INTERMODAL IMPACTS: INTERSTATE HIGHWAYS AND AIRPORT VIABILITY

By William R. Black*

Proponents of urban and regional highway investments are quick to point out their positive economic impacts, e.g., increases in land values, land use, and business activity; and there is a voluminous body of literature on the subject (references and bibliographies are given in [1], pp. 22–24, 47–49). Yet little is known of the impacts of highway construction on other subnetworks or modes of a regional transport system. Certainly highway development and the increase in motor vehicles can be related to the general decrease in railway construction and flows during the early 1900s. Similarly, one can easily establish the relationship between national increases in motor vehicles and decreasing utilisation of public transit. However, in these illustrations there is a need to consider technological developments, changing levels of service, and changes in tastes and preferences, as well as general changes in affluence. When these other factors are considered, the relationships posited may be more apparent than real.

If the development of a “balanced” regional transport system is desirable, it is essential to consider the potential impact of each project on other modes and networks. Very few examples can be offered at the individual project level as evidence that immediate positive or negative impacts may result on certain modes. Interpretation, design and policy problems are inherent in impact studies: (1) there is always the possibility that an impact may have resulted from factors not considered when the original research was planned; (2) “before-after” frameworks may suggest that there has been an impact, but generally do not enable the researcher to identify the source objectively; and (3) until recently policy makers were not concerned about the possibility of positive or negative intermodal impacts.

The purpose of this paper is to examine the impact of individual Interstate highway projects on airport viability in the state of Indiana for the period from 1957 through 1970. The airports of interest are or have been terminals for major trunk and local service air carriers serving the state since 1957. Total passenger enplanements are taken as the measure of airport activity and viability. Although other modes could be examined, air passenger transport is particularly suitable, since at the macro level air transport and interstate construction have been increasing over the past ten years.

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THE LITERATURE AND THEORY

A recent study by Scheiner sought to assess the impact of the Interstate Highway System on the demand for short haul (between 100 and 200 miles) air passenger services [2]. The demand was measured by the percentage change in air passengers for 17 city pairs between 1962 and 1965. By regression analysis this demand was related to a general airport use variable, a dichotomous interstate construction variable and a “scheduling” variable. The regression accounted for 36 per cent of the variation in demand; the contribution of the scheduling variable was insignificant. Scheiner concluded that: (1) the short haul air market is not growing in the same proportion as the overall air travel market; (2) the number of passengers between two cities less than 200 miles apart can be expected to decrease by 35½ per cent after the construction of an interstate link; (3) the construction of an interstate link results in a substitution of modes, i.e., air passengers switch to automobiles or buses.

A recent cross-sectional study by Barnard and Oyen of the demand for local air service in the midwest established that the longer the travel time between a local service airport and the nearest hub airport, the larger the number of passenger originations at the local service airport [3]. A hub is a metropolitan area generating more than 0.1 per cent of the total air traffic in the U.S.

These studies, in conjunction with existing knowledge on travel patterns to airports, suggest that use of a non-hub or local service airport may be reduced by highway construction [4]. It is also possible to infer these effects from theory.

As an illustration, consider a situation involving two airports: \( A_1 \), a non-hub airport, and \( A_2 \), a hub airport (Figure 1). Given that to a given destination the cost of the trip from \( A_1 \) is \( P_1 \) and the cost of the trip from \( A_2 \) is \( P_2 \), it is possible to examine changes in market areas, using a familiar graph from location theory. It is assumed that each flight has the same destination and that economically rational behaviour prevails. It is apparent that the airport with the lower trip price will have a disproportionate share of the market. This price difference is attributable to the general tendency for flights from non-hub airports to cost more than trips from hub airports; this in turn is due primarily to the fact that there is generally only one level of service (first class) from non-hub airports. If a highway is constructed between \( A_1 \) and \( A_2 \), resulting in a uniform increase in accessibility, then as the transport rate changes from \( t_1 \) to \( t_2 \) the area served by the hub airport (\( A_2 \)) increases from \( k_1 \) to \( k_2 \).

Since the Interstate Highway System, almost by design, connects the cities which are the hubs of the national air transport network, these slight advantages result in multiple increases for those hubs. For example, Indianapolis enplanements increase and there are slight decreases at its non-hub feeder airports.

AIRPORTS AND GENERAL TRENDS

Thirteen airports have been engaged in air carrier service within the state of Indiana over the past 14 years (Figure 2). These airports are located at: Bloomington, Columbus, Evansville, Fort Wayne, Gary, Indianapolis, Kokomo, Lafayette, Marion, Muncie, Richmond, South Bend, Terre Haute. Of these, three were not included in the analysis which follows. Gary ceased operations as an air carrier terminal in 1958, after the construction of O'Hare Field in Chicago. Richmond and Columbus ceased
operations in January 1966. Although the closing of these latter airports coincided with the construction of Interstate Highways between Richmond and Dayton, Ohio, and between Columbus and Louisville, Kentucky, it is not certain that this was the cause of their closure. The primary reasons for their exclusion are in the case of Columbus an insufficient number of years of operation as an air carrier terminal (1961–1965), and for Richmond a generally negative trend throughout the period from 1960 through 1965.

If the theory previously discussed is valid, enplanements at the major hubs should be relatively stable though increasing over time. A graph of these enplanements for calendar years and fiscal years from CY 1957 through FY 1970 confirms that this is so for Indianapolis, a medium hub, and Evansville, Fort Wayne and South Bend, which are small hubs (Figure 3). These series and the data are generally sensitive to impacts. For example, the series for Evansville reveals the impact of a labour strike by Eastern Airlines for CY 1962 and FY 1963 (the strike occurred between 23 June and 13 September 1962) [8]. A similar strike is apparent for the three small hubs during the latter part of 1966; this was a labour dispute in TWA, Northwest, Eastern and United Airlines from 8 July to 19 August 1966 [8]. Apart from these exceptions, air passenger enplanements at the hubs generally increase over time.

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1 The source of information on Interstate construction is Indiana State Highway Commission [5].
2 Enplanement data are from [6] and [7].
FIGURE 2

until 1969, when a decrease occurred, generally attributed to economic conditions.

The six non-hub airports in the state have not displayed the same regularity as the hubs (Figure 4). Bloomington and Lafayette are perhaps the most stable of these, probably because of the presence of large universities. Each airport experienced a slight peak during 1965 and 1966. It is believed that this is related to university expansion within the state, as well as to the strike in 1966: the air carrier serving these cities did not take part in the strike. Since FY 1968 enplanements have been generally decreasing at Lafayette, while Bloomington appears to be relatively stable except for the economic slump in FY 1970. The decrease at Lafayette coincides with the opening of Interstate I-65 between Lafayette and Chicago in October 1968.

The series of enplanements for Terre Haute is stable through 1965. After that
point the series fluctuates and begins to decrease. TWA, the only major trunk airline serving the airport, had a strike (8 July to 19 August 1966), which is responsible for the initial decrease during CY 1966 and FY 1967. The airline subsequently dropped Terre Haute from its route structure. At the same time Interstate 70 was under construction between Indianapolis and Terre Haute; it was opened to traffic a section at a time, being completed in October 1969.

Explanations for variations in the enplanements for Kokomo, Marion and Muncie are less easy. There are significant fluctuations for these airports, and enplanements at each began to decrease in 1966 and continued through 1969. Air carrier service to Kokomo and Marion was terminated in 1969, and to Muncie during the summer of 1971. These cities are currently served by air commuters. It is possible that this decrease is due to highway construction in the case of Marion and Muncie (I-69 from Fort Wayne to Indianapolis was opened to traffic); however, Kokomo is not at present connected to an Interstate.
METHODOLOGY

In order to examine whether the Interstate Highway has had an impact on airport viability, a multivariate time series methodology was adopted. Although there are numerous statistical problems involved in the use of this technique, it is clearly more rigorous and powerful than the traditional "before-after" frameworks employed in most impact studies.

"Air passenger enplanements" is the total number of revenue passengers boarding aircraft of certificated air carriers, including originating, stop-over, and transfer passengers. This measure of airport viability is affected by numerous variables. Aircraft departures by scheduled air carriers form one of the more dominant of these, and may be viewed as the supply of the service offered. Connectivity is also of paramount importance. The number of routes passing through a terminal, the number of trunk lines using the terminal, and the number of routes connecting the airport with airports of a larger order may affect enplanements. Although local weather conditions (such as severe snowstorms and fog) affect enplanements, they also affect departures and therefore need not be considered as a separate variable. Similarly, labour strikes and disputes affect enplanements, but they also affect departures. There will nevertheless be a positive residual resulting from the uncertainty over when a labour dispute will be resolved; thus a strike will affect reservations after it has been settled. The variable of interest may also be influenced by changes in scheduling and increases in aircraft capacity, as well as by general increases in use over time.

A general model was formulated to eliminate the impact of the variables noted. This model has the general form

\[ E_t = f(D_t', C_{L_t}', C_{S_t}', C_{H_t}', t) \]

where

- \( E_t' \) = air passenger enplanements;
- \( D_t' \) = total number of departures of scheduled air carriers;
- \( C_{L_t}' \) = local service connectivity;
- \( C_{S_t}' \) = total system connectivity (local service and trunk line);
- \( C_{H_t}' \) = connectivity to small, medium and large hubs; and
- \( t \) = time, which is taken as a surrogate for increases in the use of aircraft, increases in capacity, and so forth. \( t \) is operationalised as \(-26, -25, -24, \ldots, 0\), to represent data for CY 1957, FY 1958, CY 1958, \ldots, FY 1970.

Decreases in air passenger enplanements have occurred at each of the six non-hub airports in Indiana during a period of significant highway construction and changes in route structure and service. If variations in the number of enplaned passengers is a function of the variables posited above in the general model, fitting that model to the data should eliminate most of the variation. If the Interstate highway system has had an impact on enplanements, that impact should be revealed in the residuals from regression.

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3Data on the number of departures are published with enplanement. See [6] and [7].
4Connectivity represents the number of routes connected to the airport. This is the local degree of a vertex in graph theory; see R. Busacker and T. Saaty [9].
5Data on connectivity were drawn primarily from Air Transport Association [10]. Recent issues of this publication are also published on an irregular basis by the Air Tariff Association, Washington, D.C.
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Table 1
Correlations Between Enplanements and Level of Service Variables

<table>
<thead>
<tr>
<th>Airports</th>
<th>D_l</th>
<th>C_l</th>
<th>C_y</th>
<th>C_h</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloomington</td>
<td>0.721</td>
<td>0.786</td>
<td>0.786</td>
<td>0.859</td>
<td>0.943</td>
</tr>
<tr>
<td>Kokomo</td>
<td>0.563</td>
<td>0.009</td>
<td>0.009</td>
<td>0.071</td>
<td>0.017</td>
</tr>
<tr>
<td>Lafayette</td>
<td>0.591</td>
<td>0.826</td>
<td>0.826</td>
<td>0.901</td>
<td>0.922</td>
</tr>
<tr>
<td>Marion</td>
<td>0.811</td>
<td>0.721</td>
<td>0.721</td>
<td>0.468</td>
<td>0.653</td>
</tr>
<tr>
<td>Muncie†</td>
<td>0.391</td>
<td>-0.370</td>
<td>-0.648</td>
<td>-0.644</td>
<td>0.684</td>
</tr>
<tr>
<td>Terre Haute</td>
<td>0.661</td>
<td>0.889</td>
<td>0.351</td>
<td>0.250</td>
<td>0.834</td>
</tr>
</tbody>
</table>

†The Muncie time series extends from 1959 to 1970 and includes 23 observations. All other series are based on 26 observations for CY 1957 through FY 1970.
Source: Calculated by author.

THE ANALYSIS

The correlations between enplanements and each of the level-of-service variables were higher than expected (Table 1). As expected, departures have a significant impact on enplanements at most of the airports examined. In addition, the three measures of connectivity emerge as being far more influential than expected. It should be noted that several of the connectivity correlations are equal. This occurs because in some cases the airports are served only by certificated local service air carriers; this means that the series for system connectivity and local service connectivity are the same.

By a step-wise regression analysis, a multivariate time series model was developed for each of the non-hub airports. The addition of variables continued until the standard error of estimate began to increase. Summary statistics for the models developed suggest that relatively good fits were obtained (Table 2).

Examining the standardised residuals from regression for Bloomington and Lafayette, it can be seen that the general pattern of residuals is similar over the 14 years (Figure 5). The peak positive value occurs in the 1965–66 period and, as noted, is probably due to economic and labour factors not incorporated in the models. Also apparent is the general over-estimation of enplanements for Lafayette in 1969. There is every reason to believe that this residual is due to the construction of Interstate I-65 linking Lafayette and Chicago. The general disappearance of the residual is due to a change in the number of departures by the airline serving Lafayette.

The residuals from regression for Terre Haute are admittedly puzzling (Figure 5). The large positive residual during 1959–1960 did not occur in any other series

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6This is surprising in view of the fact that cross-sectional studies have not been very successful in demonstrating the relationship between network structure and flow; see, for example, Leslie P. Cummings [11] and David A. Smith [12].

7The standardised residuals are equal to the actual number of enplanements, less the estimated number of enplanements, divided by the standard error of estimate; see Edwin N. Thomas [13].
### Table 2

**Summary Statistics and Models for the Six Airports**

<table>
<thead>
<tr>
<th>Airport</th>
<th>$\bar{X}$</th>
<th>S.D.</th>
<th>S.E.</th>
<th>$R$</th>
<th>$D_r$</th>
<th>$C_L$</th>
<th>$C_S$</th>
<th>$C_H$</th>
<th>$t^b$</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloomington</td>
<td>5743</td>
<td>3255</td>
<td>724</td>
<td>0.9790</td>
<td>1.2</td>
<td>-1177</td>
<td>---</td>
<td>1501</td>
<td>336.4</td>
<td>9241</td>
</tr>
<tr>
<td>Kokomo</td>
<td>4031</td>
<td>1182</td>
<td>676</td>
<td>0.8364</td>
<td>2.1</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>139.1</td>
<td>1775</td>
</tr>
<tr>
<td>Lafayette</td>
<td>18493</td>
<td>6386</td>
<td>1131</td>
<td>0.9861</td>
<td>2.9</td>
<td>3611.5</td>
<td>---</td>
<td>---</td>
<td>522.5</td>
<td>7286</td>
</tr>
<tr>
<td>Marion</td>
<td>2378</td>
<td>575</td>
<td>325</td>
<td>0.8479</td>
<td>0.8</td>
<td>271.1</td>
<td>---</td>
<td>-198.6</td>
<td>---</td>
<td>442</td>
</tr>
<tr>
<td>Muncie</td>
<td>5121</td>
<td>915</td>
<td>410</td>
<td>0.9138</td>
<td>3.6</td>
<td>-1106.9</td>
<td>---</td>
<td>-142.3</td>
<td>64.0</td>
<td>3805</td>
</tr>
<tr>
<td>Terre Haute</td>
<td>15406</td>
<td>2898</td>
<td>1436</td>
<td>0.9413</td>
<td>1.4</td>
<td>1717.3</td>
<td>---</td>
<td>458.7</td>
<td>138.9</td>
<td>5916</td>
</tr>
</tbody>
</table>

*aSystems connectivity may be substituted for local connectivity.

*bTime units are $t = 0 = FY 1970$, $t = 1 = CY 1971$, and so forth.

Source: Calculated by the author.
examine the state. The rather noticeable decrease in enplanements which occurred in the unadjusted series in conjunction with the opening of Interstate 70 does not stand out as clearly in these residuals. It was believed that inclusion of the time variable in the Terre Haute model might have resulted in the elimination of this residual; however, deleting that variable from the model did not appreciably change the pattern of residuals.

The residuals for Kokomo, Marion and Muncie are generally similar, i.e., the positive and negative values tend to coincide (Figure 6). There appears to be a cyclical pattern to these residuals; this is more a function of the method of analysis than of the data. These series were among the most variable in their raw form, and it was noted that perhaps the construction of Interstate 69, between Indianapolis and Fort Wayne, could have affected the series for Marion and Muncie. However, an examination of the residuals does not support that inference. The variation in the original series is more a function of changes in the level of service and route structure than of highway developments. In addition, the fits of the general model were poorest for these three airports. This suggests a rather unstable pattern of demand, which may have also contributed to their closure.

It should be apparent that highway improvements may affect scheduled departures (supply) as well as enplanements (demand). Therefore, if a carrier adjusts
FIGURE 6
Standardised residuals from regression models for non-hub airports at Kokomo, Marion, and Muncie. Source: Calculated by the author.

schedules immediately this design would not illustrate the impact, because there would be no residuals. But air carriers do not generally change the number of departures until at least one time interval after the major impact; that explains the disappearance of the residual in subsequent time periods.

SUMMARY AND CONCLUSIONS
For a given airport the construction of an Interstate highway may have either positive or negative effects on enplanements. The positive effect is an increase in accessibility, which is beneficial to the larger airports with numerous flights and connections. Unfortunately, the gain for the larger airports is usually at the expense of the smaller airports. The smaller airports lose passengers who are willing to substitute highway travel for a portion or the whole of their trips.

This research was initiated to determine whether there was a relationship between passenger enplanements at the six non-hub airports in Indiana and increases in accessibility resulting from the construction of the Interstate Highway System in the state. On the surface a negative relationship was apparent; Interstate construction was increasing and enplanements were decreasing. An analysis of the time series of enplanements for these six airports reveals that the Interstate-65 project has probably
had a negative impact on Lafayette. For the other five airports the major sources of variation are changes in the number of departures and route connectivity, not highway improvements. Three (Muncie, Marion, and Kokomo) are no longer served by air carriers. Air carrier service to Columbus and Richmond was terminated in 1966. That the Interstate acted as the proverbial "straw" in these events remains a possibility.

REFERENCES


