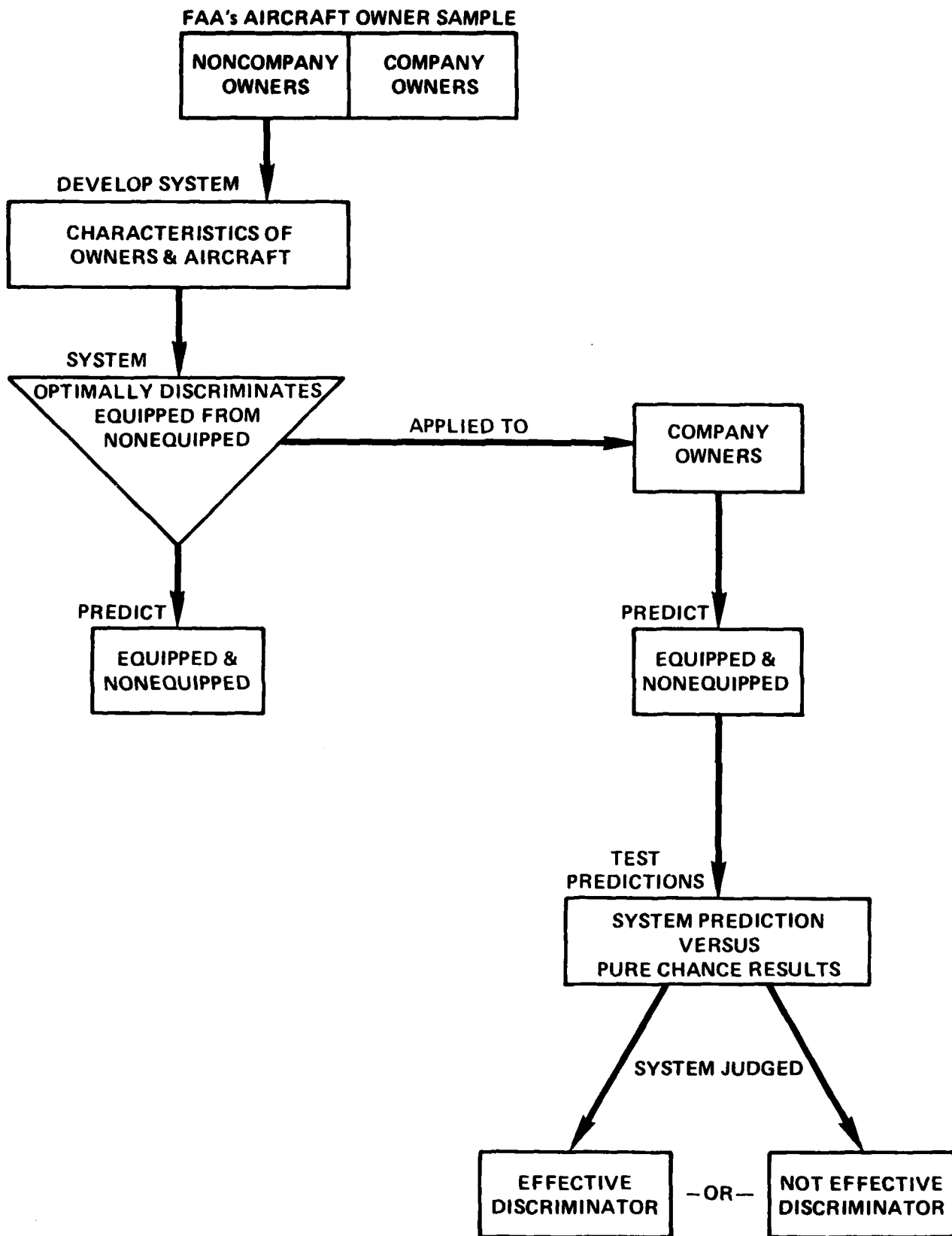


Table 4 - B
OUTLINE OF DISCRIMINANT ANALYSIS APPROACH

data has been used to develop such a system and the system is stringently tested (see Section 4.3). The results identify those characteristics or factors that are important in the avionics equipage decision, thus describing areas of profitable market concentration to manufacturers, and earmarking key indicators to watch for FAA manpower and facility planning purposes. These results are representative of the universe of all GA aircraft owners, and are obtained at a fraction of the cost associated with a complete survey of each and every GA aircraft owner.

4.3 RESULTS

This section presents the results of the analysis for each of the eight separate categories of avionics. The results are presented using bar-charts and pie-charts. The bar-charts (odd numbered Figures 4-1 through 4-15) show the relative importance of each factor in discriminating or explaining the difference between the avionics equipped and nonequipped groups. Since the discriminatory power of a particular factor is not quantitatively effected by its sign (positive or negative), the direction of impact is not shown in the bar-charts. The following subsections present a detailed discussion of the direction of impact for each of the discriminatory factors. As an aid to the reader, Table 4-C presents the results for the direction of impact for each factor.

TABLE 4-C

DIRECTION OF IMPACT OF FACTORS ON AVIONICS EQUIPAGE

<u>FACTOR</u>	<u>DIRECTION OF IMPACT</u>
Average Cruising Speed	+
Pre-1960 Vintage	-
Itinerant Hours	+
Instructional Use	-
Personal Use	-
Industrial Use	-
Rental Use	-

Key:

- + means that an increase in this factor (for factors expressed in continuous form--cruising speed and itinerant hours) or possession of this attribute (for the age and use factors) increases the likelihood of belonging to the avionics equipped group.
- means that this factor varies inversely with the likelihood of being avionics equipped.

For readers interested in the direction of impact as well as the importance of a factor, Table 4-C may be used as a handy reference in conjunction with the bar-charts presented in each of the following subsections.

The results of the predictions for each of the avionics categories are presented using pie-charts (even numbered Figures 4-2 through 4-16). These predictions are derived from the systems presented in the bar-charts. The pie-charts show the percentage of correct and incorrect predictions. Two important comments must be kept in mind when using the pie-charts. First, the raw numerical values given in the pie-charts refer to the number of sample observations, not to the number of aircraft equipped with avionics in the GA fleet. Second, the predictions for the nonequipped group are not shown. This is done to focus the discussion on the equipped group. However, the nonequipped group is included in the percentages associated with the "total." Thus, for example in Figure 4-2, for noncompany owners, 71.8 percent correct predictions for the total means that including both the predictions made for the equipped and nonequipped groups, 71.8 percent of these predictions were correct. This computation is referred to in the previous section as $(n_{11} + n_{22})/N$. However, in Figure 4-2, 65.8 percent correct predictions for the equipped group means that for the aircraft equipped with avionics, 65.8 percent of the predictions for this group were correct and the remainder were incorrect.

This computation is referred to in the previous section as the column sum divided into its respective number of correct predictions for that group. While there is no way to discern the actual percentage of correct and incorrect predictions for the nonequipped group from the information given in the pie-charts, the percentage of correct predictions associated with the total is always somewhere between the percentages of correct predictions associated with the equipped and the nonequipped groups. Thus, when the percentage of correct prediction associated with the total is high, and the corresponding percentage for the equipped group is low, it can be assumed that the percentage of correct predictions for the nonequipped group is very high. Figure 4-10 demonstrates the extreme case. This figure shows that for noncompany owners, the percentage of correct predictions for equipage and nonequipage is quite high (85.2 percent), while the percentage of correct predictions for the avionics equipped group is considerably lower (5.7 percent). Then the number of correct predictions for the nonequipped group (not shown) must be very high, i.e., greater than 85.2 percent. In fact, the number of correct predictions for the nonequipped group is 99.3 percent.)

The format for the discussion in the remainder of this chapter is as follows. A separate subsection is devoted to each of the eight types of avionics, and each subsection

begins with a thumbnail sketch of the purpose of the type of avionics under consideration.* Within each subsection the relative importance of each of the factors comprising the discriminating system is discussed, this is followed by a breakout of the correct and incorrect predictions for the total and for the equipped groups--first for noncompany owners and then for company owners. Remember that the systems described in the bar-charts were developed using noncompany owner data, hence the prediction results for noncompany owners cannot be used to judge the effectiveness of the system to distinguish between the avionics equipped and nonequipped groups. The true test is based on the prediction results obtained when the system is applied to the heretofore unconsidered company owner data. Thus, the final part of each subsection discusses the company owner results as tested against the pure chance criterion. The results of this test determine the predictive efficacy of the system.

4.3.1 INSTRUMENT LANDING SYSTEM (ILS)

As the name implies, this type of avionics is used by aircraft performing a precision approach to land under instrument flight rules, that is, an operation that is controlled by an approach control facility. Hence, instrument approaches may utilize one or more of the following subcategories of ILS capabilities: (a) ILS localizer--receives a signal, emanating from an airport, which serves to guide the aircraft down the

* A more detailed description of the various avionics functions may be found in Reference 5.

center of the runway; (b) ILS glide slope--receives a signal, emanating from an airport, which serves to guide the aircraft down the proper landing slope; (c) ILS marker beacon--the aircraft receives signals from marker beacons, which are placed in series at discrete intervals from the beginning of the airport runway, and these signals indicate that the pilot should begin his descent or that the aircraft is at minimum altitude for the approach. In this chapter an aircraft is counted as ILS equipped if it had any one of these avionics subcategories on board.

Figure 4-1 shows that the most important factor in discriminating or explaining the difference between the ILS equipped and nonequipped groups is aircraft cruising speed. This factor is included as a surrogate for aircraft type. Because turboprops and turbojets are structurally designed for longer distance and high altitude flights, requiring avionics for communications and navigation, and the smaller piston aircraft are not, cruising speed has a positive impact on avionics equipage. As will be evident from the following subsections, this factor is by far the most powerful discriminator between the equipped and nonequipped groups.* The pre-1960 vintage factor (designating aircraft manufactured

* Given its importance, it should be noted that alternative representations of the type of aircraft factor, including separate indicators for each type of aircraft were tested in the preliminary stages of the analysis. These alternative formulations were not acceptable, most commonly because they did not work well when used with other factors (i.e., multicollinearity problems) considered to be important in discriminating between the avionics equipped and nonequipped groups.

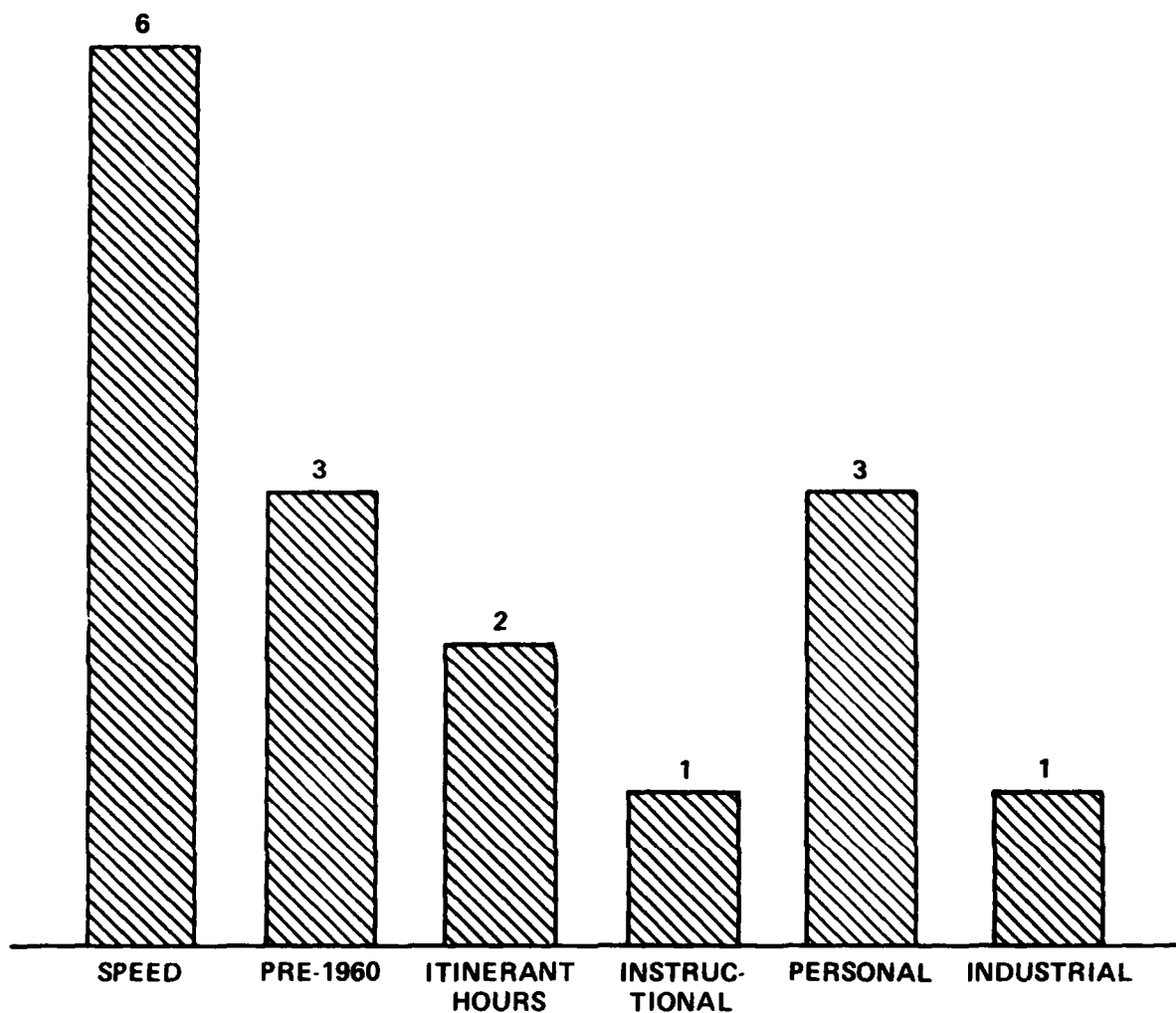


Figure 4 - 1

RELATIVE IMPORTANCE OF FACTORS IN
ILS AVIONICS EQUIPAGE

prior to 1960) and the personal use factor are the next most important factors. The deleterious effects of age/use on utilization rates for pre-1960 vintage aircraft, their lower market values, and their shorter expected useful life, relative to more recent vintage aircraft, argues against the installation of costly avionics for these aircraft (direction of impact is negative). The aircraft owner's type of use factors are identical to those used in Chapter 3. In the present chapter they are utilized to reflect variations in avionics equipage due to type of use. Since business users, the category held constant, are more likely than the other users to fly in congested airspace (e.g., around large cities), where FAA avionics requirements are especially stringent, the user group factors have a negative influence on avionics equipage. As may be noted from Figure 4-1 the rental category is not among the final set of factors utilized to differentiate between the ILS equipped and nonequipped owners. Without entering a lengthy statistical discussion, this is because when this factor was tried as an entrant, after the other factors were selected, it did not add any significant information to the existing system. Itinerant hours rank slightly higher than the two remaining user factors in its discriminating power. Because of the added pilot safety margin derived from avionics equipage, especially on trips where origin and destination differ, itinerant hours exert a positive influence on avionics equipage.

When the system described in Figure 4-1 is applied to non-company owners, the data set which was used to generate that system, to predict the ILS equipped and nonequipped group membership the results depicted in Figure 4-2 are obtained. This figure shows that when both the equipped and nonequipped group predictions are considered, 71.8 percent of the predictions are correct and 28.2 percent are incorrect (cross-hatching indicates incorrect predictions in all the pie-charts). When only the predictions for the avionics equipped group are considered 65.8 percent of the predictions are correct and 34.2 percent are incorrect.

Figure 4-2 also shows the results obtained for company owners. That is, the system described in Figure 4-1 is applied to predict ILS group membership for data not previously utilized in the analysis. The results obtained for company owners' ILS avionics are impressive. 74.3 percent of the total predictions (i.e., predictions for the equipped and nonequipped groups) are correct and 25.7 percent are incorrect. For the ILS equipped group, 76.2 percent of the company owner predictions are correct. Since there are 1,950 total owners in the ILS sample and 1,215 of these are equipped with ILS avionics and the remainder are nonequipped, by pure chance it is expected that 62.3 percent (i.e., $1,215/1,950 = 62.3$ percent*) are

* Multiplying the proportion by 100 gives the percentage result.

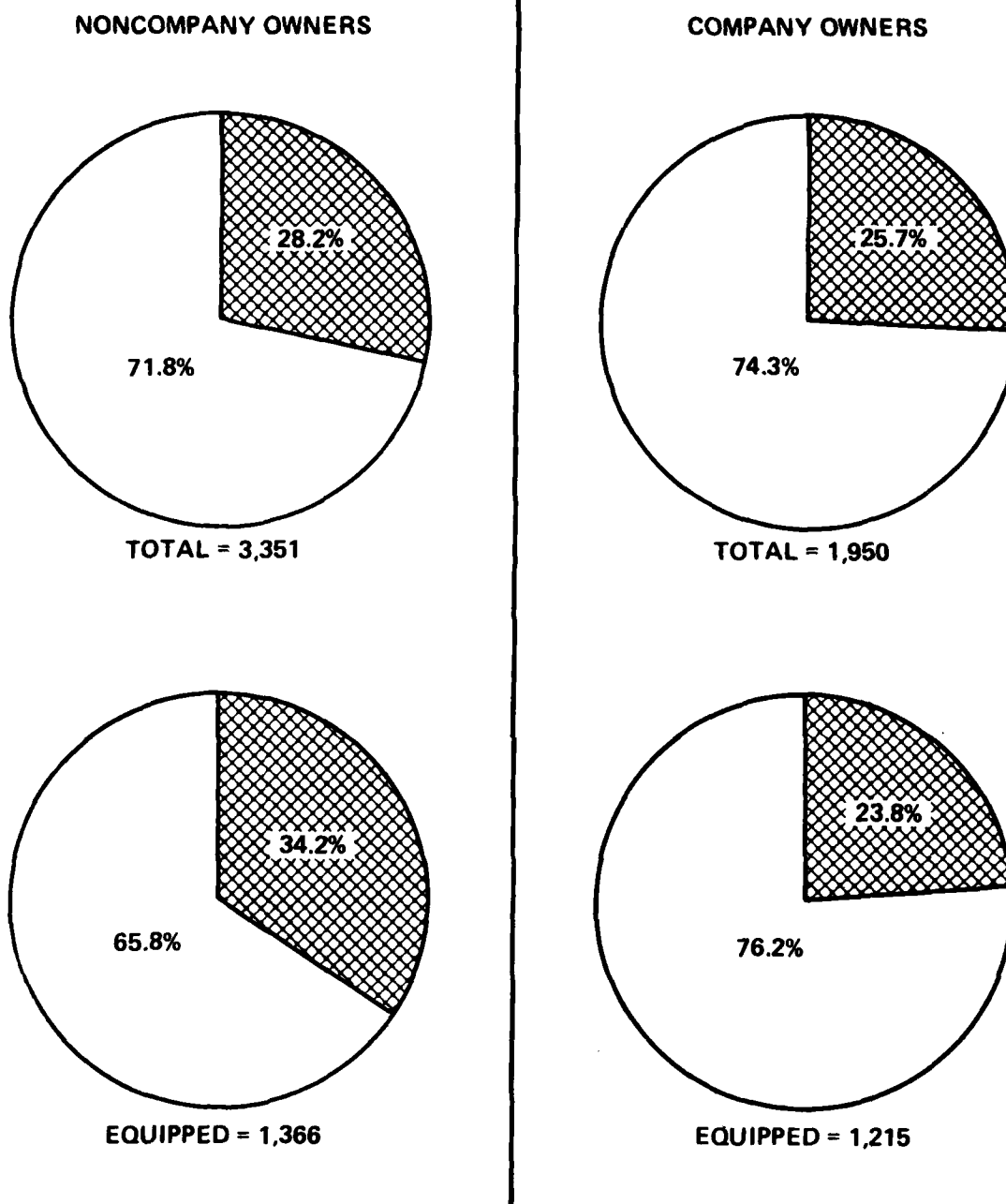


Figure 4 - 2

ILS: PERCENTAGE OF CORRECT AND
INCORRECT PREDICTIONS

correct predictions. Thus, the 76.2 percent correct predictions for the company owner ILS equipped group exceeds that which could be expected by the pure chance criterion.

As explained in Section 4.2, the relevant pure chance criterion value against which to judge the system's 74.3 percent total correct predictions is the maximum or highest of the pure chance expectations for the equipped group (62.3 percent) and the nonequipped group (i.e., the higher probability between 62.3 percent and 37.7 percent is 62.3 percent).^{*} Thus, the 74.3 percent correct predictions for the total exceeds the maximum correct guesses that could be expected from pure chance, 62.3 percent. These results strongly support the effectiveness of the system described in Figure 4-1 to predict ILS avionics equipage.

In the following subsections the reasons supporting a factor's inclusion in the system will not be repeated. Since the direction of impact of each factor and its supporting hypothesis do not vary with the type of avionics, the arguments are identical to those presented in this subsection. Table 4-C is furnished as a quick reference guide. In addition, while the following subsections present the relevant pure chance criteria values for company owners, the computation per se is not given.

^{*} The pure chance criterion value for the nonequipped group is computed as the number nonequipped ($1,950 - 1,215 = 735$) divided by the total number in the sample ($735/1,950$), or more simply $100.0 - 62.3 = 37.7$ percent.

The pie-charts provide all the necessary information should the reader wish to check the given pure chance criterion values. The number of company owners equipped can be subtracted from the total to obtain the number nonequipped. For each type of avionics, the pure chance criterion value applicable to the percentage correctly predicted for the equipped group is obtained by dividing the number equipped by the total number. A similar computation for the nonequipped group gives its relevant pure chance criterion. The latter is relevant only in so far as it is used to arrive at the maximum pure chance criteria--the value against which the system's total correct predictions obtained for company owners are judged. The maximum pure chance criterion is the greater between the two pure chance values obtained for the equipped and nonequipped groups.

4.3.2 VERY HIGH FREQUENCY OMNI-DIRECTIONAL RECEIVER (VOR)

VOR is used to keep the aircraft on the desired origin-destination flight path by receiving a specific VOR signal. That is, once the angle of flight from origin to destination is computed and the VOR receiver indicator is set at this "heading" (cruise bearing), all the pilot need do is to keep the aircraft adjusted such that the VOR indicator remains centered on this predetermined degree angle.

Figure 4-3 shows that the most important factor in differentiating between the VOR equipped and nonequipped groups

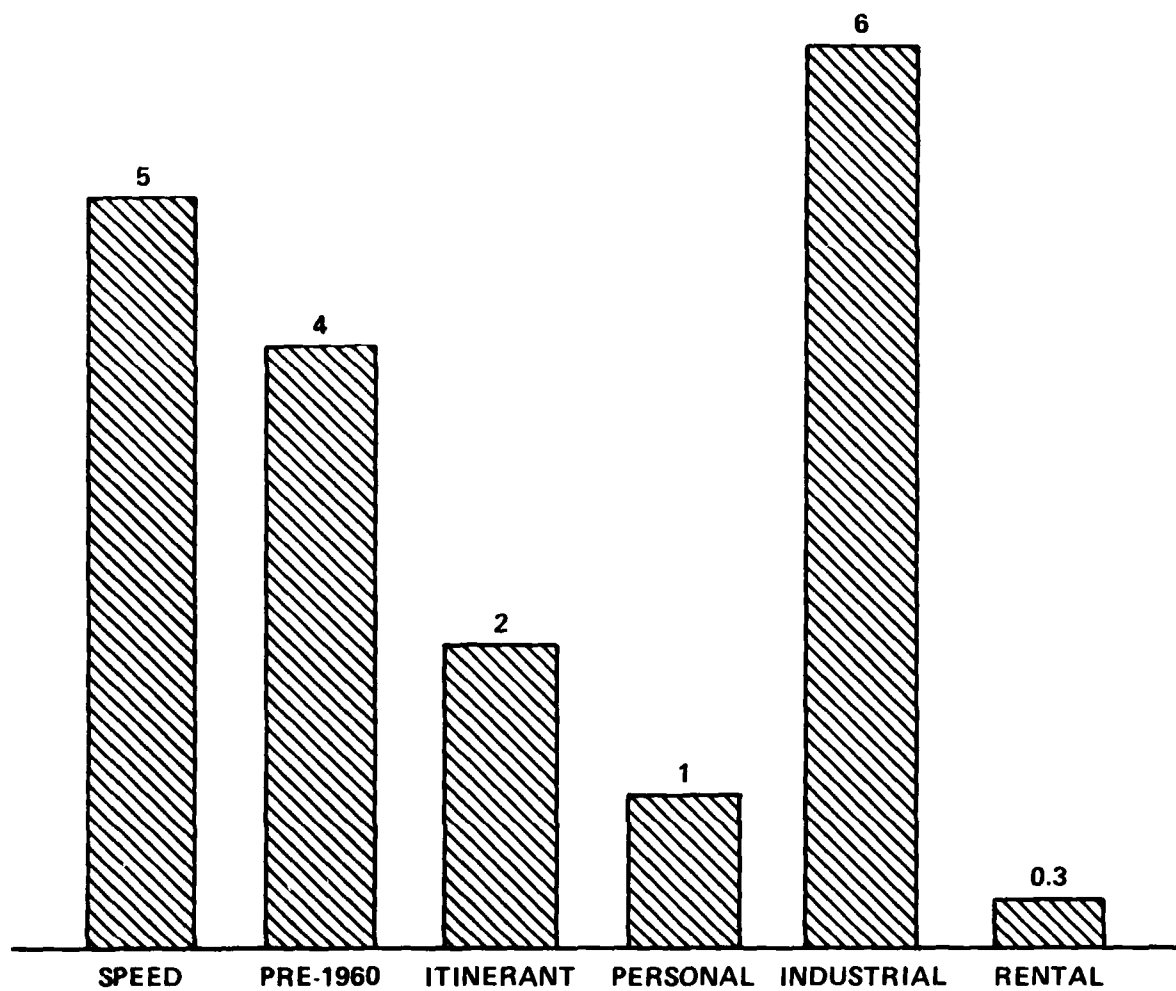


Figure 4 - 3

RELATIVE IMPORTANCE OF FACTORS IN
VOR AVIONICS EQUIPAGE

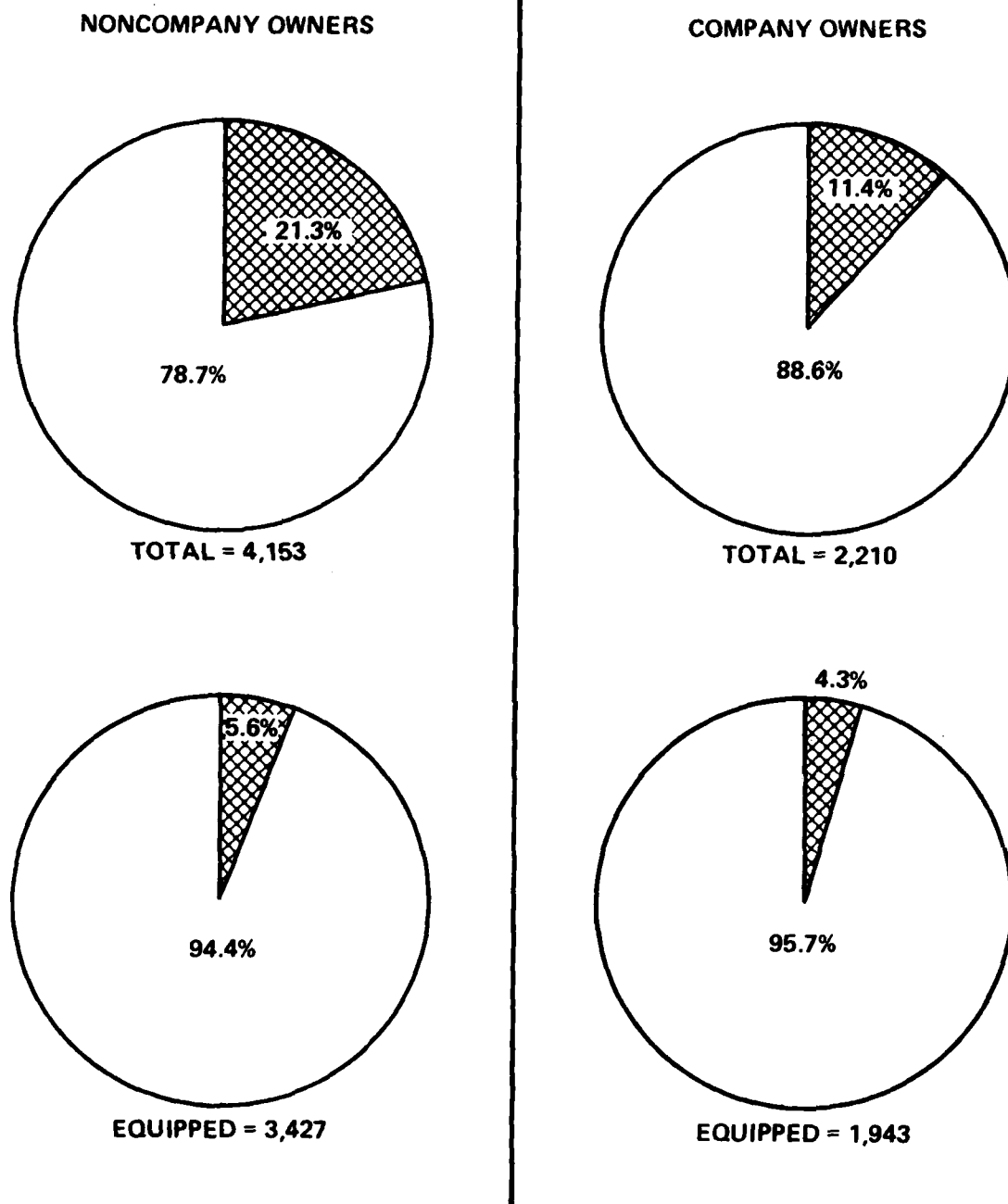


Figure 4 - 4

VOR: PERCENTAGE OF CORRECT AND
INCORRECT PREDICTIONS

is the industrial use factor, followed closely by aircraft cruising speed. The pre-1960 vintage factor is the third most important factor. These results are similar to those obtained for ILS (subsection 4.3.1) in that the aircraft speed and age factors achieve relatively high levels of importance as discriminators between the avionics equipped and nonequipped groups. The most striking difference between the results obtained for ILS (Figure 4-1) and those obtained for VOR (Figure 4-3) is the varying level of importance achieved by the industrial use factor. Its powerful position as a discriminator in the VOR results may be attributed to the function of this type of avionics. That is, industrial use activity is not generally compatible with longer inter-city flights, whereas VOR equipment is very useful on such flights. Hence, its strongly negative impact on equipage with VOR avionics. Instructional use did not enter the VOR system since it failed to add any significantly new discriminatory information in addition to that obtained from the other factors.

Figure 4-4 shows the results obtained when the system described in Figure 4-3 is applied to noncompany owners. Of the total predictions, 78.7 percent correctly identified the aircraft owner as being VOR equipped or nonequipped. When the equipped group is taken separately, 94.4 percent of the predictions were correct.

Figure 4-4 also shows the results of applying the system described in Figure 4-3 to company owners. The results obtained are very impressive. The system correctly identified 88.6 percent of the owners as to their equipage disposition (i.e., equipped or nonequipped). When only the VOR equipped group is considered, 95.7 percent were correctly identified.

Comparable expectations using the pure chance criterion are 87.9 percent correct guesses for both the total and for the equipped group. Thus, similar to the results for the previous subsection, the system once again beats the odds. As was pointed out in Section 4.2 this is very impressive because not only is the system required to pick the "winner" (the equipped group) but also the "loser" (the nonequipped group).

4.3.3 DISTANCE MEASURING EQUIPMENT (DME)

DME avionics is generally used simultaneously with VOR equipment. DME equipment automatically computes and displays the distance from origin to destination. This is done in two stages. The signal received via the VOR receiver and DME receiver is used to compute the azimuth and distance of a current flight position from the origin point. The low and high altitude enroute charts inform the pilot as to when he should change to the destination frequency. When the latter point is reached, the DME unit

computes and displays the distance of current flight position from the destination point. The VOR and DME avionics may be used alone or may be used with ILS equipment. For example, when the DME indicates a certain minimum distance from an airport, the ILS equipment may be used by the pilot to govern the aircraft's descent slope and altitude configuration as well as to center the aircraft on the runway.

Figure 4-5 illustrates the relative strength of the factors in differentiating between the DME equipped and nonequipped groups. The results for DME are considerably different than those obtained for either ILS or VOR avionics in that four factors receive about equal importance as discriminators. Results obtained for ILS and VOR were clearly more decisive as to the relative importance of the discriminatory ability of the factors. This result is interesting because it implies that, although DME equipment may be compatible in use with other types of avionics, it would be misleading to use the results obtained for complementary avionics categories as a basis for determining DME equipage. Detailed examination of why the relative importance of the factors vary for compatible types of avionics (i.e., whether it may be attributable to a real and structurally different method of assessment in the equipage decision based on the incremental benefits acquired by the "add-ons," or simply a function of a larger number of owners having only one or the other type of avionics) is beyond the scope of this chapter. Figure 4-5 shows that aircraft cruising

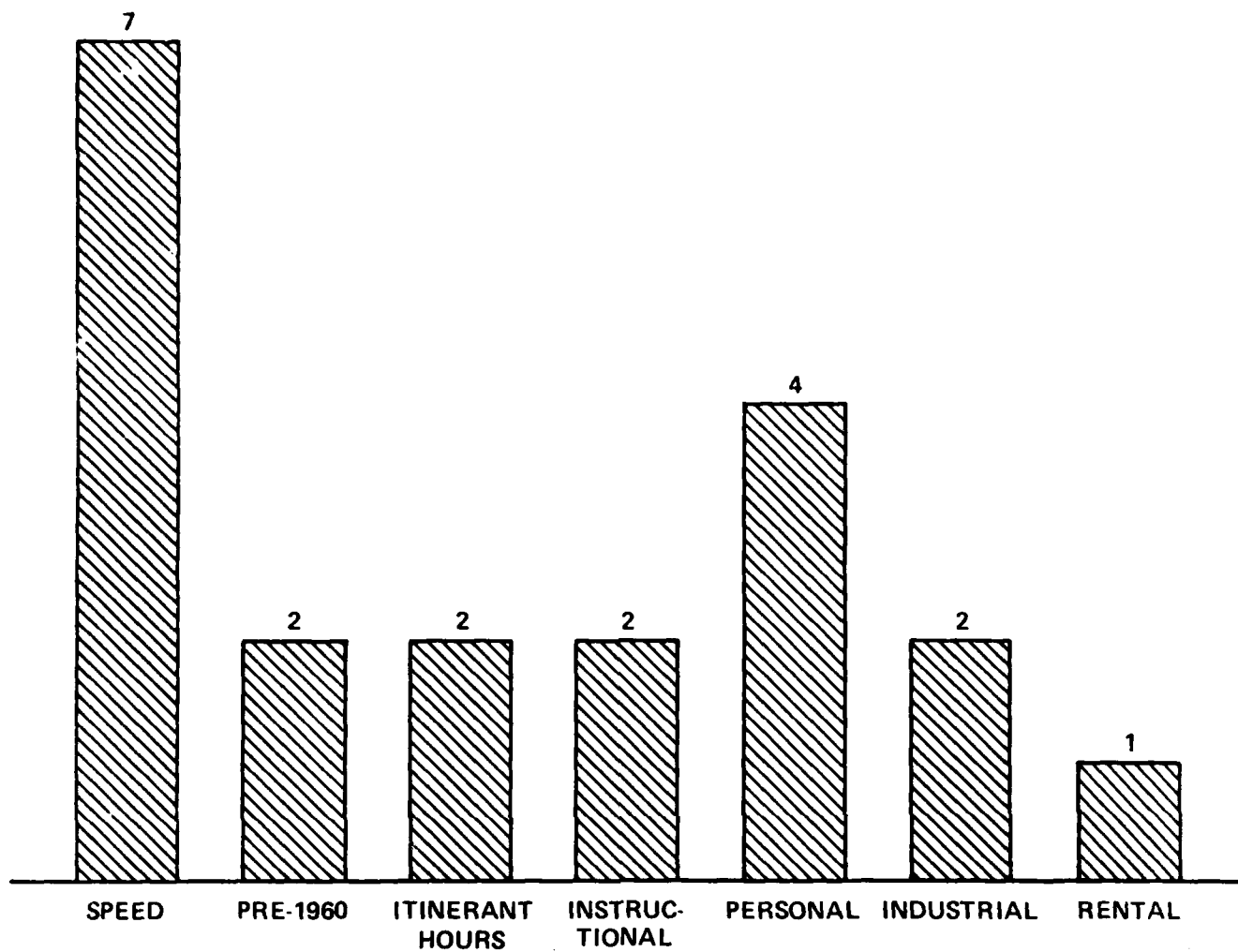


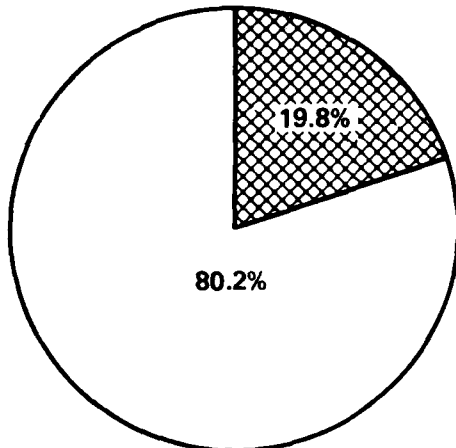
Figure 4 - 5

RELATIVE IMPORTANCE OF FACTORS IN
DME AVIONICS EQUIPAGE

speed is clearly the dominant factor in explaining the difference between the DME equipped and nonequipped group. Since DME equipment is especially suited to higher altitude and longer distance flights, which are highly compatible with turboprop and turbojet activities, this result is not surprising. Personal use is the second most important discriminating factor--explained by its high noncompatibility (negative impact) with the application of VOR avionics.

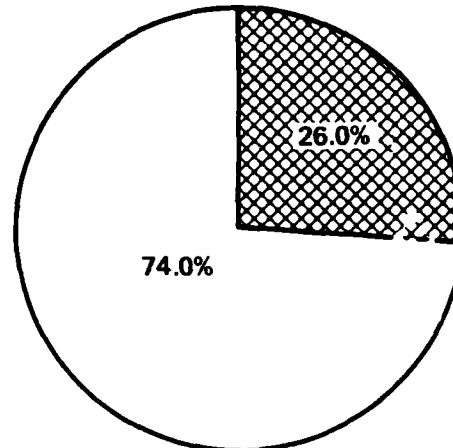
Figure 4-6 shows the results of the DME predictions. For noncompany owners, the system illustrated in Figure 4-5 predicts 80.2 percent of the total correctly. When the equipped group is taken alone, 40.1 percent of the predictions are correct. When the system is applied to company owner data, 74.0 percent of the predictions for the equipped and nonequipped groups are correct and 59.8 percent of the predictions for the equipped group are correct. The percentage of correct predictions for the equipped group, for both noncompany and company owners, is somewhat lower for DME than for that obtained in the other avionics cases examined previously. However, as may be noted the equipped group for DME represents a smaller proportion of the total than for any of these other avionics categories. Thus, the degree of difficulty of correctly identifying members of this smaller group increases more than proportionally. In any case, the critical test to ascertain the predictive efficacy

NONCOMPANY OWNERS

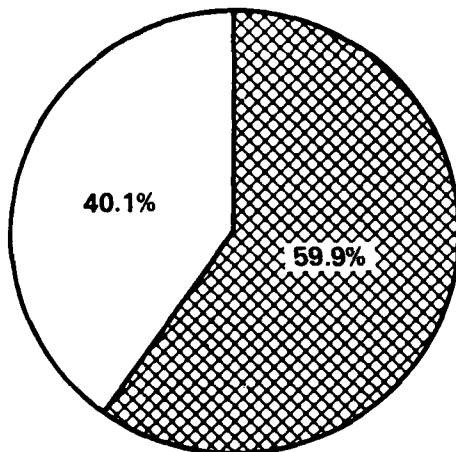


TOTAL = 4,145

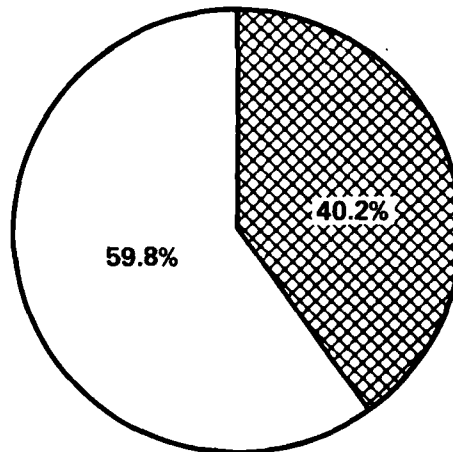
COMPANY OWNERS



TOTAL = 2,210



EQUIPPED = 599



EQUIPPED = 809

Figure 4 - 6

**DME: PERCENTAGE OF CORRECT AND
INCORRECT PREDICTIONS**

of the system is how the predicted results (percentage of correct predictions) for company owners compare with the pure chance criterion. For DME the pure chance expectations are 63.4 percent correct guesses for the total and 36.6 percent correct for the DME equipped group. The percentage of correct predictions obtained using the system for company owners (Figure 4-6) far exceed the pure chance criterion. Thus, the system is judged to be an effective discriminator between the DME equipped and nonequipped groups.

4.3.4 AUTOMATIC DIRECTION FINDER (ADF)

The ADF receives signals from a commercial radio station or low frequency transmitter, say in the city of destination, and the indicator on the ADF unit shows the direction (compass degree angle) of the source of transmission from the current position of the aircraft. Similar to the VOR receiver, the pilot's task is to maintain the indicated angle to achieve the proper flight path.

Figure 4-7 illustrates the relative strengths of the factors in differentiating between the ADF equipped and nonequipped groups. This figure shows that aircraft cruising speed is more than twice as important as any other factor in explaining the ADF equipage decision. Similar to the results obtained for DME (Figure 4-5), several factors appear to share equal importance in their respective contributions to differentiating between the ADF equipped

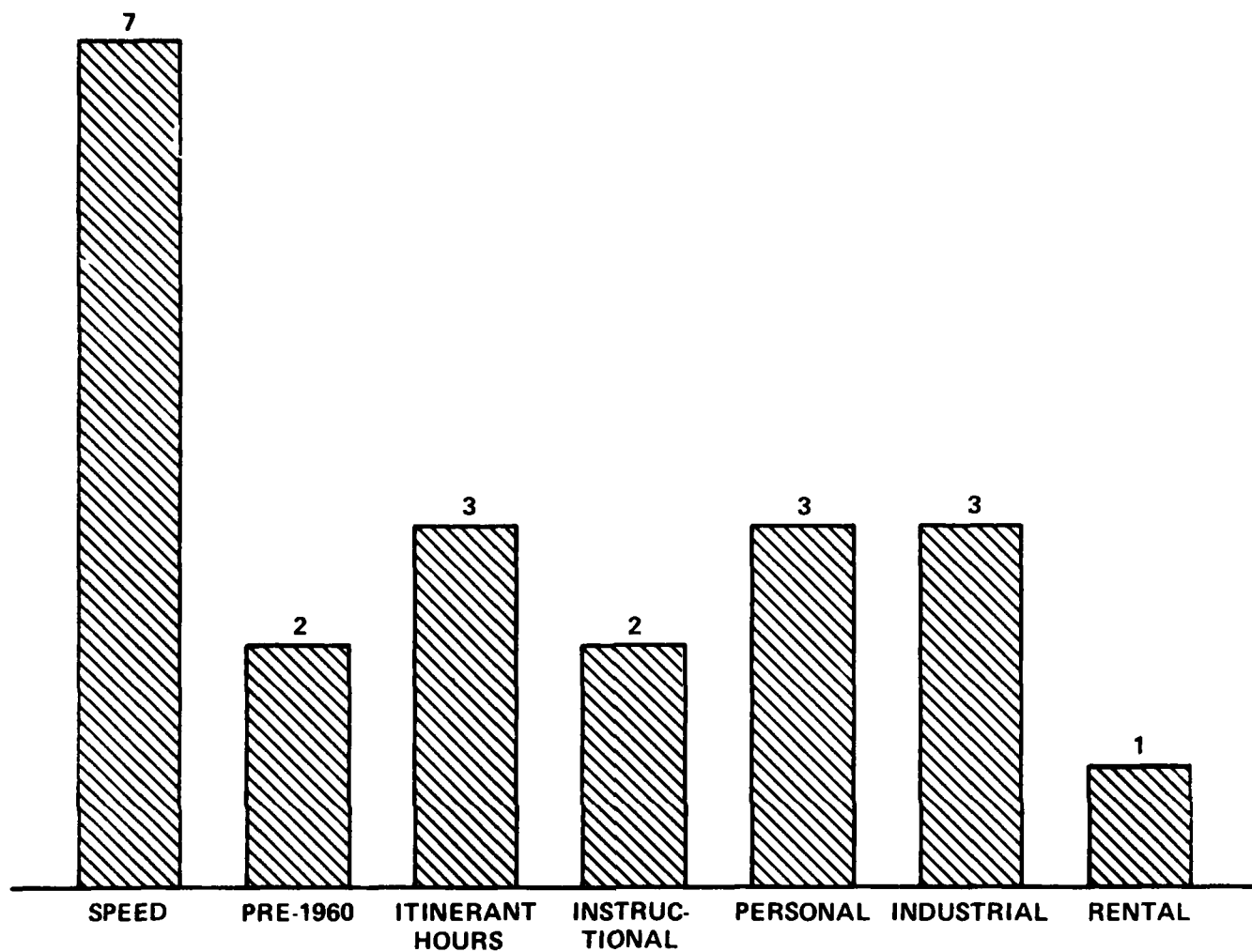


Figure 4 - 7

RELATIVE IMPORTANCE OF FACTORS IN
ADF AVIONICS EQUIPAGE

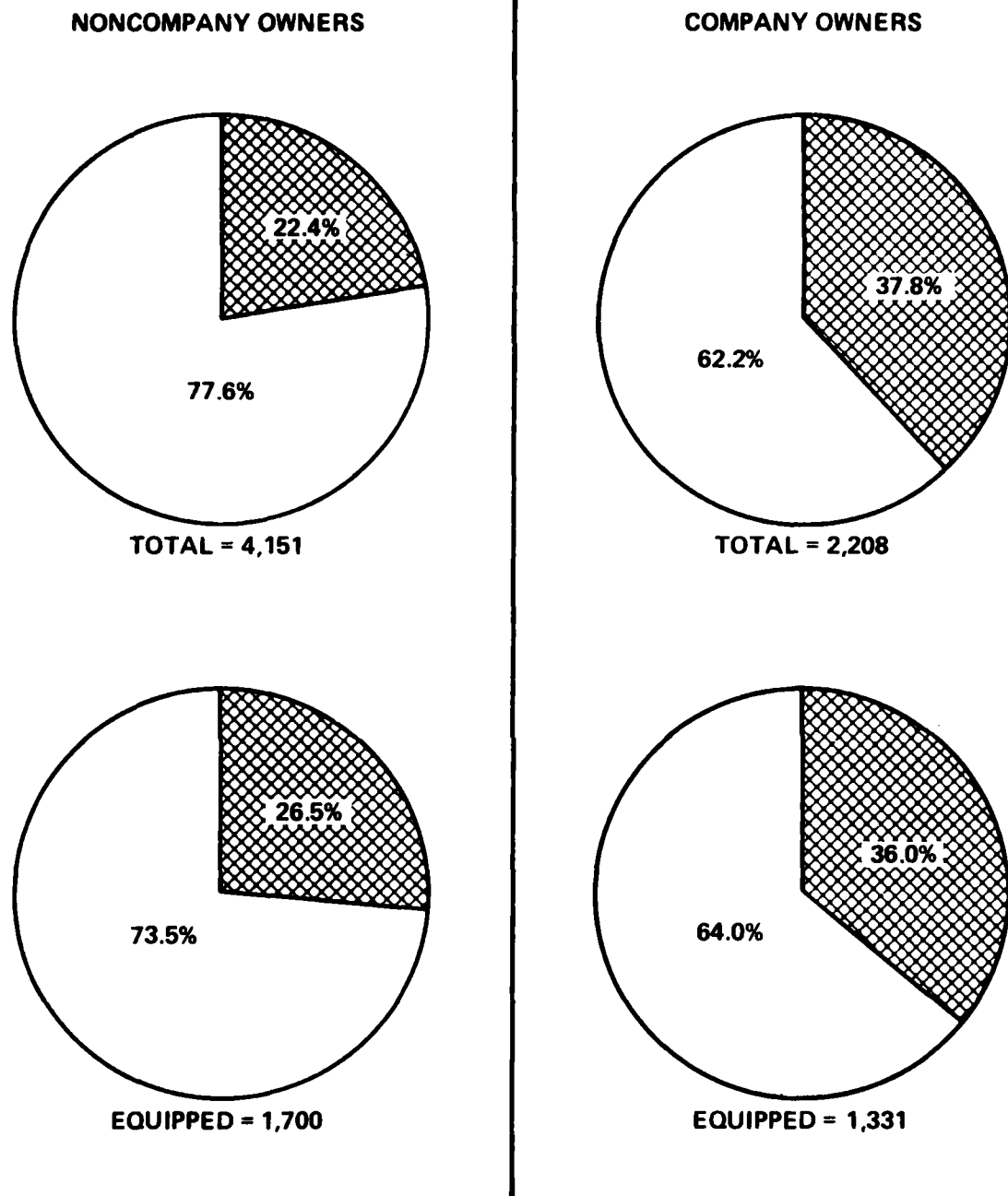


Figure 4 - 8

ADF: PERCENTAGE OF CORRECT AND
INCORRECT PREDICTIONS

and nonequipped groups. While factors of equal rank are about equal in importance, it must be remembered that they are not redundant in the sense that they describe the same aspect of the equipage decision. Rather, this type of result suggests that the equipage decision is multifaceted and several factors share equal importance in that decision.

The results of the ADF predictions for noncompany owners (Figure 4-8) show that 77.6 percent of the total predictions are correct and that 73.5 percent of the predictions for the equipped group are correct. When the system illustrated in Figure 4-7 is applied to company owners, 62.2 percent of the total prediction are correct and 64.0 percent of the ADF equipped group predictions are correct. Since the pure chance criterion indicates that 60.3 percent correct predictions are expected for both the total and the equipped group, the system described in Figure 4-7 is considered to be an effective discriminator between the ADF equipped and nonequipped groups.

4.3.5 WEATHER RADAR

As the name implies, the purpose of this avionics is to display weather information to the pilot.

Figure 4-9 shows the relative discriminatory power of the factors for weather radar. The very high degree of importance achieved by aircraft cruising speed is supported by

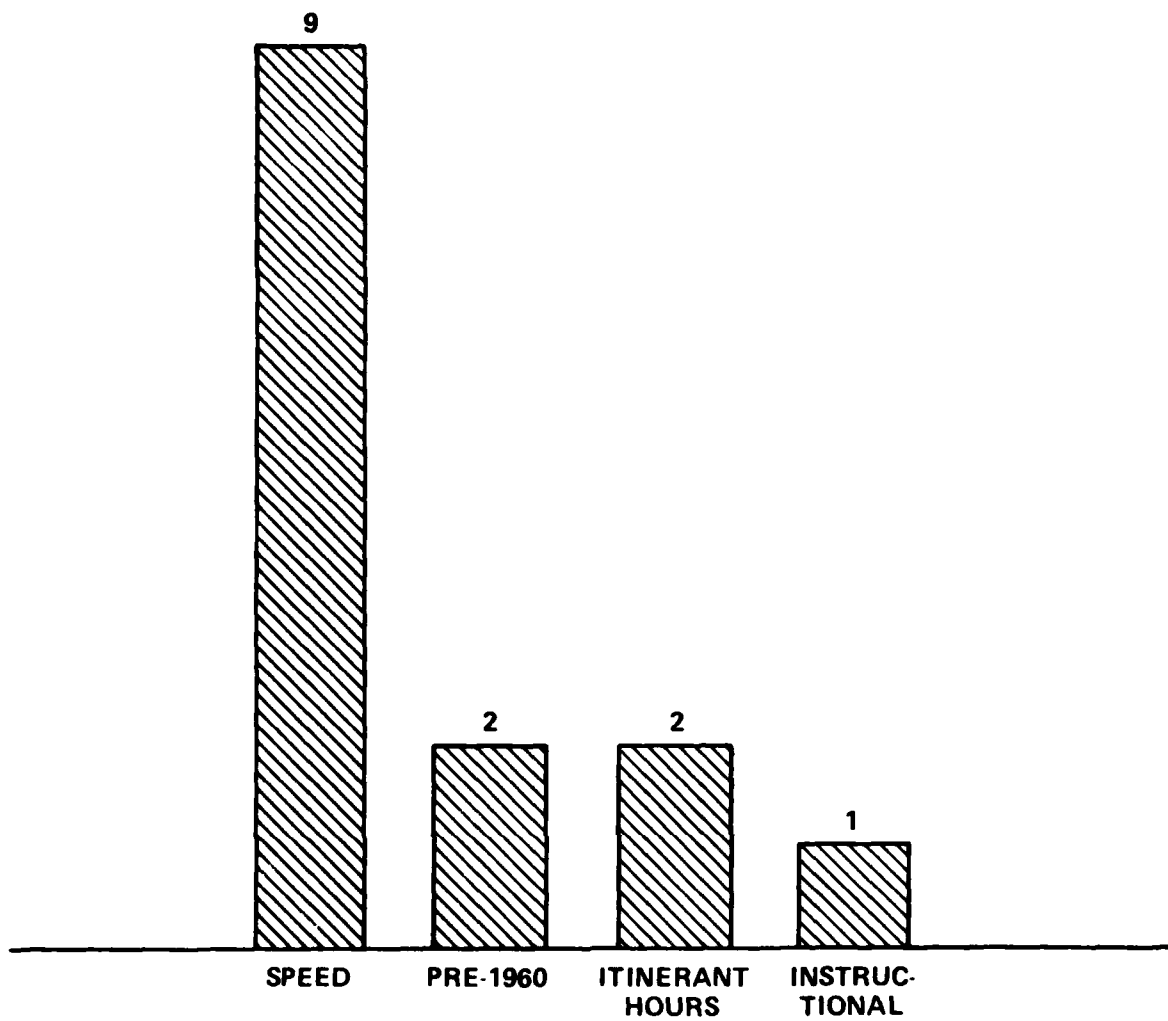


Figure 4 - 9

RELATIVE IMPORTANCE OF FACTORS IN
RADAR AVIONICS EQUIPAGE

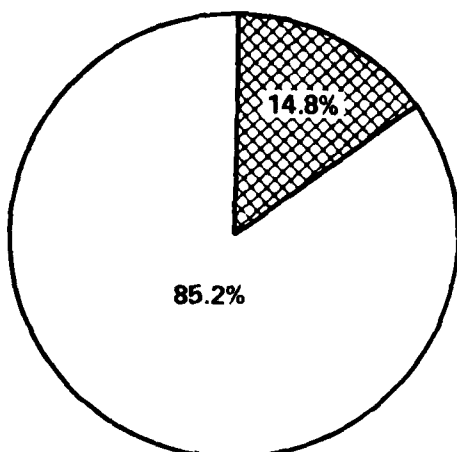
the fact that this type of avionics is extremely useful at high altitude longer distance flights. Since this type of flying is highly compatible with turboprops and turbojets, the result that aircraft speed is four and one-half times more important than any other factor is not too surprising. The rental, industrial, and personal use factor failed to add any significant discriminatory information beyond that obtained by the system presented in Figure 4-9.

The results presented in Figure 4-10 are interesting. This figure shows that, for both noncompany and company owners, while the percentage of correct predictions for the total (equipped and nonequipped groups) are respectable, the percentage of correct predictions for the equipped group is considerably lower. This case is particularly interesting because it offers an opportunity to enhance the reader's understanding, by practical example, of several important points about the nature of the research results. That is, because the percentage of the system's correct predictions for the equipped group is low does not, by itself, automatically lead to the conclusion that the system is not an effective discriminator. As pointed out in Section 4.2, assessment of the effectiveness of the system is based on how well it correctly predicts the total, not on one or the other of the components of the total. The logic supporting the use of

the total as the primary basis of ascertaining the predictive efficacy of the system is that predictions for both the avionics equipped and nonequipped groups are important. The present case exemplifies this in that the large percentage of correct predictions for the nonequipped group represents valuable information to avionics manufacturers. As pointed out in Section 4.3, the system illustrated in Figure 4-9 correctly predicts over 99.0 percent of the nonequipped group for both noncompany and company owners. Thus, despite the low percentage of correct predictions for the weather radar equipped group, avionics manufacturers (utilizing the system presented in Figure 4-9) could identify, with a high degree of accuracy, the group least likely to purchase this avionics. As a second best solution, marketing strategies could be geared to minimize attention to this group and concentrate on the remaining owners.

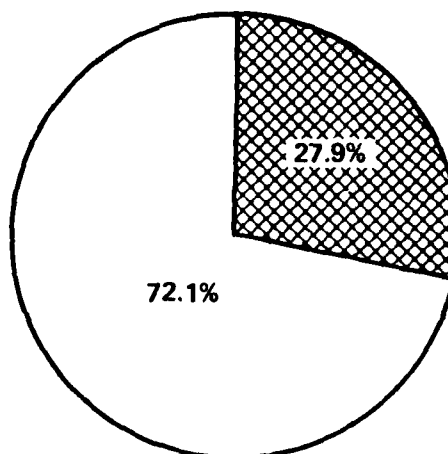
Another important point to be gleaned from the results presented in Figure 4-10 is that even a low percentage of successful prediction may be useful. Here the basis for assessing the usefulness of such predictions is somewhat arbitrary and arises because of necessity. To explain, the low percentage of correct predictions for the weather radar equipped group exhibited in Figure 4-10 is to a large extent a function of the few number of owners, relative to the total, equipped with this avionics. Hence the high

NONCOMPANY OWNERS

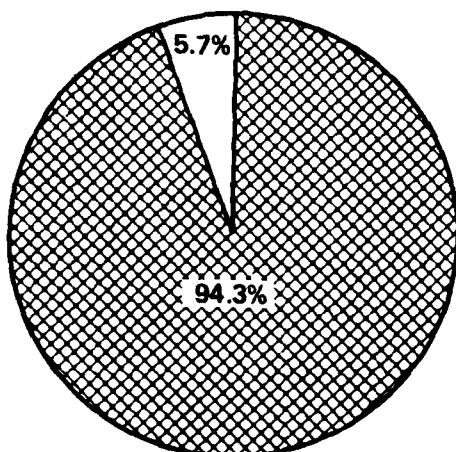


TOTAL = 4,146

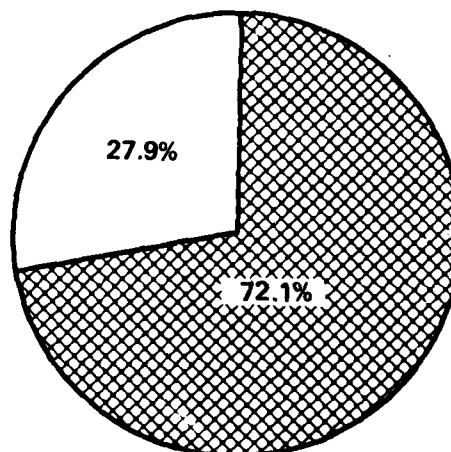
COMPANY OWNERS



TOTAL = 2,210



EQUIPPED = 60



EQUIPPED = 244

Figure 4 - 10

**RADAR: PERCENTAGE OF CORRECT
AND INCORRECT PREDICTIONS**

degree of difficulty of correctly identifying these owners. The pure chance criterion as applied to the total simply selects the highest standard to judge the system, and ignores the significant problem of defying the odds. However, it may well be that pure chance, when applied to identifying the equipped owners, cannot do as well as the system. This is because the degree of difficulty of identifying members of a group with significantly fewer members holds for all alternative schemes of identification. If predictions about the equipped group are required, the system presented in Figure 4-9 may provide better results than the pure chance alternative. Thus, while the system's percentage of correct predictions in toto may not meet the stringent maximum pure chance criterion, the system's correct predictions for the equipped group--albeit low in the absolute sense--may be greater than that expected by pure chance. In the latter case, the system could still be considered (on the basis of a judgmental assessment) useful. The predictive efficacy of the system illustrated in Figure 4-9 is ascertained in the following paragraph in light of the above discussion.

For noncompany owners Figure 4-10 shows that 85.2 percent of the total predictions are correct and 5.7 percent of the predictions for the radar equipped group are correct. For company owners, the system described in Figure 4-7

identifies 72.1 percent of the total correctly and correctly predicts 27.9 percent of the radar equipped group. By pure chance it is expected that 89.0 percent of the total is correctly identified and 11.0 percent of the guesses for the equipped group are correct. Thus, although the system cannot be judged effective as discriminating between the groups based on the results for the total, it exceeds the pure chance criterion for correct predictions for the radar equipped group.

4.3.6 AREA NAVIGATION EQUIPMENT (ANE)

ANE automatically computes and displays both the distance and the proper compass degree heading from any city to any other city utilizing a mini-computer. That is, it receives standard VHF (to - from) transmissions for known city pairs, and computes the above information points. The information is continually updated, utilizing the most appropriate known city pair information, as the flight progresses.

Figure 4-11 presents the relative weights attained by the factors in the ANE equipage decision. The aircraft's age (pre-1960 vintage) and cruising speed are the two most powerful discriminating factors. The powerful impact of older aircraft on this avionics equipage decision is supported by the noncompatibility in ANE equipment use and its relatively expensive purchase price versus the

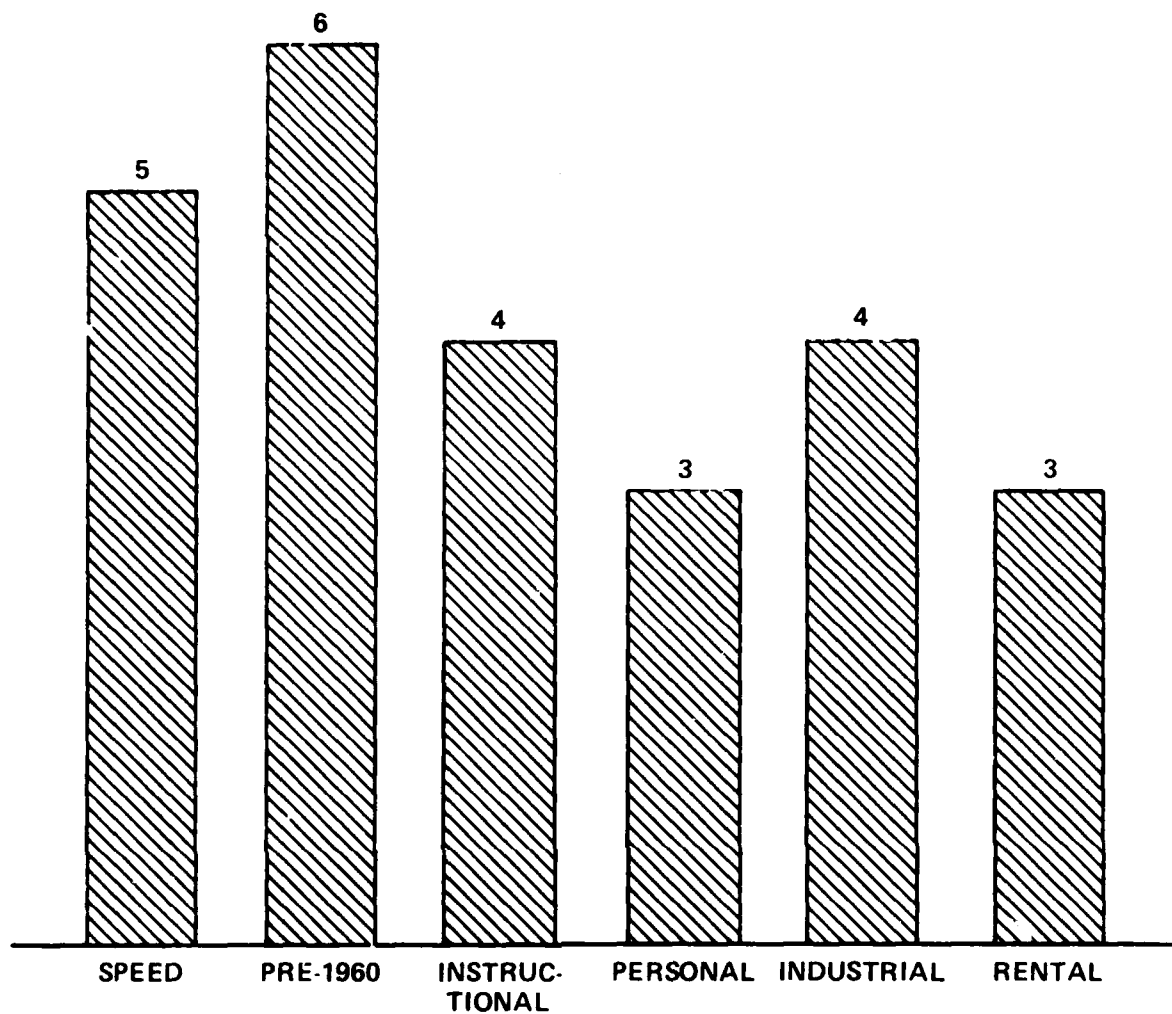


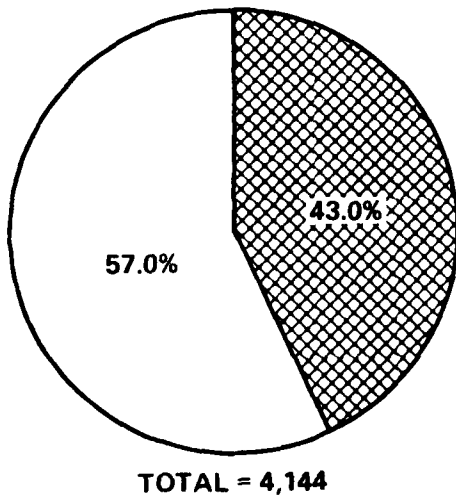
Figure 4 - 11

RELATIVE IMPORTANCE OF FACTORS IN
ANE AVIONICS EQUIPAGE

likely shorter missions and useful life or older vintage aircraft. The relatively high positive impact of aircraft speed is supported by a contrary argument--compatibility of longer mission length with the more mechanically and aerodynamically sophisticated aircraft. Itinerant hours flown did not enter the system presented in Figure 4-11 because it did not add any additional discriminating information.

Figure 4-12 presents the results of the ANE predictions. The results for the ANE equipped group are similar to those obtained for weather radar (Figure 4-10) in that the equipped group represents a low proportion of the total and the percentage of correct predictions are considerably lower for the equipped group than for the total. Thus, the discussion presented in the preceding subsection, regarding the low percentage of correct predictions for the group with few members and the assessment of system results versus pure chance, applies equally here. For noncompany owners, 57.0 percent of the predictions for the equipped and nonequipped groups are correct and 11.7 percent of the ANE equipped group predictions are correct. For company owners, 46.2 percent of the members of each group are correctly identified in total and 18.7 percent of the ANE equipped group are correctly identified. Using the pure chance criterion, it is expected that 85.8 percent of the total is correctly identified and 14.2 percent of the guesses

NONCOMPANY OWNERS



COMPANY OWNERS

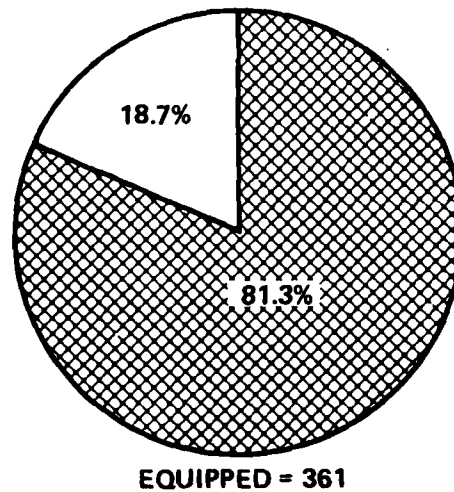
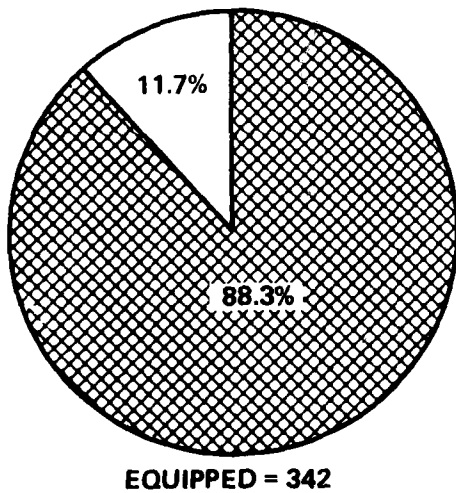
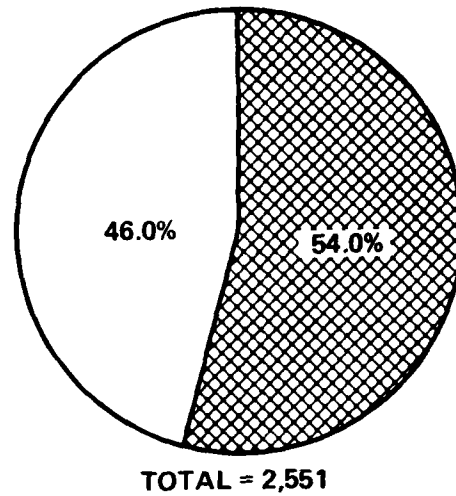


Figure 4 - 12

**ANE: PERCENTAGE OF CORRECT AND
INCORRECT PREDICTIONS**

for the equipped group are correct. Thus, similar to the results obtained for weather radar (subsection 4.3.5), the system (Figure 4-11) cannot be judged to effectively discriminate between the equipped and nonequipped groups in toto. However, the percentage of correct predictions using the system described in Figure 4-11 for the ANE equipped group exceeds the number of correct guesses that is expected by pure chance.

4.3.7 TRANSPONDER

Basically, transponder equipment is used in conjunction with ground radar to allow the air traffic controller to identify that particular aircraft. That is, the transponder transmits a specific code, requested by the controller, which appears as a patterned indicator along with the aircraft "blip" on the ground radar scope.

Figure 4-13 shows that the most important factors in discriminating between the transponder equipped and nonequipped groups are aircraft cruising speed and age of aircraft. They are each more than one and one-half times more powerful in discriminatory ability as the next most important factor, itinerant hours. Contrary to almost all of the results obtained previously (the only exception is weather radar), none of the user group factors are very powerful in discriminating between the transponder equipped and nonequipped groups.

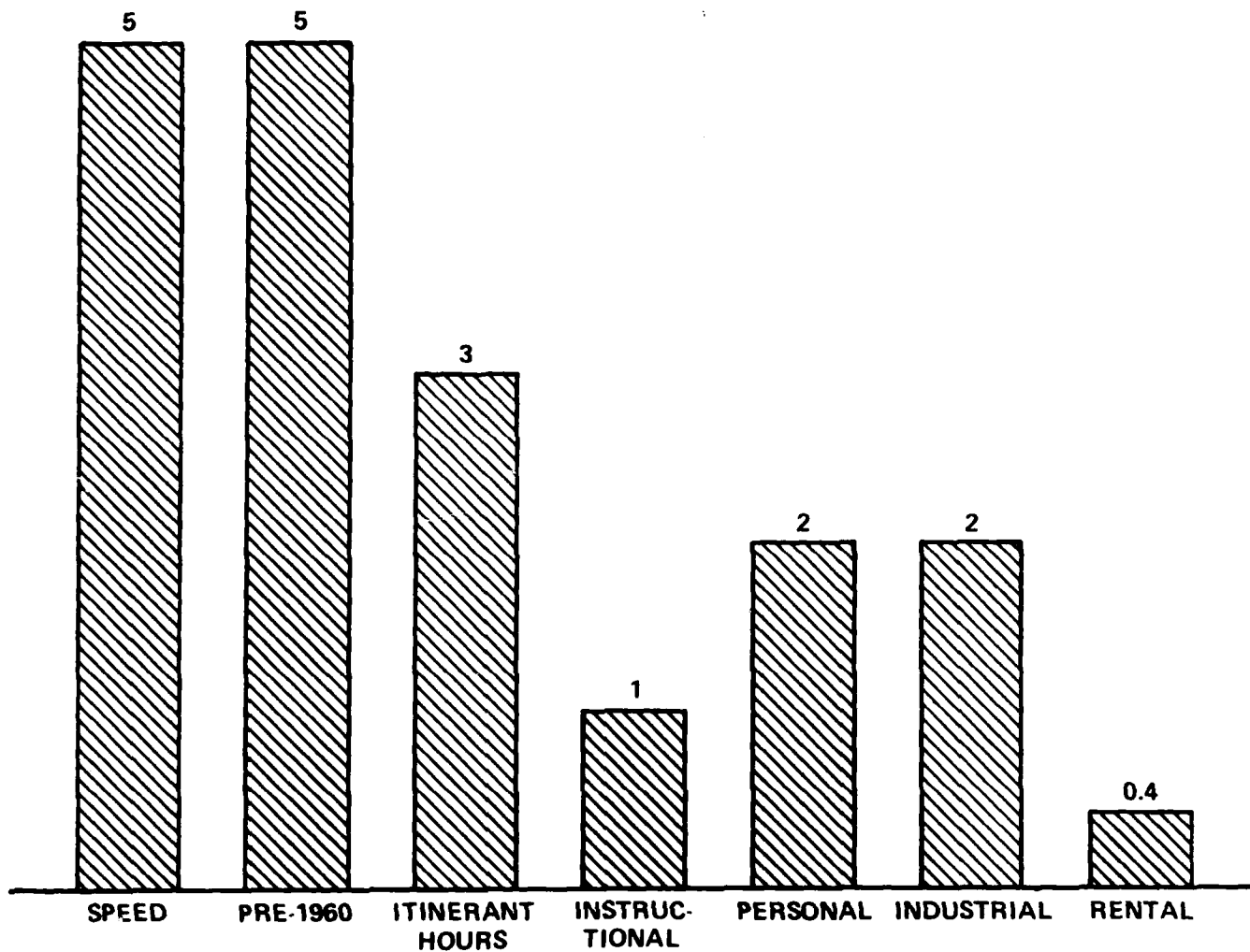


Figure 4 - 13

RELATIVE IMPORTANCE OF FACTORS IN
TRANSPONDER AVIONICS EQUIPAGE

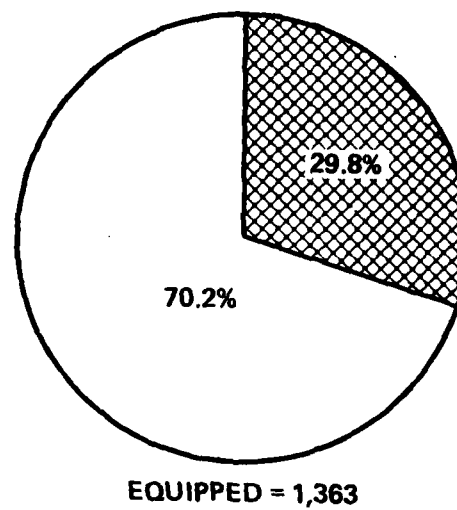
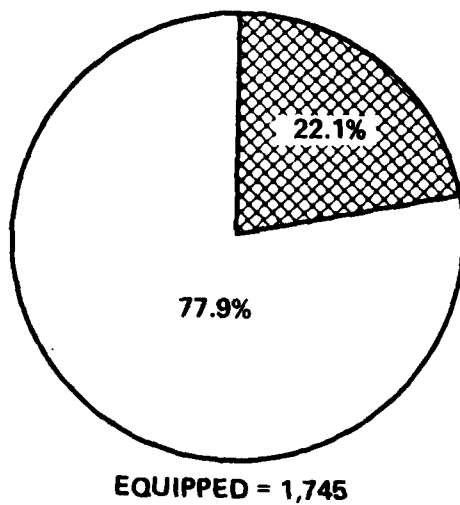
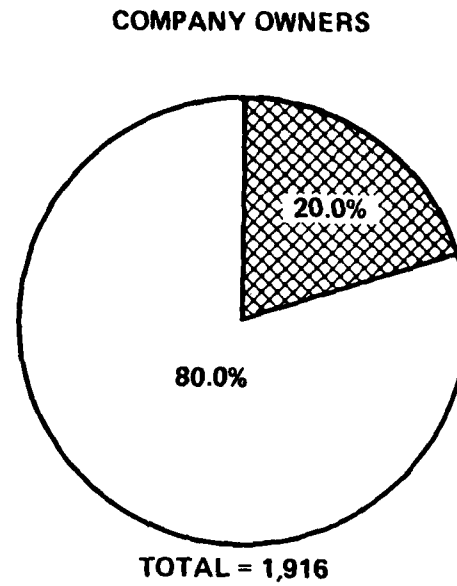
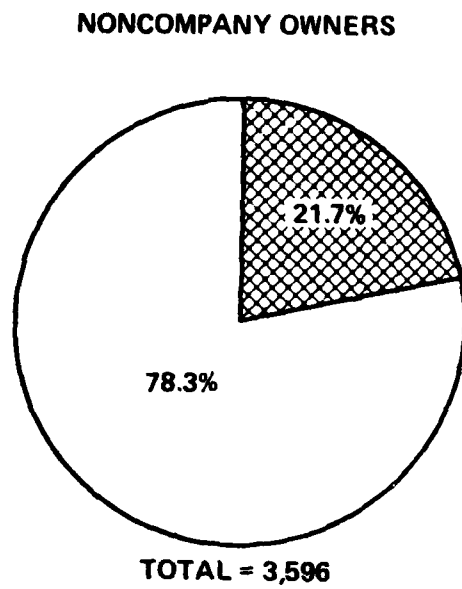


Figure 4 - 14

**TRANSPONDER: PERCENTAGE OF CORRECT
AND INCORRECT PREDICTIONS**

Figure 4-14 shows that the system illustrated in Figure 4-13 predicts 78.3 percent of the noncompany owner equipped and nonequipped group members correctly. For the equipped group taken separately, this system predicts 77.9 percent of the member correctly. When the system is applied to company owners, 80.0 percent correct predictions are obtained for the total and 70.2 percent correct predictions are recorded for the transponder equipped group. For comparison, the relevant pure chance criterion for both the total and the transponder equipped group is 71.1 percent. Thus, based on the results for the total, the system described in Figure 4-14 is judged to be an effective discriminator between the transponder equipped and nonequipped groups.

4.3.8 ALTITUDE ENCODING TRANSPONDER

This avionics is a transponder equipped with an altitude encoder. It automatically computes, displays, and broadcasts to the air traffic controller the altitude of the aircraft.

Figure 4-15 shows that aircraft cruising speed is the most powerful discriminator between the altitude encoding transponder equipped and nonequipped groups. Itinerant hours is the second most important factor. It may be noted that itinerant hours achieve this high level of importance only in the weather radar (Figure 4-9) and altitude encoding

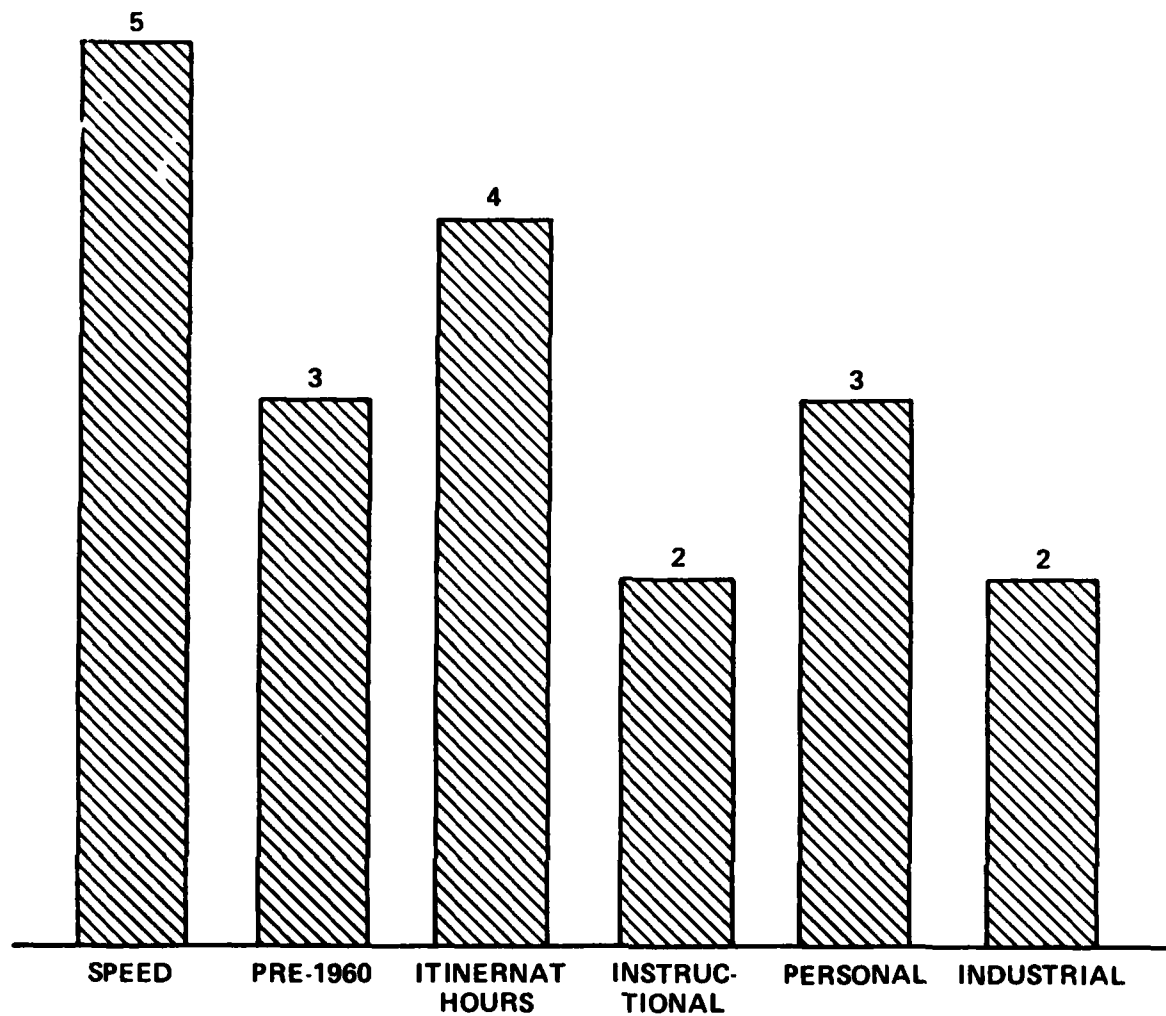
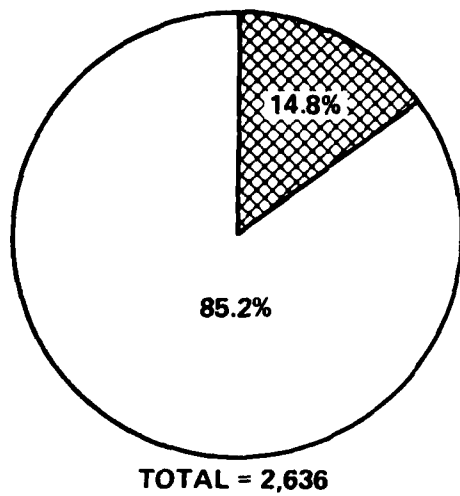


Figure 4 - 15

RELATIVE IMPORTANCE OF FACTORS IN
ALTITUDE ENCODING TRANSPONDER
AVIONICS EQUIPAGE

NONCOMPANY OWNERS



COMPANY OWNERS

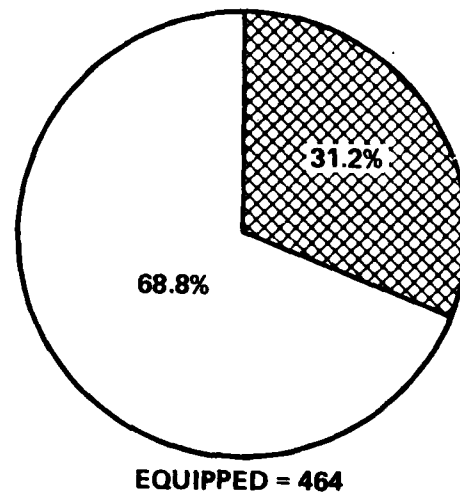
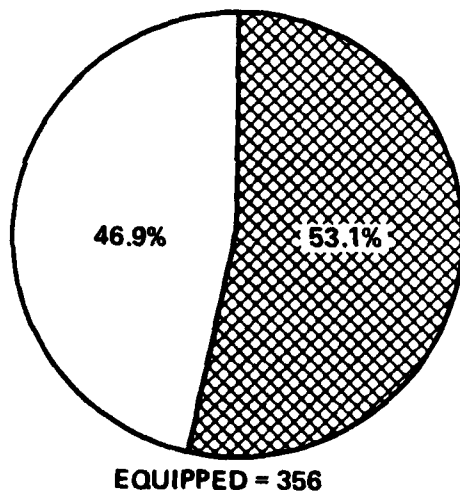
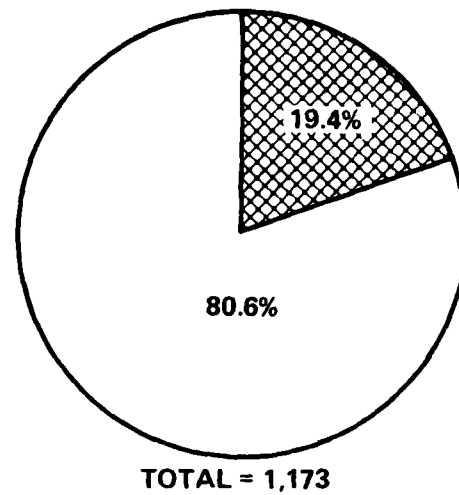


Figure 4 - 16

**ALTITUDE ENCODING TRANSPONDER:
PERCENTAGE OF CORRECT AND
INCORRECT PREDICTIONS**

transponder results. Since among avionics devices, the latter two are particularly useful at higher altitude flights (which are generally longer itinerant flights) these results are understandable. The older vintage and personal use factors share equally the position of the third most important discriminators.

When the system described in Figure 4-15 is applied to noncompany owners, Figure 4-16 shows that 85.2 percent correct predictions are obtained when both the equipped and nonequipped groups are considered. When the avionics equipped group only is considered, 46.9 percent of the predictions made using the system are correct. For the company owners, the system correctly predicts 80.6 percent of both the equipped and nonequipped groups in total, and it correctly predicts 68.8 percent of the altitude encoding transponder equipped group. The percentage of correct predictions for noncompany owners are considerably higher than those which could be expected by pure chance. That is, the pure chance criterion for both the total and the equipped group is 60.3 percent. Thus, the system illustrated in Figure 4-15 is judged to be an effective discriminator between the altitude encoding transponder equipped and nonequipped groups.

4.4 CONCLUSIONS

The results presented in this section have shown that, in general, aircraft cruising speed and age of aircraft

are the two most powerful factors discriminating between avionics equipped and nonequipped aircraft owners. Utilization rate becomes especially important for two types of avionics--weather radar and altitude encoding transponders. In general, the results suggest that the systems developed for each type of avionics are effective in discriminating between, or correctly predicting, members of the avionics equipped and nonequipped groups. The systems developed for radar and ANE to predict the correct avionics disposition (equipped or nonequipped) did not meet the maximum pure chance criterion in total. However, for each of these two type of avionics, the systems developed to predict the members of their respective equipped groups surpassed the relevant pure chance criterion. Thus, even for these two types of avionics the results are not as bleak as they might have at first appeared.

CHAPTER 4 REFERENCES

1. Cooley, W.W. and Lohnes, P.R. Multivariate Data Analysis (Chapter 9). New York: John Wiley and Sons, Inc., 1971.
2. Frank, R.E.; Massy, W.F.; and Morrison, D.C. "Bias in Multiple Discriminant Analysis," Journal of Marketing Research, II (Augues, 1965), 250-258.
3. Morrison, D.G. "Discriminant Analysis" in Handbook of Marketing Research (Part E, Chapter 8) ed. Robert Ferber. New York: McGraw-Hill Book Company, 1974.
4. Morrison, D.G. "On the Interpretation of Discriminant Analysis" Journal of Marketing Research, VI (May 1969), 156-163.
5. Federal Aviation Administration, Office of Management Systems, General Aviation Avionics Statistics: 1974. Springfield, Virginia: National Technical Information Service, 1977.