Estimating Aircraft Activity at Nontowered Airports: Results of the Aircraft Activity Counter Demonstration Project

MARK L. FORD and ROSALYN SHIRACK

ABSTRACT

The findings and conclusions of the Aircraft Activity Counter Demonstration Project are reported. Data obtained at 24 of the airports studied are used to evaluate alternative methods of estimating aircraft activity from sample data. The counter project used acoustical aircraft activity counters to obtain periodic samples of activity at selected nontowered airports throughout a full year. The paper analyzes the use of independent measures of variation for expanding sample counts and develops a sampling plan for use at nontowered airports when reliable independent measures are not available. Analysis of independent measures of variation includes operations data from related towered airports, weather data, and record of fuel sales. The paper concludes that tower data are not a reliable source for estimating nontowered airport activity because the variations in operations over the year at towered and nontowered airports are not sufficiently similar. Fuel sales data will probably prove to be a more useful indicator of variation, but more research is needed. The paper recommends the use of seasonally stratified, systematic samples of aircraft activity for estimating operations at nontowered airports. This type of sample data may be used to estimate the seasonal distribution of operations and peak loadings and to estimate total annual operations.

Insufficient knowledge of activity at nontowered airports has been a concern of state and federal aviation agencies as well as local airport sponsors. Until recently there was no accurate alternative to visual observations for determining aircraft activity. This means that where there is no tower, estimates of operations are often no better than guesses. This is especially true of small general aviation facilities which often are without full time managers or fixed-base operators.

The Aircraft Activity Counter Demonstration Project was conducted from November 1980 through April 1982. During the project operations data were gathered at 37 nontowered airports in Oregon, Washington, and Idaho by using acoustical aircraft activity counters. These counters record the sound of departing aircraft on cassette tapes which are then audited and the activity is classified by time and date. The sounds of departing aircraft can often be classified into several aircraft types; however, results of the project indicate that the most reliable data are based on total fixed-wing departures. Usually a single counter was used to make periodic counts at several airports throughout a 1-year period.

The estimates of annual operations presented in Table 1 are based on sample data for 24 of the airports in the study. Data on the 13 other airports were not complete enough for use in evaluating alternative sampling and estimating methods. Although there was no attempt to obtain a proportional representation of general aviation airports in the study, a review of the operations estimates in Table 1 indicates a cross section of medium to small general aviation airports. The airports are widely distributed geographically throughout Washington and Oregon and represent a variety of general aviation uses.

Because data were obtained throughout a full year at each of the airports in the study, the data provide information on the seasonal variation of operations. These data were used to test the accuracy of independent data sources as measures of variation of operations at nontowered airports. Independent data sources analyzed include tower operations data, weather data, and fuel sales data. The project data also provide valuable information for designing sampling procedures when accurate independent estimates of seasonal variation are not available. Analysis of sampling procedures and project data demonstrates the use of sampling for estimating seasonal, daily, and hourly variations as well as total annual operations.

<table>
<thead>
<tr>
<th>Airport</th>
<th>Estimated Annual Fixed-Wing Operations</th>
<th>Approximate Sampling Error at 95 Percent Confidence Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oregon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albany</td>
<td>30,272</td>
<td>23</td>
</tr>
<tr>
<td>Arlington</td>
<td>618</td>
<td>35</td>
</tr>
<tr>
<td>Ashland</td>
<td>16,460</td>
<td>12</td>
</tr>
<tr>
<td>Beaver Marsh State</td>
<td>630</td>
<td>36</td>
</tr>
<tr>
<td>Christmas Valley</td>
<td>3,242</td>
<td>19</td>
</tr>
<tr>
<td>Creswell</td>
<td>26,196</td>
<td>16</td>
</tr>
<tr>
<td>Hermiston</td>
<td>15,956</td>
<td>9</td>
</tr>
<tr>
<td>Hood River</td>
<td>11,724</td>
<td>15</td>
</tr>
<tr>
<td>Josephine County</td>
<td>22,498</td>
<td>15</td>
</tr>
<tr>
<td>LaGrande</td>
<td>3,940</td>
<td>21</td>
</tr>
<tr>
<td>Lebanon State</td>
<td>11,662</td>
<td>19</td>
</tr>
<tr>
<td>Wolford-Jackson County</td>
<td>89,244</td>
<td>16</td>
</tr>
<tr>
<td>Newport</td>
<td>12,472</td>
<td>18</td>
</tr>
<tr>
<td>Paterhood State</td>
<td>390</td>
<td>36</td>
</tr>
<tr>
<td>Seaside State</td>
<td>1,650</td>
<td>23</td>
</tr>
<tr>
<td>Siletz Bay State</td>
<td>4,146</td>
<td>27</td>
</tr>
<tr>
<td>Snowier</td>
<td>10,135</td>
<td>16</td>
</tr>
<tr>
<td>Tillamook</td>
<td>2,737</td>
<td>25</td>
</tr>
<tr>
<td>Wasco State</td>
<td>3,954</td>
<td>26</td>
</tr>
<tr>
<td>Washington</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bellingham</td>
<td>13,810</td>
<td>26</td>
</tr>
<tr>
<td>Kelso</td>
<td>28,404</td>
<td>22</td>
</tr>
<tr>
<td>Chelan</td>
<td>11,556</td>
<td>13</td>
</tr>
<tr>
<td>Richland</td>
<td>25,118</td>
<td>12</td>
</tr>
<tr>
<td>Wenatchee</td>
<td>31,938</td>
<td>13</td>
</tr>
</tbody>
</table>
USE OF INDEPENDENT DATA TO ESTIMATE OPERATIONS AT NONTOWERED AIRPORTS

Because of the high cost of obtaining complete visual counts of operations, independent data are often used in conjunction with a limited sample of observed operations to estimate annual operations at nontowered airports. The underlying assumption in the use of independent data is that they measure the variation in operations throughout the year. The measured variations then are used to extrapolate the limited sample into an estimate of annual operations. Estimates of operations based on independent data have always been suspect, because until recently there has been no means of testing the degree of error in such estimates.

Tower Operations Data

Airport operations data at towered airports are used currently to estimate operations at nontowered airports. An FAA publication (2) identifies five methods for estimating operations. Tower data are used to adjust nontower operations data obtained from a small (7-to-21-day) sample. Several different estimating equations are presented, but all are based on the ratio relationship of Equation 1.

\[ \frac{y}{Y} = \frac{x}{X} \]  

where

- \( y \) = average daily nontower operations during the sample period,
- \( Y \) = average daily nontower operations during the year,
- \( x \) = average daily tower operations during the sample period, and
- \( X \) = average daily tower operations during the year.

Equation 1 assumes that paired towered and nontowered airports will have a similar distribution of operations over the year. The equation also assumes that towered and nontowered airports can be logically paired according to similarities in mix of operations, weather, and daily traffic variation.

Method of Comparing Towered and Nontowered Airports

To test these two assumptions, estimates of each quarter of annual operations at 23 nontowered airports were compared with quarterly operations data for the closest or otherwise best-paired towered airport. The Medford Airport was used as a control because both tower operations data and data gathered by acoustical counters were available. Tower operations data were obtained from unpublished FAA tower operations data for 1981. A total of seven towered airports in Washington and Oregon were used in the study. Only itinerant and local general aviation data for towered airports were used so that the data would be comparable to the type of data available from nontowered airports. The quarterly distributions of operations at towered and nontowered airports were considered to be similar if they did not differ by more than 25 percent in any one quarter. A 25 percent difference was allowed because (a) it provides for a liberal but reasonable tolerance of variation and (b) the quarterly distribution of sampled operations data at Medford Airport differed by as much as 25 percent during a single quarter from the quarterly distribution of tower data for the Medford Airport. The difference in the quarterly distribution of operations between the Medford sample data and tower data may be due to (a) the difference between a sample and a complete count and (b) the fact that the sample estimate reflects all operations, whereas only general aviation statistics were used from the tower data.

Result of Comparison of Operations

The comparison of the quarterly distributions of operations at nontowered and nearby towered airports yielded few similar pairs (see Table 2). Of the 23 paired towered and nontowered airports studied, only six had similar distributions of operations. The other 17 towered and nontower pairs were not similar because of the wide fluctuation in the quarterly distributions of operations at nontowered airports.

Among nontowered airports, the proportion of annual operations that occurred in a single quarter ranged from a low of 7 percent to a high of 61 percent. Furthermore, among nontowered airports there was no consistent pattern in the distribution of operations across quarters. With few exceptions, each nontowered airport exhibited a unique distribution of quarterly operations.

By comparison, the distribution of operations among towered airports followed a much more consistent pattern across quarters. The proportion of annual operations that occurred in a single quarter ranged from a low of 14 percent to a high of 36 percent, less than half the range of nontowered airports. Generally the first and fourth quarters each accounted for about 20 percent of annual operations, and the second and third quarters each had about 30 percent of annual operations.

This relationship is more visible in pre-1981 tower data. The 1981 data were affected by the air traffic controller walkout and the recession, which lowered fourth quarter activity at towered airports.

This comparison indicates that the distributions of operations at towered airports are not sufficiently similar to paired nontowered airports for estimating purposes. Therefore, tower operations data should not be expected to provide reliable estimates of operations at nontowered airports.

This conclusion would hold even if nontowered airports were paired with different towered airports. Given the similarity in the quarterly distribution of operations among all towered airports, and the varied distribution of operations among nontowered airports, it is not probable that a better pairing of towered and nontowered airports could improve the estimating capability of tower operations data.

An example using the Josephine County nontowered airport illustrates how an overestimation of operations at Josephine County Airport could result from using Medford tower operations data. Josephine County Airport is about 25 miles from the Medford Airport. The two airports share the same weather and, therefore, the same flying conditions. Based on acoustical counter data Josephine County Airport was estimated to have 22,498 operations a year, which is 19 percent of the general aviation activity at the Medford Airport. Data reports for Medford tower show 122,961 general aviation operations in 1981. This number differs from the Medford operations estimate given in Table 1 because that estimate is based on a sample and does not include helicopters or missed approaches.

The two airports appear to be a good nontowered
and towered pair for the purposes of estimating non-
towered operations. However, the quarterly distribu-
tion of operations at the two airports is not simi-
lar. If general aviation operations data from the
Medford Airport were used to expand sample data from
26 estimate (MCE) equation given by
operation at the two airports is not simi-
lar. If general aviation operations data from the
estimation based on a more complete sampling of
operations at the Josephine County Airport, annual operations would be estimated at 38,190. This
estimate was obtained by using the minimum change
estimator (MCE) equation given by FAA (2).

The estimate of 38,390 annual operations is 71
percent higher than the 22,498 estimate of annual
operations based on a more complete sampling of
actual activity at Josephine County. This large
discrepancy is due to the compounding of two errors
in the estimating technique. First, the technique
assumes that the proportion of annual operations
that occur in the first quarter at Josephine County
and Medford Airports are the same. This was not the
case. Medford had 17 percent of annual operations
occurring in the first quarter, whereas Josephine
County had 35 percent of annual operations in the
first quarter (Table 2). This difference in the
distribution of operations accounted for 65 percent
of the error in the estimate. Second, the technique
relies partially on the use of previous activity
data, or in which quarter to sample opera-
tions, without more knowledge of seasonal operations
at nontowered airports.

The difference in seasonal distributions of oper-
ations at towered and nontowered airports appears to
result from a combination of factors, including the
effect of weather and the types of uses that tend to
concentrate at nontowered airports. General aviation
activity appears to be more sensitive to weather
conditions at nontowered airports. An obvious reason
for this difference is the nature of the airport
facilities. Towered airports provide for instrument
approaches, whereas the majority of nontowered air-
ports do not have this capability. Another reason
for the varying impact of weather may be because
business and commuter aircraft constitute a higher

### Table 2: Quarterly Distribution of Operations at Selected Towered and Nontowered Airports, 1981

<table>
<thead>
<tr>
<th>Towered Airport</th>
<th>Nontowered Airport</th>
<th>Percent of Annual Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quarter 1</td>
<td>Quarter 2</td>
</tr>
<tr>
<td>McNary (Salem, Oreg.)</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>Albany</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>Creswell</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>Lebanon State</td>
<td>18</td>
<td>21</td>
</tr>
<tr>
<td>Siletz Bay State</td>
<td>35</td>
<td>32</td>
</tr>
<tr>
<td>Portland-Hillsboro (Oreg.)</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>Tillamook</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td>Seaside State</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Bluebon</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Kebo</td>
<td>33</td>
<td>27</td>
</tr>
<tr>
<td>Portland-Trouthdale (Oreg.)</td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td>Hood River</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>Kingsley (Klamath Falls, Oreg.)</td>
<td>22</td>
<td>30</td>
</tr>
<tr>
<td>Sunriver</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>Christmas Valley</td>
<td>23</td>
<td>71</td>
</tr>
<tr>
<td>Beaver Marsh State</td>
<td>9</td>
<td>48</td>
</tr>
<tr>
<td>Medford-Jackson County (Oreg.)</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>Medford-Jackson County</td>
<td>17</td>
<td>33</td>
</tr>
<tr>
<td>Josephine County</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Ashland</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>Pincusair State</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Walla Walla (Wash.)</td>
<td>25</td>
<td>36</td>
</tr>
<tr>
<td>LaGrande</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>Tri-Cities (Pasco, Wash.)</td>
<td>20</td>
<td>31</td>
</tr>
<tr>
<td>Richland</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Omak</td>
<td>29</td>
<td>24</td>
</tr>
<tr>
<td>Wenatchee</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>Wasco State</td>
<td>61</td>
<td>14</td>
</tr>
<tr>
<td>Arlington</td>
<td>36</td>
<td>50</td>
</tr>
<tr>
<td>Hermiston</td>
<td>30</td>
<td>28</td>
</tr>
</tbody>
</table>

*Quarterly percentages may not sum to 100 because of independent rounding.

walkout in August 1981. Worse case examples are
apparent in Table 2, such as the 205 percent differ-
ence in the proportion of first quarter operations
at Tri-Cities and Wasco State Airports. Another
example is the 136 percent difference between third
quarter operations at Walla Walla and LaGrande Air-
ports.

On the other hand, some paired towered and non-
towered airports had similar distributions of opera-
tions in each of the four quarters. The Wenatchee
tower data would have a 10 percent or less error (plus the sampling error). The problem is that
one does not know beforehand which nontowered air-
ports can be successfully estimated from tower op-
erations data, or in which quarter to sample opera-
tions, without more knowledge of seasonal operations
at nontowered airports.

The difference in seasonal distributions of oper-
ations at towered and nontowered airports appears to
result from a combination of factors, including the
effect of weather and the types of uses that tend to
concentrate at nontowered airports. General aviation
activity appears to be more sensitive to weather
conditions at nontowered airports. An obvious reason
for this difference is the nature of the airport
facilities. Towered airports provide for instrument
approaches, whereas the majority of nontowered air-
ports do not have this capability. Another reason
for the varying impact of weather may be because
business and commuter aircraft constitute a higher
propriety of the operations at towered airports. Business aircraft tend to be better equipped for
instrument flying and more likely to fly regardless of the weather. By contrast, training and recrea-
tional flying probably accounts for a larger proportion of operations at nontowered airports. This type
of fair weather activity tends to be more sensitive to weather conditions.

The dissimilarity in the seasonal distribution of operations also may be due to different types of
activities. At nontowered airports it is probable that a large portion of operations results from
specialized activities. For example, the LaGrande Airport is used extensively by the U.S. Forest Ser-
vice when fighting forest fires during the summer months. This activity results in an unusually high
percentage (52) of annual operations occurring in the third quarter. At the Wasco State Airport 61
percent of annual operations occurred in the first quarter because of local crop spraying schedules.
These types of local activities are not reflected in tower operations data.

Weather Data

During the Aircraft Activity Counter Demonstration Project weather data were gathered for most of the
days on which aircraft departures were sampled. Daily weather logs indicate that there is a correla-
tion between weather condition and departures. As a result, daily departures were generally higher in
the second and third quarters (April through September), when flying conditions tended to be better,
than in the fourth and first quarters (October through March). Furthermore, departures varied with
weather conditions within each quarter.

If daily weather data for a sampled airport were available, they would be expected to help provide an
estimate of variation in operations so that the size of the sample of operations could be reduced. Un-
fortunately, using weather data as an independent indicator of variation has several drawbacks. Weather
data must be available for every day of the year, not just when flying activity is being sampled. Data
collected by the National Weather Service do not include visibility and cloud ceiling, which are the
most important weather factors affecting operations. Also, site-specific weather data are not available
for many nontowered airports. Finally, use characteristics of individual airports result in different
sensitivities to weather conditions; therefore, even if adequate weather data were available, it could
not be expected to account for all variations that affect operations. Other components of variation,
such as type of day (weekday, or weekend or holiday) and other nonweather seasonal variations would still
have to be captured directly by sampling operations.

Fuel Sales Data

In Oregon retail sales of aviation gasoline and jet
fuel are reported monthly by most retail dealers. A comparison of fuel sales data and number of depart-
ures was made for seven nontowered Oregon airports.

Analysis was limited to the months that had both
adequate samples of departures and complete fuel
sales data. The correlation coefficient of gallons
of aviation gasoline sold and number of departures
was between 0.92 and 0.97 at five of the seven air-
ports. The other two airports had coefficients of
about 0.68. Jet fuel was also sold at three of the
airports studied but inclusion of jet fuel sales in
the analysis did not improve the correlations. One
of the airports with the lower correlation coeffi-
cient also had a very high ratio of departures per
gallon, indicating that most users of this facility
probably bought their fuel elsewhere.

To test the use of fuel sales data for estimating
operations, a ratio of departures to gallons of
aviation gasoline sales was calculated for each airport for each month in which complete data were
available. In spite of the close relationship of fuel sales and aircraft activity, these data indi-
cate that wide errors could result if fuel data were used to expand a single weekly count to an annual
total. On the other hand, when the average depart-
ures for all months were used to estimate opera-
tions from fuel sales, the results were similar to
those obtained by the direct survey, even for those
airports with the lower correlation coefficients.

Extreme ratios of departures to fuel sales probably
resulted from a combination of two factors.

First, the data on departures actually consisted of
week-long samples expanded to a full month. Although
this sampling period provides a very good confidence interval over a several month period, it allows for
wide deviation in a single month. Second, changes in
types of aircraft and types of activity throughout
the year may have affected the ratio of departures
to fuel sales.

In response to this second concern, a check was
also made to determine if variations in the ratio of
departures to fuel sales followed a seasonal pat-
tern. Although a seasonal pattern was not identified, it is
interesting to note that the greatest variation in
the measure of departures to fuel sales occurred in
the first quarter at most airports.

The comparison of departures-to-fuel-sales ratios
among airports also provides useful information on
the relationship between fuel sales and operations.
Although there was a high correlation between fuel
sales and departures at most of the individual air-
ports studied, there were significant differences in
the ratios of departures to gallons of fuel sales
among airports. Mean ratios of departures per gallon
were tested for significant difference at a 95 per-
cent confidence level using a one-tailed t-test with
pooled variance. Of 21 possible pairings, 19 were
significantly different.

Two studies are needed to confirm these general
findings and determine the potential accuracy of
methods relying on fuel sales as an independent
indicator of variation. One is to conduct operations
counts during periods that correspond exactly to the
fuel reporting periods. Both the operations counts
and fuel data should be collected periodically over a
full year. Second, a follow-up study is needed to
determine fueling practices at each airport sur-
veyed. For instance, how much in fuel sales is not
reported because of private tanks or unlicensed
dealers and how much is consistently ferried into or
counts for each airport. The other two airports had coefficients of
about 0.68. Jet fuel was also sold at three of the
airports studied but inclusion of jet fuel sales in
the analysis did not improve the correlations. One
of the airports with the lower correlation coeffi-

SAFETY DESIGN FOR NON-TOWERED AIRPORTS

Use of Systematic Cluster Samples

When there is no accurate independent indicator of
seasonal variation at a particular nontowered air-
port, or in cases where the indicators themselves
must be tested for reliability, it will be necessary
to conduct sample counts during periods that
must correspond exactly to the fuel reporting periods. Both the operations
and fuel data should be collected periodically over a
full year. A cost-effective method of sampling activity using
an acoustical counter is to sample clusters of 7
days systematically throughout the year. All depart-
ures occurring during each of the sampled 7-day
periods would be counted. Analysis of data obtained in the Aircraft Activity
Counter Demonstration Project indicates that
significant differences in airport activity are associated with day of the week and season of the year. In order to sample where the variation occurs, days should be stratified into weekdays, and weekends and holidays. Seasons should be stratified based on annual weather patterns. For most areas of the country two, three, or four seasons could be used. If four seasons are used, the sample would be stratified into eight separate cells.

If 7-day clusters are used, a stratified sample is automatically proportional with respect to the day of the week. A systematic sample of 7-day clusters, which provides for an equal number of evenly spaced clusters per season, will provide proportionality of seasons. If seasonal as well as annual estimates of operations are desired, it is necessary to sample at least two 7-day clusters in each season.

To ensure randomness in the sample, the first of the sample weeks is chosen randomly. Subsequent sample weeks occur at equal intervals throughout the year. The sample size may be chosen to reflect the desired trade-off between cost and accuracy. Preliminary estimates of sampling error for alternative sample sizes and expected numbers of annual operations are shown in Table 3.[1]

**TABLE 3** Approximate Percentage of Sampling Error in Estimates of Annual Operations by Size of Airport and Size of Sample

<table>
<thead>
<tr>
<th>Approximate Annual Operations at Airport</th>
<th>No. of Weeks Sampled per Year</th>
<th>Approximate Sampling Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Being Sampled</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>900-2,399</td>
<td>54</td>
<td>44</td>
</tr>
<tr>
<td>2,400-4,399</td>
<td>47</td>
<td>38</td>
</tr>
<tr>
<td>4,400-7,199</td>
<td>44</td>
<td>35</td>
</tr>
<tr>
<td>7,200-10,499</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td>10,500-14,599</td>
<td>36</td>
<td>29</td>
</tr>
<tr>
<td>14,600-19,199</td>
<td>33</td>
<td>26</td>
</tr>
<tr>
<td>19,200-24,599</td>
<td>29</td>
<td>23</td>
</tr>
<tr>
<td>24,600-30,499</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>More Than 30,500</td>
<td>22</td>
<td>17</td>
</tr>
</tbody>
</table>

**Sample Cost**

One of the most significant aspects of the acoustical aircraft activity counter is that it permits periodic sampling or continuous monitoring at non-towered airports at a reasonable cost. The cost of resampling the Oregon airports previously counted as part of the Aircraft Activity Counter Demonstration Project was calculated based on the sampling plan presented in this paper and costs factors relevant to Oregon. Assuming a sample size to keep the sampling error in the range of 20 percent, costs range from $1,000 to $2,000 per airport. Costs would be higher if a larger sample size were desired to reduce the sampling error. Costs could be lowered by tolerating less accurate estimates.

**Estimating Annual Operations from Sample Data**

After the sampling of departures has been concluded, the sample data must be extrapolated to estimate a full year of operations. This section illustrates how annual operations and sampling error are estimated from data gathered according to the sampling plan discussed previously. Specifically this estimating procedure assumes that sample data consist of counts of departures taken during two or more 7-day periods in each season.

Total operations (landings and departures) during each season may be estimated by expanding the sum of the sampled departures in each season by \(2N/n_i\); where \(N\) = number of weeks per season (e.g., 13 if quarters are used), and \(n_i\) = number of weeks sampled in each season. Total annual operations is estimated by summing the seasonal operations estimates.

Calculation of the variance of the estimate is not as straightforward because the sampling plan was based on weekly clusters instead of random days. The variance of the estimated seasonal operations is estimated by Equation 2:

\[
\text{var}(\hat{N}) = (\frac{Q^2}{N^2})(1 - (n/N)) \times \left[ \frac{\sum_{i=1}^{n} d_{ij}^2}{n} - (\frac{\sum_{i=1}^{n} d_{ij}}{n})^2 \right] \frac{1}{n^2(n-1)}
\]

where

- \(\hat{d}_{ij}\) = estimated departures in the \(j\)th season,
- \(\text{var}(\hat{N})\) = estimated variance of estimated total operations for the \(j\)th season, and
- \(d_{ij}\) = departures counted during the \(i\)th week of the \(j\)th season.

The variance of the estimate of total annual operations then is given by Equation 3.

\[
\text{var}(\hat{N}) = \sum_{j=1}^{J} \text{var}(\hat{N}_j)
\]

where \(J\) = total number of seasons.

The estimated variances of the estimates of seasonal and annual operations may then be used to calculate the percent sampling error of each estimate at the 95 percent confidence level by using Equations 4 and 5. The sampling error of seasonal estimates is

\[
\text{E}(\hat{N}_j) = 100 \left[ \text{var}(\hat{N}_j) \right]^{1/2}
\]

and the sampling error of annual estimates is

\[
\text{E}(\hat{N}) = 100 \left[ \text{var}(\hat{N}) \right]^{1/2}
\]

It should be noted that the procedure for estimating sampling error can be used even if seasons in the stratified sample are not proportional. However, if proportionality of the day of week stratification is lost, further adjustments are required.

**Distribution of Operations**

Often the distribution of operations, including seasonal distributions and monthly, daily, and hourly peaks, is as important to airport planning, funding, and management decisions as the estimate of total annual operations.

A representative sample of departures can provide information on the distribution of airport activity. The empirical or observed distribution of sample data can be considered the most probable distribution of the population in the absence of other information about the population distribution (4).

The seasonal distribution may be determined by dividing the seasonal estimates of operations by the annual estimate. Independent information, such as fuel sales data, also may be useful in making estimates of seasonal or monthly operations, especially when the sample is small.

Samples of departure data can also provide a frequency distribution of hourly and daily departures for planning purposes. Because daily operations are expected to be twice the number of daily
departures (assuming an equal number of landings and departures), the distribution of daily operations should mirror the distribution of daily departures. However, the distribution of hourly operations cannot be inferred from the distribution of hourly departures because it cannot be assumed that an equal number of landings and departures will occur in any one hour.

The peak number of departures can be identified directly from the frequency distribution of departures per hour or day. Peak daily operations are used to plan for airport design capacity, airport improvement projects, and service demands. Peak hourly departures are useful to airport managers and fixed-base operators in planning for service demands and staffing requirements.

In some cases, the daily or hourly peak-to-mean ratio also may be a useful statistic. Sample data indicate that peak-to-mean ratios tend to be inversely related to the size of the airport. Peak departures tend to increase as mean departures increase, but at a slower rate.

IMPACT OF ECONOMIC DOWNTURN AND AIR TRAFFIC CONTROL WALKOUT ON FINDINGS

Before concluding, some attention should be given to two important factors that affected the level of operations during the sample period used in this analysis. The severe economic downturn in 1981 reduced all aviation activity. In August 1981 the air traffic controllers walkout resulted in an additional reduction in operations at many airports. Because of these events, 1981 may have been an atypical year for aviation, but it is improbable that they affected the major conclusions of the study.

Conclusions about the comparison of towered and nontowered operations are based on differences in the seasonal distribution of operations. Seasonal variations of operations would not have been changed substantially because of economic recovery or the elimination of the third quarter downturn resulting from the air traffic controllers walkout. The sampling procedures developed and the estimates of confidence intervals reflect the seasonal and daily variations in operations at nontowered airports. Sample size requirements might be reduced if these variations were reduced, but the procedure itself would not change substantially.

CONCLUSIONS

Aircraft operations data gathered during the Aircraft Activity Counter Demonstration Project have provided useful analytical data for estimating activity counter to obtain a series of cluster samples systematically drawn throughout the year. Such samples can provide valuable information on seasonal and peak use patterns as well as total annual operations.

Based on these findings it is recommended that the FAA devote more attention to techniques that do not rely on comparisons with tower data to estimate air activity at nontowered airports. Further research should be devoted to finding and evaluating alternative independent measures of variation in activity at nontowered airports. Further research is also needed on the use of acoustical aircraft activity counters or similar equipment to reduce the cost of periodic sampling.

The Oregon Aeronautics Division is currently conducting a counting program using the procedures recommended in this study as part of the federally sponsored Continuous Aviation System Planning Process. Activity counts are being used in system planning and to update Airport Master Records (5010 forms); and significantly improved data are being supplied to airport sponsors, managers, fixed-based operators, and planners.

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