# The Philadelphia Airport Origin-Destination Survey—A Statistical Analysis

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Philadelphia International Airport is expecting a threefold increase in air travelers between 1967 and 1992. To properly plan for such growth, a comprehensive survey of airport activity was completed in November 1967. This analysis included an in-flight survey conducted during a 5-day period, in which over 2,200 commercial flights arrived at or departed from Philadelphia International Airport. These were comprised of 231 inbound flights and 229 outbound flights, each of which was surveyed once during the 5-day period. Trip data developed through the in-flight survey enabled tests to be performed to determine whether the number of trips made by air travelers from locations within the metropolitan area to the airport equal the number of trips made from the airport on an average weekday. Five statistical tests were conducted. Each was performed for the Philadelphia metropolitan area, the individual counties that comprise the metropolitan area, and the Philadelphia CBD. Results of these tests indicate that a one-directional survey, properly designed and conducted, accurately mirrors the reverse direction of travel. In this way, one-half the in-flight survey effort can be eliminated and survey costs reduced without lessening the survey accuracy. A comparison of the trip information developed by the in-flight survey with comparable data produced through a home-interview survey indicates that the latter technique cannot be used to fully reconstruct ground travel generated by airports because of the absence of data on nonresident air travelers. Any analysis of airport ground travel based on data drawn from home-interview surveys should be supplemented by an examination of nonresident air passenger traffic.

•A SURVEY of ground and air traffic at the Philadelphia International Airport was the initial step in a comprehensive effort to solve the ground-air interface problems confronting airport activities. Through it, new and interesting facts have emerged that may be of assistance in planning other airport studies. This paper presents two of these findings:

1. The statistical adequacy of conducting an in-flight survey in only one direction and reversing the results to obtain a complete travel picture of trips made between the airport and metropolitan area locations; and
2. The inadequacy of home-interview surveys to accurately reflect special generator traffic patterns.

Philadelphia International Airport served less than one million air passengers when it opened in 1953. In 1967, five million air travelers were processed, and growth to 27 million passengers is expected by 1985.

The present airport complex is located approximately 9 miles southwest of downtown Philadelphia, with ground access provided solely by the four-lane Industrial Highway. On an average weekday, 51,000 vehicles use the highway, with over 65 percent of these (33,400) entering and leaving the airport (Fig. 1).

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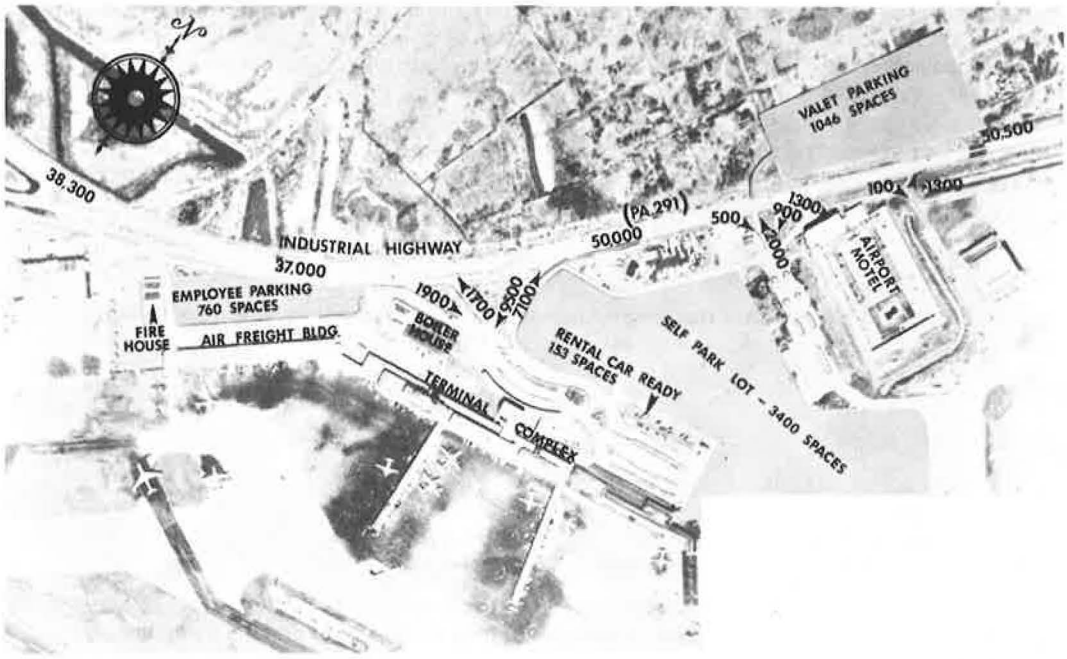


Figure 1. Access to Philadelphia International Airport and parking lot capacities.

Ground transportation to the airport consists of automobile taxi, limousine, and surface-bus modes. Private automobiles carry about two-thirds of all the passengers to and from the airport, while taxi traffic represents one-sixth of the total. Limousine service provides extensive coverage of the metropolitan area (12.6 percent of all traffic) with concentration on the Philadelphia CBD where 40 percent of all limousine traffic is generated. Direct public transportation is not available from center city, and transfer service is provided at no better than 30-minute headways.

## BACKGROUND OF IN-FLIGHT SURVEY

To meet the ground transportation planning objectives at the airport, a battery of surveys was conducted during November 1967. Field studies included in-flight, employee, parking, and ground transportation surveys. The in-flight survey was conducted during a 5-day period beginning 12:01 a. m. Monday, November 13, 1967, and concluding midnight Friday, November 17. During this period, over 2,200 commercial flights arrived at or departed from Philadelphia International Airport. These were comprised of 231 distinct inbound and 229 outbound flights, each of which was surveyed once during the survey.

## STATISTICAL ADEQUACY OF ONE-DIRECTIONAL SURVEY

The in-flight survey provided information as to whether the number of trips made by air travelers from locations within the metropolitan area to Philadelphia International Airport equaled the number of trips made from the airport on an average weekday. Tests of this hypothesis were performed in an attempt to eliminate the need to conduct in-flight surveys in both directions.

The data used in this analysis were recorded on the traffic district basis—192 districts (only 150 non-zero trip districts)—established by the Delaware Valley Regional Planning Commission. The traffic district was chosen as a base because this is the primary level at which socioeconomic, land use, and demographic data are available and, as a result, it is at this level that traffic models are developed. It is essential,

then, that tests for the "likeness" of inbound-outbound trip distributions be conducted on the district basis if the trip distributions are to be useful in model development.

Five following statistical tests were conducted: simple linear regression, analysis of variance (ANOVA), same variance, same mean, and Kolmogorov-Smirnov. Each of these was performed at the 99 percent confidence level with the number of trips from the traffic zones to the airport as the independent variable. It was assumed that both the inbound and outbound trip distributions were normal and independently distributed.

## TESTS AND RESULTS

### Simple Linear Regression

Simple linear regression develops an equation that describes the relationship between two variables. In this case the equation takes the form

$$y = a + bx$$

where

y = dependent variable (inbound trips),
a = constant,
b = coefficient, and
x = independent variable (outbound trips).

Through this technique a measure of the degree of linear association between two variables can be developed. The measure, known as the correlation coefficient r, varies between -1 and +1 with an index of 0 indicating no association and ±1 indicating perfect correlation.

For a comparison of the inbound and outbound distributions of airport trips, the equation developed is

$$y = 2.1 + 0.8\ (x)$$

The correlation coefficient for this relationship is 0.94 (Table 1), indicating that the distribution of outbound airport trips mirrors the inbound trip distribution with a high degree of accuracy.

### Analysis of Variance

In conjunction with simple linear regression, an analysis of variance (ANOVA) can be conducted to further test for linearity. The test statistic, F, is the ratio of the mean square due to linear regression to the mean square of the deviation from regression. This statistic must be larger than the tabulated F-value (1) for the conditions specified (1 and 148 degrees of freedom and 99 percent confidence level) if linearity truly exists. In this case, the calculated F is 1,027, which is much larger than the tabulated value of 6.82 (Table 1). Therefore, true linearity can be considered a fact.

TABLE 1

STATISTICAL TESTS ON OUTBOUND-INBOUND AIRPORT TRIP DISTRIBUTIONS

| Test Name | Hypothesis (Ho) | Test | Calculated Statistic | Tabulated Statistic | Conclusion |
|---|---|---|---|---|---|
| Linear regression | x distribution = y distribution | R = 0.7 | 0.94 | | Cannot reject Ho |
| ANOVA | x distribution = y distribution | F | 1,027 | 6.82 | Cannot reject Ho |
| Same variance | | F | 1.37 | 1.47 | Cannot reject Ho |
| Same mean | | t | 0.74 | 2.35 | Cannot reject Ho |
| Kolmogorov-Smirnov | x distribution = y distribution | D | 0.067 | 0.189 | Cannot reject Ho |

## Same Variance

Another test that can be performed to determine whether two distributions are similar is the sameness of variance. In this case, the F-statistic is also employed and calculated as the ratio of the larger to smaller sample variances. If the resulting value of F is less than that tabulated for specified conditions (149 and 149 degrees of freedom and 99 percent confidence level), then the hypothesis that the variances are equal cannot be rejected.

Applying this test to the variances of the inbound and outbound distributions of airport trips results in a calculated statistic of 1.37, less than the 1.47 tabulated F-value (Table 1). Therefore, the assumption of same variance cannot be denied.

## Same Mean

Another essential test for an agreement between two distributions is a comparison of sample means to test the null hypothesis, Ho: $u_1 = u_2$. The t-test is employed, and the calculated statistic must be less than that tabulated for specified conditions (298 degrees of freedom and 99 percent confidence level) to confirm the hypothesis. In this case the t-statistic tabulated is 2.35, which is much larger than the calculated value of 0.74, giving further proof of the agreement between the two distributions.

## Kolmogorov-Smirnov

The Kolmogorov-Smirnov test examines the goodness-of-fit of two distributions. Basically, it compares the relative cumulative distributions of the two samples and, based on the absolute maximum deviation between the two, a decision on goodness-of-fit can be reached. A good fit of the two distributions can be considered a fact if the calculated statistic is less than that tabulated for specified conditions.

The relative cumulative trip distributions have a maximum deviation of 0.067. Because this statistic is less than the tabulated value of 0.189 (Table1), the ability of each distribution to accurately reflect the other is verified once again.

## Further Tests

Each of the tests conducted proved that the outbound distribution of airport trips for those districts within the Philadelphia metropolitan area mirrors the inbound distribution with significant statistical accuracy. However, these tests are unable to detect the possible existence of geographical bias for subdivisions of the metropolitan area. To ascertain whether geographical bias does exist, tests on the inbound-outbound trip distributions for those traffic districts in each of the nine counties within the area and the Philadelphia CBD were conducted. The five tests performed on the metropolitan area data were performed on the data for each of these smaller geographical units.

The results of these tests indicate that for all but Gloucester County a good fit between the two trip distributions is evident (Table 2). For Gloucester County, both the linear regression and ANOVA tests were failed, even though the means and variances compared favorably. An inadequate number of trips to and from Gloucester County resulting in too few data points is the principal cause of this failure; but, because Gloucester County generates only 1 percent of the metropolitan area air traffic, its effect is minimal.

It should also be noted that the ANOVA test for Chester County was failed; however, this also can be attributed to an inadequate generation of air trips (only three data points). The correlation coefficient for Chester County is 0.98. Burlington County also failed the ANOVA test at the 99 percent confidence level. However, at the 95 percent level of significance, it proved to be linear.

On the whole, these results indicate that there is little geographical bias when inbound and outbound trip distributions are examined.

TABLE 2

STATISTICAL TESTS ON OUTBOUND-INBOUND AIRPORT TRIP DISTRIBUTIONS

| Area | Hypothesis | Number of Tests Conducted | Number of Tests Failed | Conclusion |
|---|---|---|---|---|
| Philadelphia County | x distribution = y distribution | 5 | 0 | Cannot reject Ho |
| Delaware County | x distribution = y distribution | 5 | 0 | Cannot reject Ho |
| Montgomery County | x distribution = y distribution | 5 | 0 | Cannot reject Ho |
| Bucks County | x distribution = y distribution | 5 | 0 | Cannot reject Ho |
| Chester County | x distribution = y distribution | 5 | 1 | Inconclusive |
| Camden County | x distribution = y distribution | 5 | 0 | Cannot reject Ho |
| Mercer County | x distribution = y distribution | 5 | 0 | Cannot reject Ho |
| Burlington County | x distribution = y distribution | 5 | 0 | Cannot reject Ho |
| Gloucester County | x distribution = y distribution | 5 | 2 | Reject Ho |
| Philadelphia CBD | x distribution = y distribution | 5 | 0 | Cannot reject Ho |

## Conclusion

Through these tests, it can be concluded that a one-directional survey properly designed and conducted can be "flipped over" to accurately mirror the reverse direction of travel. In this way, one-half of the in-flight surveying effort can be eliminated and surveying costs accordingly reduced without lessening the accuracy of the survey results.

It should be noted that this conclusion applies only to a survey designed to sample each flight once during 5 consecutive weekdays. It is questioned whether survey results obtained from a single day, thought to be average, are reversible. Further research in this area is suggested.

# HOME-INTERVIEW SURVEY INADEQUACIES

A widely used procedure for gathering information on trip-making and travel characteristics in an urban area has been the home-interview survey. Although these surveys result in trip reporting that may be as much as 25 percent below actual trip-making, factoring to equal screenline volumes will usually produce an accurate travel picture. Subdividing this information into smaller parts, however, may cause some problems. A subdivision to reflect travel characteristics of an airport may not reveal a true picture of its travel activity.

To this point, little information has been available to prove or disprove this contention. However, the data collected in the ground transportation survey provide an opportunity to test this hypothesis by comparing the travel patterns developed with those obtained by the Penn-Jersey Transportation Study (now the Delaware Valley Regional Planning Commission). The latter are reported by Keefer (2).

## Study Characteristics

The most significant characteristics of the studies to be compared are as follows:

1. The Keefer report was based on origin-destination (O-D) data collected in home interviews. As a result, the analyses were limited almost exclusively to trip-making by residents of the study areas considered, because short-term visitors from other areas—particularly air travelers lodging at hotels and motels or those who do not stay overnight—are usually missed by the standard origin-destination surveys. (Data for Philadelphia are for 1960.)

2. The Simpson and Curtin study interviewed air travelers and airport employees only. Resident and nonresident travel for social-recreational purposes was not surveyed. (Data used in this study represent 1967 conditions.)

Due to these shortcomings, neither study constructs the total airport traffic picture exactly. However, the Simpson and Curtin study shows that, of the 3,200 work trips made to and from the airport on an average weekday in 1967, less than 4 percent (122 trips) were made by nonresidents of the Philadelphia metropolitan area. It would seem, then, that nonresident travel is not a significant portion of airport work traffic and that the Penn-Jersey O-D data present an accurate image of trips for this purpose.

However, the Simpson and Curtin report also shows that, of the 15,093 average weekday air travelers, only about one-third (5,085 person trips) live in the Philadelphia study area. The logical conclusion reached, then, is that the data presented by Keefer "somewhat underestimate" air travel trips by reporting only resident travel. This also causes overestimation of the proportions of airport work and social-recreational traffic in the total airport traffic acitivity.

In particular, the home-interview social-recreational travel statistic of 32.8 percent of total traffic to the airport seems to be a gross exaggeration. Considering that this classification includes only those trips to shop, to eat meals, and to sightsee, (and not those who accompany air travelers as greeters or "Godspeeders") and in light of the fact that only 5.0 percent of the airport terminal floor area and 0.02 percent of the airport complex space is devoted to attractions that could support social-recreational activities, 32.8 percent seems to be an extroadinarily high proportion.

## Mode Distribution Comparison

A comparison of the mode split for air travel trips reveals a marked difference between the two study results (Table 3). The Simpson and Curtin study indicates that almost 21 percent of all air travelers made their trips by transit, compared to 2.5 percent developed through the home-interview data. About 60 percent of the trip-makers used the automobile, in contrast to the 86.6 percent statistic developed through the home-interview survey.

These differences can be attributed to the underestimation of air travel trips made by nonresidents of the Philadelphia metropolitan area by the home-interview technique. As a result, many of the limousine transit trips made by nonresidents—particularly between the CBD and the airport—are uncounted. On the other hand, automobile trips, the predominant access mode of residents, are counted quite closely. The combined effect, then, is to overestimate automobile access at the sacrifice of transit's share of the ground traffic to and from the airport.

The discrepancy between the taxi mode statistics given in Table 3 can also be explained in this same way.

## CBD Traffic

From the home-interview data, the conclusion has been reached that, perhaps, the need for special travel facilities connecting CBD and airport has been overstressed. The home-interview data show that only 8.3 percent of all airport trips by residents originating in the Philadelphia metropolitan area begin in the CBD. The Simpson and Curtin study of air traveler and airport work trips shows that 4.5 percent of the resident trips to the airport originate in the CBD. However, of the total average weekday airport trips (7,132) from points within the metropolitan area by workers and air travelers (residents and nonresidents), 17.1 percent originate in downtown Philadelphia—more than any other single concentrated area. This 100 percent increase over the home-interview data results is primarily attributable, once again, to the failure to account for nonresident

TABLE 3

TRAVEL MODE DISTRIBUTION TO PHILADELPHIA INTERNATIONAL AIRPORT

| Study | Air-Travel Trips (percent) | | | |
|---|---|---|---|---|
| | Automobile | Transit | Taxi | Other |
| Keefer (NCHRP) | 86.6 | 2.5 | 10.9 | — |
| Simpson and Curtin | 60.3 | 20.9 | 16.7 | 2.1 |

travelers, who represent over 85 percent of CBD airport trip origins and destinations. As such, the CBD is the principal originator of airport traffic in the entire metropolitan area, and the importance of providing quick and efficient ground transportation between it and the airport should not be de-emphasized.

## Conclusion

It is evident from this comparison that home-interview data cannot be used to fully reconstruct ground travel generated by airports. Although the traffic due to airport employees may be accurately represented, the absence of data on nonresident air travelers distorts the overall result.

The precision of this analysis can be questioned because of differences in the scope and purpose of the two surveys compared. However, the effect is undeniable, and any analysis of airport ground travel based on data drawn from home-interview surveys should be supplemented by an examination of nonresident air passenger traffic.

## REFERENCES

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2. Keefer, Louis E. Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants. NCHRP Rept. 24, 1966, 116 pp.