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RURAL INTRASTATE AIR SERVICE SYSTEMS: A BASIC PLANNING AND EVALUATION TOOL

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Introduction

Cost-attractive, readily accessible intrastate air service has been proposed as one key to expanding the economic base in rural, predominantly agricultural states (SRI, 1990). Some have claimed that reliable, cost-effective air transportation for business travel will help attract new and retain existing enterprise. Further, it is anticipated that an intrastate air service system, as opposed to an urban-based hub system serving rural locations, will foster economic growth and interdependencies that are state-wide rather than urban-focused. This distinction is important in states such as Nebraska where the few urban centers tend to dominate economic and, to a lesser extent, political life. For the rural population, an intrastate air service system is expected to help validate its readiness and ability to participate more fully—and competitively—in the economic growth of the state. Although empirical support for the linkage of rural economic growth and air transportation availability is mixed at best, the concept has attracted wide public interest in rural areas. Public interest in Nebraska has generated political support, as reflected in enabling legislation for a state airline authority to serve rural air transportation needs.

Identifying the need for new intrastate air service and generating the necessary community support, legislative authorization, system planning, and financial backing is a process rooted as much in politics as economics. Absent clear evidence to discount the linkage theory, and recognizing that it is not economically feasible to provide air service for all communities that may desire it, how can issues of cost and effectiveness be examined in a manner that will gain credibility with the interested public and their elected representatives? While extensive research has provided a multitude of sophisticated tools for defining and clarifying urban transportation system issues, considerably less attention has been devoted to similar problems in the rural setting. In predominantly rural states, the community leaders, public servants, and political institutions that craft and implement transportation policy often lack the resources, and perhaps the inclination, to hire the expert assistance needed to tailor and employ the data-intensive, highly analytic approaches routinely used in urban transportation planning. They are also unlikely to be capable of doing the job themselves.

The research reported here is the first step in an effort to produce air transportation planning tools that can be understood and employed by those most likely to participate in the decision process that considers the merits and costs of new rural intrastate air service. This first step provides an analytical approach for examining the cost comparative economics of air versus ground travel. While the approach lacks the detail and accuracy required for urban planning, it should be sufficient for the lesser magnitude and complexity of the rural air service projects normally considered. Developed to gain insight into the basic concepts and cost structures involved, this approach provides a modal decision tool for rural business travel planning and a sensitivity analysis platform that can be used by public servants, elected officials, and commuter service operators to understand the economic implications of alternative approaches to providing rural intrastate air services. The spreadsheet model documented and demonstrated here uses input values that reflect the requirements of the Nebraska intrastate air service system project that fostered its development. These input values can be changed easily to reflect circumstances unique to any state or region in the country.

Nebraska Project Context

For large, predominantly agricultural states such as Nebraska, economic diversification and growth are major challenges with important implications for the state's ability to maintain and improve its public facilities and services infrastructure. Without a healthy, expanding economic base from which to generate tax revenues, state and local government can not provide the quality basic services and physical infrastructure needed to attract and retain nonagricultural enterprises. This problem is evident in Nebraska, where new business starts have been among the lowest in the nation and, due to limited economic diversity, outmigration of its better educated citizens often has been severe (SRI, 1987).

Improved access to cost-competitive intrastate airline service has been proposed in many studies of Nebraska as one element required to support economic expansion in the state's rural areas. Current intrastate air transportation is recognized as "both too inadequate and [too] uncertain for business people needing to work in the state" (SRI, 1987). The studies consistently conclude that technologically advanced manufacturing and service industries—the target of state economic growth initiatives—"rely increasingly on extensive air service in conducting their business, as they move beyond the Midwest to opportunities throughout the nation and abroad" (SRI, 1987). The studies note that if economic growth is to extend beyond the urban areas, "a state as large as Nebraska simply must have a good telecommunications system and air transport facilities to be competitive in the future" (SRI, 1988).

Anecdotal evidence, which largely defines public perceptions, suggests a correlation between intrastate air service and business growth. Chadron, NE lost a branch office of an Omaha firm to Bolder, CO over availability of air service (ASRC, 1990). The president of Nebraska's Buffalo County Development Council noted in a newspaper interview that "some sales representatives lose a day of business when visiting customers and businesses in the area because of poor air service. In the future, that's going to be an unnecessary barrier for many companies" (Hammel, 1992). One rural Nebraska airfield operator put it most succinctly, "Money doesn't come to town on a bus."

In an overview of economic development literature, Cooper (1990) concludes that a significant relationship exists between the availability of air transportation and an area's economic growth. High technology industries in particular are likely to consider access to air transport a key factor in deciding where to locate their facilities. On the other hand, he notes that the basis of the relationship is not fully understood, pointing out that relevant studies report results ranging from "the linkage has been factually established" (Aviation Advisory Commission) to "economic development drives airport development" (Kanafani and Abbes) to air service "will not induce new industry into an area without other economic incentives" (Vittek).

While it seems clear that sufficient empirical evidence does not yet exist to validate the intuitive link between air service accessibility and economic growth, this shortcoming has not deterred economic growth proponents from pursuing such initiatives as a major component of their rural economic development agenda. In 1990, enabling legislation for an intrastate airline—based on a largely unsubstantiated premise that scheduled air service located within one hour's drive of every Nebraskan was required to promote rural economic development—was enacted. Prior to funding implementation, the legislature required the state aviation authority to conduct a need and alternatives analysis. The contractor hired for the effort reported little current need for new air service based on their survey determination of existing passenger market potential. Consequently, they proposed and examined few alternatives for providing the rural air service authorized by legislation. The few alternatives considered were judged unattractive on the basis of short-term cost benefits. No consideration was given to the impact of providing new air service on future economic development or to the additional passenger demand it might generate (ASRC, 1990). Few, if any, of the approaches routinely used in urban transportation planning appear to have been used at any stage in the evolution of the Nebraska interstate air service concept or its analysis. Not surprisingly, although the enabling legislation remains on the books, funding support for implementation ultimately was withdrawn.

A review of the literature reveals that most transportation planning tools are designed to address urban, national, and international transportation issues. The methodologies that have been developed depend largely on insights gained from analysis of highly aggregated demographic, market, and other relevant data. For instance, one report on forecasting for aviation system planning notes that "air travel corresponds well with population and employment and income" and "office employment generates a ... greater number of air carrier trips than manufacturing employment" (Rubin and Lerner, 1987). Experience suggests that these empirically supported insights, while valid for an urban market, may not be applicable in a predominantly rural market. Given the unique economics and demographics of sparsely populated rural America, the limited transportation modal choices available, and the marginal nature of the transportation systems needed to meet its needs, it would appear prudent to question the need for, the cost of, and the applicability of sophisticated urban transportation planning approaches, data, and application of many of the urban planning fundamental tenets to rural areas.

While research into rural transportation issues appears to have attracted little interest to date, the increasing portability of high technology industries, the attractive economic environment and quality of life of rural America, and the widespread access to modern, high volume communication systems suggests such research now may be appropriate and fruitful. Tools, methodologies, and sophistication appropriate to the task and user are needed, as the preceding discussion of Nebraska's pursuit of expanded rural air service demonstrates.

From the foregoing discussions, three areas of profitable research emerge:

- Establishing the relationship between air service and rural economic growth;
- Identifying and determining how to project the benefits associated with providing rural air service; and
- Understanding the costs and demand basis of rural air transportation services.

This research focuses on examining the costs associated with rural air transportation because of the strong public and political presumption, demonstrated in the Nebraska experience, that air service and rural economic growth are linked. Validating the linkages and quantifying economic benefits remain fruitful areas for subsequent investigation. The research reported here employs an economic break–even approach to modeling the competing elements of air and ground travel in order to gain insight into the basic economics of intrastate travel. It is intended to provide proponents, public officials, and political bodies (rather than professional transportation planners) a means of improving their consideration and development of rural air service alternatives.

Modeling Travel Economics

Urban business travelers generally have four modes of travel upon which they can rely: automobile, train, bus, and aircraft. Their modal choice considers cost, time, and transportation schedule convenience. With the demise of convenient rural bus and rail service, the rural intrastate business traveler has two practical choices, travel by car (ground mode) or, when available, travel by air (air primary mode). Necessarily, the air primary mode involves car travel segments—from home or business to the departure airport and from the arrival airport to the ultimate destination. If we assume a rational traveler will decide between the two modes of travel based on the time or costs involved, it is possible to develop decision models that, while relatively simple, can be used to gain insight into the economics of the intrastate air travel business and market.

Travel Geometry

The notional geometry of intrastate travel can be modeled graphically, as shown in Figure 1.

When given:

D_{AIR} = The total one way distance covered by the air primary mode traveler;

D_{CAR} = The total one way distance covered by the ground mode traveler; and

D_{XY} = The distance between the subscripted points,

the geometric, point-to-point depiction of air primary mode travel between points A and F can be expressed mathematically as:

$$D_{AIR} = D_{AB} + D_{BC} + D_{CD} + D_{DE} + D_{EF}.$$

When r_{ASA} = 50 statute miles, D_{BC} and D_{DE} = 50 for all air primary mode travel cases. Substituting,

$$D_{AIR} = D_{AB} + 50 + D_{CD} + 50 + D_{EF} = 100 + D_{AB} + D_{CD} + D_{EF}.$$

Because the ground travel legs D_{AB} and D_{EF} are not really point-to-point, they must be adjusted to reflect actual travel distances more accurately. Multiplying them by $1/\beta = 1.19$ provides the necessary adjustment. Thus,

$$D_{AIR} = 100 + (1/\beta)\,(D_{AB} + D_{EF}) + D_{CD} = 100 + 1.19\,(D_{AB} + D_{EF}) + D_{CD}.$$

The geometric, point-to-point depiction of ground mode travel between points A and F can be expressed mathematically as:

$D_{CAR} = D_{AC} + D_{CD} + D_{DF}$.

Because ground travel legs are not point-to-point, they must be adjusted by $1/\beta$. Thus,

$$D_{CAR} = (1/\beta)\,(D_{AC} + D_{CD} + D_{DF}) = 1.19\,(D_{AC} + D_{CD} + D_{DF}).$$

A Time Based Travel Mode Decision Model

Using the expressions for D_{AIR} and D_{CAR}, a general time-based travel mode decision model can be developed, subject to the following assumptions:

- Single traveler (Multiple, nonhomogeneous travelers will be treated in future revisions to the model);
- Travel by competing modes starts simultaneously;
- All air travel is one way and involves no enroute stopovers (Round trip air and ground travel will be treated in future iterations of the model);
- There are no unscheduled air transportation availability delays;
- Ground travel is one way and may require enroute stops for refueling, meals, etc.; and
- The air primary mode traveler uses ground transportation from home or office to the departure airport and from the arrival airport to the ultimate destination.

Given these assumptions and the distance models, the time required for each mode of travel can be described as:

$$T_{AIR} = (D_{AB}/[(\beta)\,(R_C)]) + W_B + (D_{BC}/R_A) + (D_{CD}/R_A) + (D_{DE}/R_A) + W_E + (D_{EF}/[(\beta)\,(R_C)]) \text{ and}$$

$$T_{CAR} = (D_{AC}/[(\beta)\,(R_C)]) + (D_{CD}/[(\beta)\,(R_C)]) + (D_{DF}/[(\beta)\,(R_C)])$$

where:

T_{XYZ} = Total travel time for the subscripted mode;

D_{XY} = Point-to-point (air) distance in statute miles between subscripted points;

β = .84 and $1/\beta = 1.19$ as previously derived. Its use in the time-based model assures that actual travel distances are represented when computing and comparing the travel times of competing travel modes;

R_C = Rate of travel by car in statute miles per hour. $R_C = 55$ mph is the ground travel average speed used in this analysis to accommodate stops for refueling, meals, etc. and is predicated on a 65 mph legal speed limit for most of the travel route;

R_A = Rate of travel by air in statute miles per hour. Based on the 65 percent power, average cruise speed of the eleven single-engine, four to eight passenger aircraft considered in this analysis, R_A = 188 mph. Aircraft cruise speeds ranged from 144 to 270 mph;

W_B = Wait time to transition from ground to air travel at a small departure airport (point B). $W_B = W_C + W_T + W_S + W_P + W_G + W_M$ and includes the following components and partial times used in this analysis: W_C = 5 minutes to park a car and make way to the check-in counter; W_T = 10 minutes for check-in processing; W_S = 5 minutes for travel to the departure gate and completion of airport security processing; W_P = 20 minutes for aircraft boarding and departure procedures; W_G = 10 minutes for aircraft gate departure, taxi, and takeoff; and W_M = 5 minutes, an adjustment to account for departure procedure flight maneuvering off the point-to-point route and for the less than forecast distance covered during climb to altitude at less than cruise speed. For this analysis W_B = .55 hours. This time could increase substantially at a larger, busier metropolitan airport; and

W_E = Wait time to transition from air to ground travel at a small arrival airport (point E). $W_E = W_A + W_F + W_D + W_L + W_R$ and includes the following components and partial times used in this analysis: W_A = 5 minutes to adjust for terminal area maneuvering off the point to point route at less than cruise speed; W_F = 5 minutes for aircraft post-landing taxi and shutdown; W_D = 10 minutes for deplaning and travel to the baggage area; W_L = 10 minutes for luggage collection; and W_R = 10 minutes for car rental and loading. For this analysis, W_E = .67 hours. This time could increase substantially at a larger, busier metropolitan airport.

Given an ASA = 50 statute miles radius and substituting the study values specified above into the general form of the equation yields:

$$T_{AIR} = (D_{AB}/[(\beta)(R_C)]) + W_B + (D_{BC}/R_A) + (D_{CD}/R_A) + (D_{DE}/R_A) + W_E + (D_{EF}/[(\beta)(R_C)])$$

$$= (D_{AB}/[(.84)(55)]) + .55 + (50/188) + (D_{CD}/188) + (50/188) + .67 + (D_{EF}/[(.84)(55)])$$

$$= 1.75 + .02\,(D_{AB} + D_{EF}) + .01\,D_{CD}$$

and

$$T_{CAR} = (D_{AC}/[(\beta)(R_C)]) + (D_{CD}/[(\beta)(R_C)]) + (D_{DF}/[(\beta)(R_C)])$$

$$= (D_{AC}/[(.84)(55)]) + (D_{CD}/[(.84)(55)]) + (D_{DF}/[(.84)(55)])$$

$$= .02\,(D_{AC} + D_{DF}) + .02\,D_{CD}$$

When the time to travel by the air primary mode (T_{AIR}) is equal to that required by the ground mode (T_{CAR}), the rational traveler will be indifferent to the mode of travel if time is the only decision criterion. Thus, when $T_{CAR} = T_{AIR}$

$$.02\,(D_{AC} + D_{DF}) + .02\,D_{CD} = 1.75 + .02\,(D_{AB} + D_{EF}) + .01\,D_{CD}$$

Solving for the break-even value of the common travel leg (D_{CD}) as D'_{CD}

$$.02\,D_{CD} - .01\,D_{CD} = 1.75 + .02\,(D_{AB} + D_{EF}) - .02\,(D_{AC} + D_{DF})$$

$$.01\,D_{CD} = 1.75 + .02\,(D_{AB} + D_{EF}) - .02\,(D_{AC} + D_{DF})$$

$$D'_{CD} = 175 + 2\,(D_{AB} + D_{EF} - D_{AC} - D_{DF})$$

Substituting D'_{CD} into the equation for D_{CAR} and solving for the break-even ground distance, D'_{CAR}

$$D'_{CAR} = 1.19\,(D_{AC} + D'_{CD} + D_{DF})$$

$$= (1.19)\,(D_{AC} + [175 + 2.00\,\{D_{AB} + D_{EF} - D_{AC} - D_{DF}\}] + D_{DF})$$

$$= (1.19)\,(175 + [2.00\,\{D_{AB} + D_{EF}\}] - [D_{AC} + D_{DF}])$$

$$D'_{CAR} = 208.25 + 3.80\,(D_{AB} + D_{EF}) - 1.19\,(D_{AC} + D_{DF})$$

By specifying point-to-point distance for the variables, the D'_{CAR} equation can be solved to determine the break-even ground mileage at which air primary mode travel becomes more attractive from a time perspective. Few persons, however, enjoy the luxury of selecting their travel mode based only on its time efficiency. For most business travel, cost, including the cost of time, is the most important mode selection consideration.

A Cost-Based Travel Mode Decision Model

The travel time model can be modified to incorporate cost considerations. Given the same assumptions and travel geometry used previously, and assuming that:

- The ground mode traveler uses a personal vehicle exclusively;
- The air primary mode traveler uses a personal vehicle for travel from the start travel point (home or business) to the departure airport;
- Business travel in a personal vehicle is reimbursed; and
- The air primary mode traveler requires a rental car for travel from the arrival airport to the ultimate destination.

It can be postulated that:

$$C_{AIR} = (C_{GM})(D_{AB})(1/\beta) + (C_{SM})(D_{BE}) + (C_R) + (C_H)(T_{AIR})$$

and

$$C_{CAR} = (C_{GM})(D_{CAR}) + (C_H)(T_{CAR})$$

when:

C_{CAR}	=	Total cost of travel by ground mode;
C_{AIR}	=	Total cost of travel by air primary mode;
C_{SM}	=	Cost per seat mile for air travel. From data obtained during the Nebraska study (ASRC, 1990), C_{SM} = \$.40/nautical mile for break-even commercial air service based on \$.18/seat nautical mile full-load operating costs and a 45 percent average load factor. The data assume use of small, piston engine aircraft. Converting cost to the statute mile basis of this study, .869 C_{SM} (NAUTICAL) = C_{SM} (STATUTE) = \$.35;
D_{BE}	=	Distance traveled by air. From the geometric model, $D_{BE} = D_{BC} + D_{CD} + D_{DE} = 100 + D_{CD}$;
C_{GM}	=	Reimbursement cost per personal vehicle ground mile. The rate of C_{GM} = \$.28/mile is based on the mileage reimbursement recognized by the Internal Revenue Service as the maximum acceptable unsubstantiated cost of fuel, maintenance, insurance, and wear and tear on a vehicle. No provision is made in this iteration of the model to recognize air primary mode traveler parking costs because rural airports rarely charge for the service;
D_{AB}	=	Point-to-point distance covered by personal car by the air primary mode traveler;
C_R	=	Cost of a rental car. Assuming no mileage charge, a typical Budget or Alamo economy car rental daily rate of \$35.00 and \$.04/mile fuel costs (based on 30 mpg and \$1.10/gal), $C_R = 35 + .04\,(1/\beta)\,(D_{EF})$ where D_{EF} is the point-to-point distance from the arrival airport to the ultimate destination. Substituting $\beta = 1.19$, $C_R = 35 + .05\,D_{EF}$ for use on the day of travel;

C_H = Cost per hour of the traveler's time. For the purpose of demonstrating the model, the study uses C_H = \$18.00, equivalent to an annual (40 hour/week) salary of \$34,560, on the assumption that it is representative of a typical, rural-based business traveler;

C_{CAR} = Cost of ground mode travel;

and, from the distance and time models:

$$T_{AIR} = 1.75 + .02\,(D_{AB} + D_{EF}) + .01\,D_{CD}$$

$$T_{CAR} = .02\,(D_{AC} + D_{DF}) + .02\,D_{CD}$$

$$D_{CAR} = 1.19\,(D_{AC} + D_{CD} + D_{DF}).$$

Substituting the values and equities above into the general form of the cost equations yields:

$$C_{AIR} = (C_{GM})\,(1/\beta)\,(D_{AB}) + (C_{SM})\,(D_{BE}) + (C_R) + (C_H)\,(T_{AIR})$$

$$= (.28)\,(1.19)\,(D_{AB}) + (.35)\,(100 + D_{CD}) + (35 + .05\,D_{EF})$$

$$+ 18\,(1.75 + .02\,[D_{AB} + D_{EF}\,] + .01\,D_{CD})$$

$$= 101.50 + .53\,D_{CD} + .69\,D_{AB} + .41\,D_{EF}$$

and

$$C_{CAR} = (C_{GM})\,(D_{CAR}) + (C_H)\,(T_{CAR})$$

$$= (.28)\,(1.19)\,(D_{AC} + D_{CD} + D_{DF}) + (18)\,([.02]\,[D_{AC} + D_{DF}]$$

$$+ [.02]\,[D_{CD}])$$

$$= .69\,(D_{AC} + D_{DF}) + .69\,D_{CD}$$

When the cost of air primary mode travel equals the cost of ground mode travel, the rational traveler will be indifferent to the mode if total cost is the only decision criteria. Thus, when $C_{AIR} = C_{CAR}$

$$101.50 + .53\,D_{CD} + .69\,D_{AB} + .41\,D_{EF} = .69\,(D_{AC} + D_{DF}) + .69\,D_{CD}$$

Solving for the break-even value of the common travel leg (D_{CD}) as D'_{CD}

$$.53\,D_{CD} - .69\,D_{CD} \quad = -101.50 + .69\,(D_{AC} + D_{DF} - D_{AB}) - .41\,D_{EF}$$

$$D'_{CD} = 634.38 - 4.31\,(D_{AC} + D_{DF} - D_{AB}) + 2.56\,D_{EF}$$

Substituting D'_{CD} into the equation for D_{CAR} and solving for the break-even ground distance, D'_{CAR}

$$D'_{CAR} = 1.19\,(D_{AC} + D'_{CD} + D_{DF})$$

$$= 1.19\,(D_{AC} + [634.38 - 4.31\,\{D_{AC} + D_{DF} - D_{AB}\} + 2.56\,D_{EF}] + D_{DF})$$

$$D'_{CAR} = 754.91 - 3.94\,(D_{AC} + D_{DF}) + 5.13\,D_{AB} + 3.05\,D_{EF}$$

By specifying point-to-point distance variables, the D'_{CAR} equation can be solved to determine the break-even ground mileage at which air primary mode travel becomes more attractive from a cost perspective. In the example cases that follow, the feasible extreme values of the break-even point are investigated, and a typical travel profile is examined to gain perspective on the model relationships.

Case 1: D_{AB} and D_{EF} = 0; D_{AC} and D_{DF} = 50 (Figure 2)

In this case extreme, the start travel point and departure airport are collocated, as are the arrival airport and destination. As a result, D_{AB} and D_{EF} equal zero. Assuming the provision for vehicle-associated wait times (W_C and W_R) are consumed by foot travel in the collocated areas, only the impact of rental car cost must be extracted from the cost model equation to accommodate this case. Thus, the cost-based break-even point for the travel mode occurs when:

$$D'_{CAR} = 494.60 - 3.94\,(D_{AC} + D_{DF}) + 5.13\,D_{AB} + 2.68\,D_{EF}$$

$$= 494.60 - (3.94)(100) + (5.13)(0) + (2.68)(0)$$

= 100.60 statute miles actual ground trip length.

Case 2: D_{AB} and D_{EF} = 50; D_{AC} and D_{DF} = 0 (Figure 3)

In this case extreme, the departure ASA exit point and start travel points are collocated, as are the destination ASA entry point and destination. This maximizes the advantage for ground mode travel because the air primary mode traveler must backtrack to and from airports. Mode break-even occurs when:

$$D'_{CAR} = 754.91 - 3.94\,(D_{AC} + D_{DF}) + 5.13\,D_{AB} + 3.05\,D_{EF}$$

$$= 754.91 - 3.94\,(0) + 5.13\,(50) + 3.05\,(50)$$

= 1163.91 statute miles actual ground trip length.

Case 3: D_{AB} and D_{EF} = 50; D_{AC} and D_{DF} = 100 (Figure 4)

In this travel case, distance between the travel start point and destination is maximized for both modes of travel. Travel mode break-even occurs when:

$$D'_{CAR} = 754.91 - 3.94\,(D_{AC} + D_{DF}) + 5.13\,D_{AB} + 3.05\,D_{EF}$$

$$= 754.91 - 3.94\,(200) + 5.13\,(50) + 3.05\,(50)$$

= 375.91 statute miles actual ground trip length.

Case 4: D_{AB} = 14; D_{EF} = 22; D_{AC} = 41 and D_{DF} = 32 (Figure 5)

In this intermediate case, the travel start point and destination are located within their respective ASA (as opposed to at the ASA center or on the ASA boundary). Travel mode break-even occurs when:

$$D'_{CAR} = 754.91 - 3.94\,(D_{AC} + D_{DF}) + 5.13\,D_{AB} + 3.05\,D_{EF}$$

$$= 754.91 - 3.94\,(41 + 32) + 5.13\,(14) + 3.05\,(22)$$

= 491.3 statute miles actual ground trip length.

The case examinations show that, given the parameter values used when cost is the decision criteria, ground mode travel should be elected for all individual one way travel less than 100.6 statute ground miles and for other trips up to 1,163.91 statute ground miles if the geometry of the start travel and destination points, relative to their associated airports and ASA exit and entry points, is favorable. These boundaries will change dramatically if the air travel cost per seat mile (C_{SM}) can be reduced and the rate of travel by air (R_A) can be increased—potentials that depend on the type of aircraft and whether it is new or used. The boundaries are also sensitive to the cost per hour of the traveler's time (C_H). As C_H increases, the air travel mode is favored for increasingly shorter trips.

Business travel controllers can use the model with case-specific ground travel distances to determine cost break-even mileage to aid their travel mode decision making. Once initial variables are specified, actual ticket cost (C_{TIC}) can be substituted for the seat mile factor ([C_{SM}][D_{BE}]) in the air mode cost equation. After recomputing the break-even ground distance, a more convenient form of the model can be produced for assessing business travel. The following equation results from applying this approach using the variables previously specified:

$$D'_{CAR} = 155.16 + .6\,C_{TIC} - .42\,(D_{AC} + D_{DF}) + 1.61\,D_{AB} + .95\,D_{EF}$$

Intrastate air service operators interested in examining the potential (rational) customer base for flights between specific cities can use the basic model (with the departure ASA's population centroid as point A) to identify potentially cost-competitive city pairs. For example, given that the population centroid (A) for a Kearney, Nebraska ASA (EAR) is collocated with point B (as in Case 1), the break-even mileage is 100.60 statute miles. Comparing that figure to the driving distances between the cities paired with Kearney in a proposed intrastate air service system (Table 1), provides a basis for eliminating city pairs (in bold) that are not cost competitive. City aviation identifiers are listed in the next section.

The model can be established easily on a computer spreadsheet. The user can specify the initial, nondistance input variables that best reflect his or her estimate of current costs and conditions. The spreadsheet then provides a vehicle to examine the sensitivity of the input variables and to judge the impact of potential operational efficiencies on air travel competitiveness. For instance, improved load factors or lower operating costs associated with a specific aircraft choice can reduce the consumer cost per seat mile for air travel. Higher cruise speeds can reduce air travel time but increase operating costs. The model can be used to determine what impact such changes will have on the break-even point and, by extension, on market potential. More efficient airport design and passenger management can reduce air travel wait times, making the air primary mode more competitive. The model provides a means of gauging how much more competitive the air primary mode could be. State and local government agencies providing intrastate air service operating subsidies—or considering doing so—can vary the model's cost per seat mile to determine when air travel becomes competitive for specified city pair routings. This information can be used to help forecast and budget subsidy support. This and similar applications of the model can provide needed insight for further analyses of intrastate air service economics and can aid public and political debate of the issues involved.

Beta Derivation

The beta factor used to normalize air and ground miles is derived from the total air statute miles in the Nebraska intrastate air service system (shown in Table 2) divided by the total ground statute miles between the system's city pairs (β = total city pair air miles/total city pair ground miles = (28,096/23,586) = .8395). State of Nebraska aeronautical and ground travel map distance tables provide the input data. The following three letter Federal Aviation Administration airport codes are used in Table 1 and Table 2 to identify the system's cities:

Alliance (AIA)	Hastings (NSI)	Norfolk (OKF)
O'Neill (ONL)	Beatrice (BIE)	Kearney (EAR)
North Platte (LBF)	Scottsbluff (BFF)	Broken Bow (BBW)
Lincoln (LNK)	Ogallala (OGA)	Sidney (SNY)
Chadron (CDR)	McCook (MCK)	Omaha (OMA)
Valentine (VTN)	Grand Island (GRI)	

Conclusions and Recommendations:

Without definitive, persuasive evidence to the contrary, rural economic growth proponents are unlikely to be swayed from their conviction that intrastate air service is an important factor in attracting and retaining business enterprise to their communities. Given this circumstance, analytic tools that can be understood and employed by those involved in debating and deciding intrastate air service initiatives could facilitate a more rational consideration of alternatives and costs. Approaches routinely used in urban transportation planning, generally far more complex and expensive to employ than justified by rural transportation needs, do not lend themselves to such use. The spreadsheet models proposed in this paper provide the interested layman with an ability to analyze some of the economic assumptions and costs associated with rural air service and to gain a more informed perspective on the issues involved.

It is important to note that the values used in the development and examination of these models, and the results they generate, are case specific. As such, the output values cited in this demonstration of the model should not be generalized. Model users must determine and input the values that best represent their unique circumstances.

Further research is needed to understand the linkages between rural economic growth and access to affordable, convenient intrastate air service. If the linkage can be established empirically, it should help motivate development of analysis methodologies and tools that are better tailored to the needs, economic realities, and political culture of rural America.

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Table 1—Preliminary Air Route Structure/Driving Distances for Kearney (EAR), Nebraska City Pairs

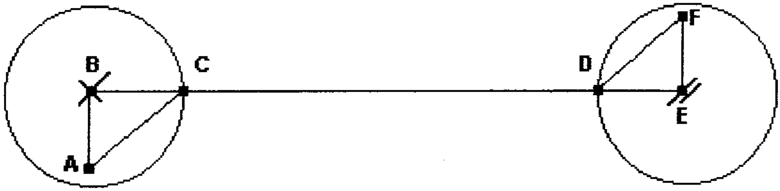
To	From EAR	To	From EAR
AIA	257	OKF	152
BIE	156	**LBF**	**95**
BBW	**78**	OGA	147
CDR	315	OMA	185
GRI	**43**	ONL	154
NSI	**53**	BFF	269
EAR	**0**	SNY	214
LNK	129	VTN	196
MCK	103		

Table 2—Nebraska Intrastate Air Service System City Pair Distances (Statute Miles)

City Pair—Air Miles (above the diagonal); City Pair—Ground Miles (below the diagonal)

	AIA	BIE	BBW	CDR	GRI	NSI	EAR	LNK	MCK	OKF	LBF	OGA	OMA	ONL	BFF	SNY	YTN
AIA		335	167	54	242	247	217	323	171	274	125	83	358	210	43	67	126
BIE	406		169	364	93	90	120	39	202	121	213	267	82	178	368	328	262
BBW	320	215		195	76	85	58	156	97	120	58	194	194	87	204	173	108
CDR	59	461	185		277	279	254	354	218	287	165	133	376	218	74	119	122
GRI	275	137	80	332		26	38	81	130	84	126	180	127	104	278	242	173
NSI	295	106	106	352	26		31	88	117	108	123	177	140	128	279	239	189
EAR	257	156	76	315	43	53		118	90	116	90	145	167	122	249	208	165
LNK	366	40	172	423	92	101	129		206	83	206	261	56	149	361	324	239
MCK	230	211	126	289	1446	127	103	228		205	64	83	256	184	192	138	182
OKF	327	163	160	324	108	135	152	121	260		178	230	92	71	314	291	169
LBF	176	253	75	233	138	148	95	225	68	233		55	249	138	157	118	118
OGA	122	314	127	1891	189	197	147	274	110	283	52		304	183	106	62	134
OMA	397	99	228	436	148	160	185	58	284	112	281	330		163	396	360	260
ONL	275	236	143	284	117	137	154	194	253	76	202	244	187		253	239	98
BFF	53	436	248	99	311	319	269	396	226	385	173	122	452	330		61	169
SNY	78	372	194	137	257	267	214	344	181	351	119	67	400	320	76		175
YTN	167	343	123	138	213	233	196	305	198	187	130	180	299	111	217	247	

Figure 1—Travel Geometry



where:

A = Local start travel point (home or business);

B = Departure airport and center of the departure airport service area (ASA). The airport is assumed to offer the only scheduled air travel option within its ASA. For this study, the ASA is a circle of 50 statute miles radius (r_{ASA} = 50), and the air service system is designed so that all departure points and final destinations are located within the servicing airport's ASA. The 50 mile ASA radius is selected to correspond with the proposal adopted by the Nebraska legislature as the basis for their air service system planning, that "all citizens should be within one hour's drive of an airport offering intrastate air service" (Nebraska Futures, 1989). Given driving conditions and habits in the rural Midwest, equating 50 miles point-to-point with a one hour drive does not unduly stretch the imagination. As with all values used in the model, any appropriate number may be substituted to tailor the model to local circumstances;

C = The exit point from the departure ASA. For the air primary mode traveler, this point lies along the most direct route to the destination airport. For the ground mode traveler, it may represent a detour from point-to-point travel. In Figure 1 this is the difference between travel from A to C to D to F, as opposed to from A to F. Direct ground travel between points is rarely possible, however, because of road system limitations. To accommodate this fact and allow comparison between air and ground transportation modes, actual road travel between any two cities in an air service system can be approximated as $1/\beta$ times the point-to-point (air) distance when $1/\beta = 1.19$. Beta is derived from a proposed Nebraska intrastate air service system's total air statute miles divided by the total ground statute miles between the system's city pairs (Table 2). This approach also mitigates the model limitation that the ground traveler exit or enter an ASA at a designated point;

D = The common entry point into the arrival ASA for all travelers regardless of mode;

E = Arrival airport and center of the 50 mile radius arrival ASA; and

F = The ultimate travel destination.

Figure 2—Collocated Start/Departure and Arrival/Destination Pairs

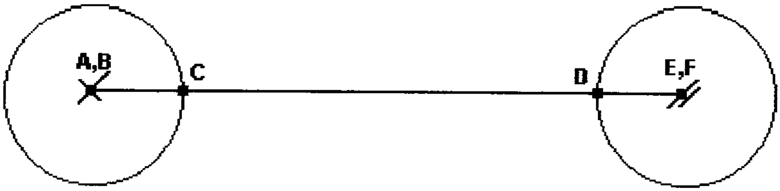


Figure 3—Collocated Start/ASA Exit and ASA Entry/Destination Points

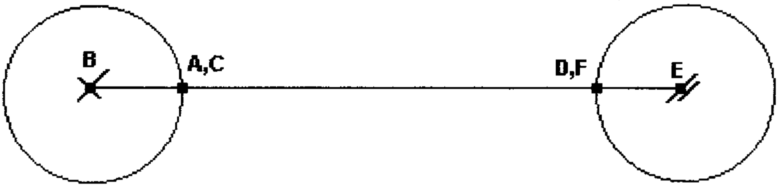


Figure 4—Travel Distances Maximized for Both Modes

Figure 5— Typical Travel Case