Table 2. ITE model estimates versus actual Manhattan only.

Item	α-Value	Terminal Location	Market: Under 300 km	300-800 km	800-1280 km	1280-2400 km	Over 2400 km
Actual		LGA	150.4	118.7	123.6	100.8	13.5
		JFK	16.4	19.2	10.7	60.1	65.6
		NWK	15.1	21.2	17.3	12.8	2.8
Model estimates	25	LGA	175.7	156.2	148.C	173.7	-
		JFK	1.3	0.4	0.2	3.8	77.4
		NWK	4.8	2.2	3.5	3.9	4.4
	15	LGA	165.6	150.0	143.1	159.1	-
		JFK	8.4	3.9	2.4	15.1	73.8
		NWK	7.9	4.8	6.1	7.1	8.0
	10	LGA	148.8	137.4	132.3	140.5	-
		JFK	19.8	11.7	8.4	28.6	68.8
		NWK	13.2	9.6	10.9	12.3	13.0
	5	LGA	113.8	105.5	102.4	107.7	-
		JFK	40.1	29.6	24.9	47.1	58.1
		NWK	28.0	23.5	24.4	26.5	23.1

Note: 1 km = 0.62 mile.

Table 2 shows the model results versus actual for Manhattan only, which accounts for more than one-third of total regional traffic generation in all distance ranges. Another reason why the model's performance in Manhattan has special significance is that for many zones the differences in accessibility to the airports are relatively small and thus the model estimates are more sensitive to the value of α to be selected. If differences in convenience among airports are large, differences in assumed values of α do not produce significant differences in model estimates.

The optimum values for α appear to be here somewhat lower than in the total regional numbers and generally fall in the 5-10 range. The declining trend as a function of length of haul is also here much in evidence. Recognizing that the actual observations as summarized are subject to sample fluctuations and, moreover, that actual behavior may reflect factors not accounted for in the model, it may be postulated that the α values basically could be represented by a linearly declining curve as a function of length of haul.

The Port Authority report to the Tri-State Regional Planning Commission also included some examples of how a model, as developed here, could be applied in estimating the traffic potential for a couple of off-airport satellite terminals.

The main objective of this paper, however, was to report on some results of the development of a passenger distribution model that could be calibrated against survey data on actual passenger choice patterns. We hope such attempts to merge theoretical model concepts with empirical data on actual passenger behavior will contribute toward the development of more realistic demand forecasting tools for use in transportation planning.

ACKNOWLEDGMENTS

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System for Planning Local Air Service

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Local air service is characterized by a strong sensitivity of traffic to a number of factors such as frequency, time of departure, trip time, and alternative transportation available by ground modes. Consequently, in planning local air service, the demand function and the scheduling constraints must be considered in more detail than is necessary with other types of air transportation. This paper presents a system developed at the University of Pittsburgh for planning local air service. The system was used in studying the potential of air service between the provincial capitals of Austria.

The motivation for this study was an overall regional development plan drawn up by the province of Steiermark in Austria. Although Austria is a federal republic of

nine provinces, each with its own government of considerable power, there is a strong trend toward centralization in Vienna. Ever since the collapse of the Austro-Hungarian monarchy, Vienna has been too large a city for a country the size of Austria. The population of Vienna is now more than a quarter of that of all Austria. This fact, together with the gravitational force of the seat of the federal government, creates a strong momentum toward centralization. Already most major corporations are headquartered in Vienna; the bulk of federally subsidized cultural activity is also located there; and Vienna has the only airport in Austria that ever had more than three scheduled daily departures.

The trend toward Vienna is aggravated for the province of Steiermark, for which holding its own would be enough. This province is faced with certain structural deficiencies. On the one hand there is sizable heavy industry with a long-standing tradition and high technological standards. This industry's existence is being threatened by today's economy. On the other hand, there are numerous farms too small to support a family at today's level of expectations. For these reasons the province has to attract settlement of new businesses and industry.

To this end, government is trying to make the province more attractive to the business community. Much has already been done in this direction. Numerous tax incentive plans and subsidies have been devised. Graz, the capital, has acquired a reputation as a center for avant-garde cultural activity. Excellent recreational facilities were developed throughout the province, which is host to a number of significant international sporting events. The availability of good transportation facilities is viewed as an important factor in its attractiveness.

The government therefore commissioned studies to examine the railway, highway, and air transportation systems. The intention was not so much to determine the long-range effects that improved transportation facilities would have on the economic development of the province, but to determine the short-range economic feasibility of improved transportation facilities. In the case of air transportation this meant determining whether air service attractive enough to justify subsidy could be designed. There were no firm limitations imposed on the amount of subsidy that could be expected, but clearly any subsidy would have to be reasonable in relation to the anticipated patronage.

Air service was expected to perform the following functions: (a) connect the province with the other provinces of Austria, (b) connect the province to large population centers outside Austria, and (c) tie the province into the international air transportation system. Special emphasis of the study was to be placed on the interaction between air and surface transportation, in particular, how major highway construction projects would affect the demand for air transportation. A new highway system is under construction and, although it will not be completed for quite some time, the development of an air transportation system could not be justified if it were to be threatened with extinction after completion of the highway system.

Our study was complicated by a number of factors, the most important ones being that, except for a brief episode, there was practically no history of local air service in the area. Furthermore, the stage length of most potential routes is quite short, which makes them highly vulnerable to competition from ground transportation. Also, the area is quite densely populated, so a number of different cities have to be considered as potential users of any one airport.

Of course, many of these factors are quite typical for the environment in which local air service operates anywhere. We have thus supplemented the funds provided by Steiermark with funds from the University of Pittsburgh and expanded the study to a far broader scope than would have been justified within the context of the Austrian situation alone. The result is a general system for planning of local air service (PLATO) that can provide a framework under which any local air service, operating over reasonably short routes, can be viewed.

Of course, as any demand function would, the demand function included in PLATO reflects the sociopolitical and cultural background of central Europe, the area for which it was developed. In any area in which the relations among factors differ it would be necessary to reformulate the demand function. Any demand function can only express the most important dependencies and incorporate only a small selection of variables. The dependencies not included are expected not to vary significantly within the framework of the study. As one moves to another region, one can expect changes in the importance of different dependencies and variables. Also, certain variables may simply not be available for other areas.

The PLATO system, nevertheless, can aid a study for another region in two ways. First, it can help in the development of a demand function by handling the massive socioeconomic and geographic data. Second, once a new demand function has been developed, that function can be entered into PLATO, and traffic estimates, revenues, and costs for air service can be obtained without difficulty.

SETTING FOR LOCAL AIR SERVICE

The type of environment PLATO is primarily designed for is characterized by a large number of relatively small cities scattered over a comparatively small geographic area. The area is served by a small number of local airports. The potential demand for air transportation comes both from people moving between one city and any other city in the region and from people moving from one city to a point outside the region.

The airports are located in such a way that passengers from some cities might use two or more different airports, depending on their final destination. The region is served comparatively well by surface transportation on highways and railways. Surface transportation does provide an alternative to air transportation and, for many, can actually beat air transportation in terms of total travel time between cities.

In this kind of environment air transportation can only compete effectively if it can meet the true transportation needs of the traveling public. This means it has to provide service at the right times, with high enough frequency so that there is a big enough chance that some transportation need can be satisfied, and at a cost differential against surface transportation that would be commensurate with the time saved. As a consequence, the traffic that can be attracted by air transportation will be highly sensitive to schedules and air fares, and it is generally meaningless to develop plans for local air service that do not express this kind of sensitivity.

On the other hand, the cost function for providing local air service is considerably less favorable than it is for interregional air service. The reasons for this are the short stage lengths, the small size, and the relatively low operating efficiency of the aircraft. This leaves a narrow margin for local air service to operate in. And, although much of the local air service enjoys healthy public subsidies of one form or another, it is generally only profitable for small companies that can avoid the pressures of strong national unions and can operate under comparatively low overhead costs.

Planning local air service thus means finding a delicate balance between the preferences of the traveling public and the dictates of the cost function. The public refuses to fly at other than the most desirable departure times: the high aircraft utilization mandated by the cost function forces one to schedule flights throughout the day. The problem can of course be solved best if differences in the time-of-day preferences for travelers on different routes can be matched.

AVAILABLE DATA

As the air service offered in Steiermark was only marginal, limited traffic data were available. A summary of the traffic originating in Graz in 1972 is shown in Figure 1. At that time, the flights offered in the morning were Graz-Salzburg-Zurich and Graz-Linz-Frankfurt; at midday were Graz-Vienna, Vienna-Graz and Zurich-Salzburg-Graz; and in the evening were Frankfurt-Linz-Graz. All flights were with DC-9 aircraft. Traffic data for the Graz-Vienna flight were not available.

Also in 1971 airport passenger surveys were conducted in all Austrian and German airports. For Graz this survey was conducted in 1972. In these surveys a sample of departing passengers were asked questions about, among other things, the starting points and final destinations of their journeys and how they got to the airports. Figure 2 shows an analysis of the passengers departing from Graz. The numbers in the figure are extrapolated average daily passengers. Since the survey did not include the routing of a passenger, the results cannot be compared directly with the traffic data of Figure 1. Exceptions would be the flights to Linz and Salzburg, for which the results are reasonably close.

It was expected that a considerable number of passengers went to Vienna by surface transportation and started their flight there. These passengers could be extracted from the Vienna airport passenger survey. It was found that an average of 38 passengers a day were traveling from Steiermark by surface to Vienna to board a flight there. This figure is only a lower bound, since it does not include passengers who spent a night in Vienna before continuing their trips.

Also available was a market survey done by an Austrian institute (Khoulhavi) in which businesses and households were asked how many trips a year they would expect to make to different destinations if air service were available. The questions that must be raised against this survey are the same for any survey of the demand for an essentially new mode of transportation. The prospective passengers cannot possibly be given a full impression of what it would actually mean to use the proposed mode. Consequently, they may use a completely unrealistic perception of the proposed mode to base their estimates on. Also, it is quite difficult for one to estimate how often he or she would travel to some city, since one cannot always distinguish between desire and reality. The results of this survey indicate quite clearly that not all of these problems could have been dealt with successfully. Therefore, the survey appeared to be of limited value within the context of this study and was not used.

Clearly the available data are not sufficient for developing a demand model. We therefore selected a cross-sectional approach with models developed for comparable environments and calibrated for the specific situation. The comparable situation was found in

Figure 1. Average passengers per day, 1972.

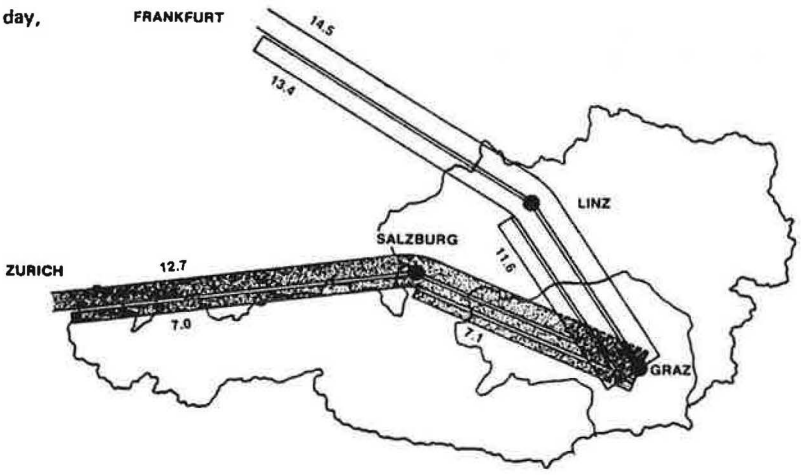
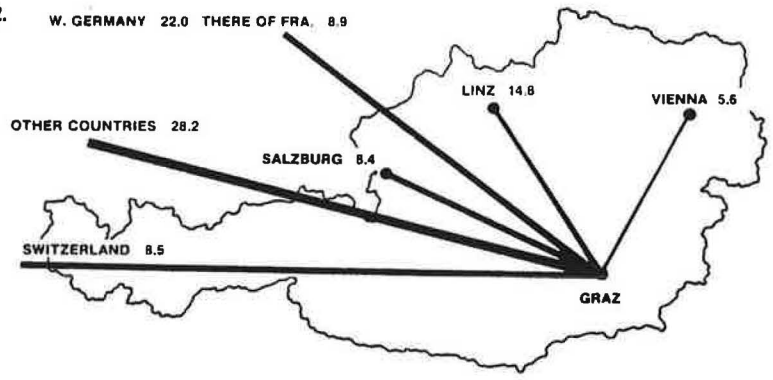


Figure 2. Passenger survey of 1972.



Germany, where considerable data as well as past models were available. The air traffic data were taken from the surveys for most German airports. Additionally, socioeconomic and geographic data about all German districts were gathered.

A model of the demand for local air service was developed by Intertraffic (1) in the study for North Rhine-Westphalia. This model was further refined by Nüsser (2), who applied it in a study of local air service for all Germany. We adopted much of the functional form of these models.

The need for change arose from the fact that some required socioeconomic variables were not available for Austria. Also, we went into considerably greater detail in the representation of the surface transportation alternatives. To accomplish this, the demand had to be determined from any district to any other district, with one airport possibly serving many districts. This led to considerable computer work and required the development of new procedures and program organizations. Finally, some modifications were made to the time-of-day variability of demand. Details of these modifications will be given in the discussion of PLATO.

STRUCTURE OF PLATO

As mentioned before, the central problem in planning local air service is one of developing a schedule for which the expected revenue matches or exceeds the expected total cost. In solving this problem for one particular company, one might use any one of a number of objective functions such as return on investment and total profit one wants to maximize. If one is solving the problem for a local government, one would be interested in maximizing the air service—possibly favoring certain airports—that can be economically justified. Often this means that the subsidies required to operate some schedules have to be reasonably related to the amount of service offered by the schedule. Quite obviously the considerations entering the evaluation of a schedule are almost impossible to formulate into a mathematical objective function. The problem really is not so much one of optimization, but of providing the government with a number of reasonable choices.

Of course it would be desirable to have an algorithm that could automatically generate a number of "most reasonable" choices, but the developmental effort, computer run times to actually perform the optimization, as well as the information required to formulate the problem, might prove prohibitive. Even the optimization simply in terms of a single-valued company objective might prove to be such an enormous task that it could actually be carried out only for very small systems. For such systems, however, good schedules might be arrived at fairly easily by hand. What seems more important, therefore, than a closed form optimization method is a system that can help a human planner to set up a schedule and that can quickly evaluate the schedule in terms of revenue and cost.

Setting up a schedule involves arranging and rearranging flights in different strings, determining departure and arrival times for all flights, and just putting the whole schedule on paper in a readable form. The evaluation of the schedule in terms of cost and revenue involves large numbers of tedious calculations for each flight. Following the pattern of most airline planning systems (3), PLATO does not perform any optimization, but concentrates on schedule editing and evaluation.

An overview of PLATO is given in Figure 3. By far the greatest part of the system is taken up by the generation of the demand function. The demand for air transportation is determined by city pair on the basis of a wealth of socioeconomic and geographic data. In this process the competition from all surface transportation modes is considered explicitly. The city pair demand functions are then assigned to the relevant airport pairs to form airport-pair demand functions. The virtue of the approach of PLATO is that all geographic and socioeconomic data are processed in the modules for local and interregional route generation and demand generation. These modules require large core space and considerable computer time, but they are used only once for any given situation. For each airport pair they arrive at two functions in which the traffic can be calculated by inserting schedule variables. This minute number of functions is then used to evaluate as many schedules as desired with a minimum amount of computer time. A special feature in the system permits the evaluation of one schedule for two different years at the same time.

ROUTE GENERATION MODULE

The route generation module preprocesses some of the input required for the local demand generation module. It takes as input the complete transportation network of the region. Highway, railway, and potential air route networks are entered separately in the forms in which they can be most easily obtained. The program converts them into the form required for the calculations.

Common to all three networks are nodes to represent the cities of the region. Other nodes are defined to represent junctions or changes in the travel speed. A number of auxiliary nodes may be defined to represent times spent to get through airport terminals or railway stations or to make connections. An example for the nodes and arcs that might be associated with one city is given in Figure 4. Figure 5 gives a schematic overview over the route generation module. The algorithm used to find the fastest routes is the one by Floyd (4).

DEMAND GENERATION MODULE

PLATO differentiates between two different kinds of demand for air transportation, namely, purely local demand—the trip originates and terminates within the region—and interregional demand—the trip originates in the region and terminates outside or vice versa. Each kind of demand is determined in a separate module. The essence of these modules is that they take the large volume of socioeconomic and geographic data and reduce them to a very small size. This permits the succeeding schedule evaluation module to work with only modest core requirements. Overviews of the two modules are given in Figures 6 and 7.

The total interregional demand that originates in a district is obtained as a function of socioeconomic and geographic parameters of that district. The model was developed using traffic data for 130 German districts obtained from the airport passenger survey of 1971. Numerous model assumptions were tested. The model that yielded the best fit had the following form:

$$Y = a \times PD^{b} GP^{c} CP^{d} [(EP - EMP)/EP]^{e} + f \times AD^{g} B^{h} \times (1/P) \qquad (1)$$

where

- $\hat{Y}$ = estimated number of annual interregional passengers per 1000 inhabitants,
- PD = population density (inhabitants per square kilometer),
- GP = gross domestic product per 1000 inhabitants,
- CP = number of businesses per 1000 inhabitants,
- EP = number of employees per 1000 inhabitants,

Figure 3. PLATO overview.

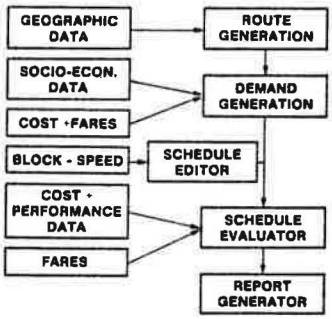


Figure 4. Nodes and arcs for Vienna.

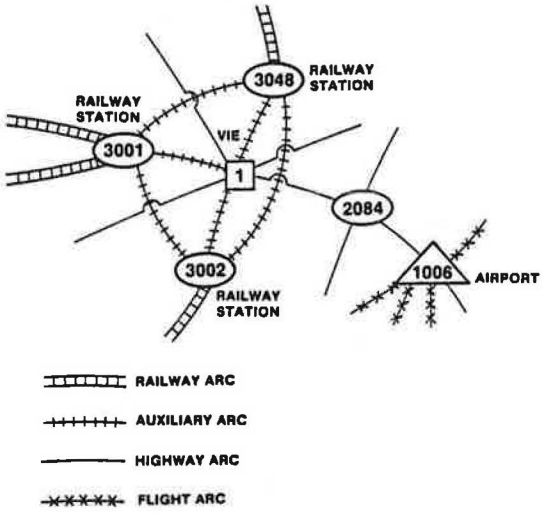
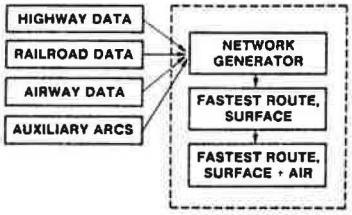


Figure 5. Route generation module.



EMP = number of employees in manufacturing per 1000 inhabitants,
AD = aircraft movements at the nearest large airport, divided by the square of the distance to that airport (a value of 10 km was used if the actual distance would have been less than that),
B = number of hotel beds, and
P = population in 1000s.

The rationale for this model formulation developed from two reasons for the transportation activity of a district. The first is the economic power of the region itself; this is represented by the first part of the equation. The second reason is the existence of transportation facilities. Although this reason cannot be separated completely from the indigenous traffic, the relationships, which govern this kind of traffic, are clearly different. The kind of traffic generated by the availability of transportation facilities would have not only the form of vacation tourism but probably, more importantly, the form of what one might call business tourism.

Business meetings of all kinds are held at places that are easily accessible. In the long run, the availability of transportation facilities tends to change the structure of business located in a district, encouraging settlement of businesses that are either origins or destinations of travel. The second part of our equation gives a modest account of this dependence.

Figure 6. Demand generation module.

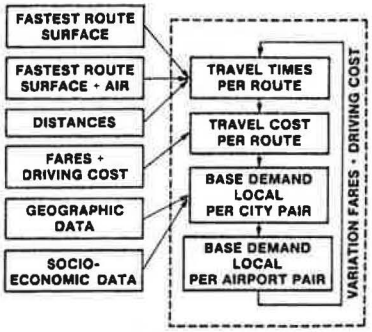
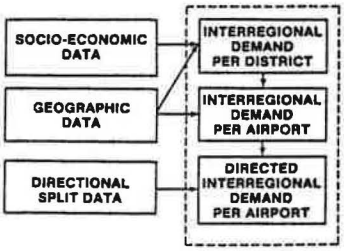


Figure 7. Interregional demand generation module.



Although overall the model provided a good fit, there is one difficulty, which eventually led us to abandon it in the Austrian study. The specific number of interregional passengers per district varies widely, ranging from a high of 1890 passengers per 1000 inhabitants for Frankfurt to a low of 41 for Gelsenkirchen. All districts in Steiermark are definitely at the low end of this range, where the variance would introduce a considerable uncertainty into the estimate. Thus the confidence in the model is no greater than the confidence in simple extrapolations from past traffic data and estimates. Therefore, in the Austrian study, such estimates, scaled up according to growth projections for local demand, were used in place of the model.

The total interregional demand that originates in a district is initially determined in undirected form. This demand is then split up according to destinations of travel prevailing in the area. In the Austrian study a total of thirteen destination regions was used. Initially, all interregional demand originating in a district is assigned to the nearest airport. How much of that demand actually uses that airport and how much travels by surface directly to the nearest hub is a function of the schedule offered and is determined in the schedule evaluation module.

For the purely local demand a multistage model is used. The local traffic attracted by some flight segment is assumed to be dependent on some base demand for that airport pair, the departure time, and the frequency with which the airport pair is served. The functional relationship is assumed to have the form

$$\text{Demand} = \text{XLD} \times \text{SERLEV} \times [\text{LD/F1(NF)}] \quad (2)$$

where

Demand = local traffic attracted by some flight,
XLD = the base demand,
SERLEV = service level of the route as a function of the frequency offered,

LD = value of the time-of-day preference, and
F1(NF) = maximum possible sum of the time-of-day preferences for the given frequency NF.

The base demand XLD between an airport pair is obtained as the sum of the base demands CLD between those city pairs that use the given airport pair. CLD for a given city pair i, j is given by the following function:

$$CLD = FI \times DT^{\alpha} \{ [f(B_i B_j) + f(D_i D_j)] / [f(DP) E_{ij}^{\beta} A_{ij}] \} \quad (3)$$

where

FI = calibration coefficient,
DT, DP = differences in travel time and price respectively for shortest route for surface transportation alone and shortest route including air transportation,
B_i = population of city i,
D_i = gross domestic product of city i,
E_{ij} = straight line distance between i and j, and
A_{ij} = mean of airport access and egress times for cities i and j.

CLD is set to zero if the time gained by using air transportation is so small that it would not justify the increased cost. It is assumed that time has a certain value for each traveler and that he or she would be willing to pay only up to a certain amount for every hour saved. The cut-off value is a variable that can be set by the user.

As was mentioned previously, the basis for these models is work done by Intertraffic (1) for North Rhine-Westphalia and by Nüsser (2). The function for the base demand is taken almost directly from Intertraffic. The major modification was necessary because no detailed balance of economic accounts is available for Austrian districts. For this reason, the gross domestic product had to be substituted in place of the gross domestic product for services required by the Intertraffic model. The most adverse effect of this substitution was eliminated by scaling and by means of a calibration coefficient.

The function Demand is a device used to consider some criticism that was already leveled by Nüsser against the Intertraffic model. The time-of-day dependence does not appear pronounced enough for the very short distances of interest here. Nüsser derived a more appropriate function, but he correctly pointed out that incorporation in the Intertraffic model would lead to changed coefficients. We tried to get around this problem by separating the frequency dependence of demand from the time-of-day dependence.

Thus we determined for each frequency the maximum number of passengers who can be attracted under optimum departure times. This is given by XLD × SERLEV, with SERLEV derived directly from the time-of-day function of Intertraffic. Then the actual traffic on a flight is determined using the actual weights under Nüsser's function relative to the maximum values possible under the given frequency. Certainly this procedure would be open to criticism. Also, good judgment has to be used in its application. As we will show, however, the results obtained thus far have been quite convincing.

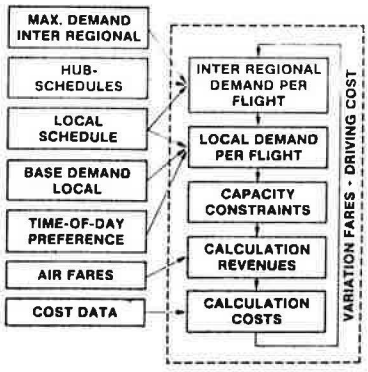


Figure 8. Schedule evaluation module.

The demand generation module only calculates XLD for the local demand. The calculation of Demand is left to the schedule evaluation model. The demand generation module is set up in such a way that results for different functions for the cost of surface and air transportation can be used in one run. This permits the user to perform a certain amount of sensitivity analyses with a minimum effort.

SCHEDULE EVALUATION MODULE

This module performs a highly efficient computation of the total cost and revenue associated with a given schedule. By producing results for a number of variations of some parameters in one run it facilitates a sensitivity analysis of the results.

The basic structure of the module is given in Figure 8. The module consists essentially of four more or less independent parts:

1. Processing interregional demand,
2. Processing local demand,
3. Considering aircraft capacity, and
4. Calculating cost and revenues.

All data entered in this module have been reduced to a form beyond which they could not be reduced without the knowledge of the flight schedule actually offered. The reason, of course, is that, while the proceding modules will be used only once for any given problem, one will want to evaluate many different schedules. Minimizing the work to be done within this module therefore means minimizing the total computational effort required for PLATO. It also means that this module can be operated from a terminal with fast run and response times.

The maximum interregional demand XJD_{ij} from airport i to region j is obtained as output of the interregional demand generation module. If airport i is not itself a hub, then this demand may be assigned to flights from i to any hub, provided they permit reasonably good connections. To permit this check all flights from the possible hubs to the different regions must be entered into the program. This is done in the form of a list that gives the number of non-, one-, and multistop flights to and from each region for each hub for every hour. The user must also enter a maximum value CT1 of the connect time accepted in each hub. Then for each local airport i and for each destination region j the following procedure is followed.

For each possible hub k all connections i→k→j are identified that use a connect time of less than CT1. If one or more connections can be found, then XJD_{ij} is split between them in proportion to their value 1/(number of stops × distance i→k→j). If the shortest connection available requires a connect time TC > CT1 and surface transportation is available to the nearest hub, requiring a time TS, then XJD_{ij} [(TS/TC)/[(TS/TC) + (TC/TS)]] is assigned to the shortest connection. The rest are assumed to travel to the nearest hub by surface transportation. If no connection can be found, all demand XJD_{ij} travels to the nearest hub by surface transportation.

A distinction is made between hubs inside the region and hubs outside of it. While the traffic that moves by

surface to a hub outside the region is of no further interest, the traffic that moves to a hub inside the region can be loaded on flights departing from that hub.

The procedure used to determine the local traffic generated by a flight was essentially outlined in the discussion of the demand generation module and will not be repeated here. It requires a time-of-day preference curve and a service level function. The time-of-day preference curve permits one to read off directly a preference value LD for each departure time.

We feel that this approach is more reasonable for a local air service environment than one that integrates the demand over a region of attraction for each flight, especially if that region of attraction reaches to the zones of indifference of the preceding and the succeeding flight. The reason is that the approach chosen here permits a better representation of the elasticity of demand. Difficulties arise when two or more flights are scheduled too close to each other so that they are competing for the same passengers. This can always be ruled out if the schedule is properly set up. In the environment of interest here any such schedule does not appear reasonable. If it were desirable to consider such situations, however, it would not be difficult to enter special provisions into the system.

PLATO permits the use of different time-of-day preference curves for each airport pair. On some routes the demand might arise mostly from business travel with a strong preference for flights near the beginning and end of the business day. On other routes there might be a substantial share of tourists who tend to prefer flights closer to the middle of the day. Recognizing this fact might permit a high utilization of the fleet at a comfortable average load factor and thus lead to reasonably profitable operations.

The service level function (SERLEV) multiplied by the base demand gives the maximum traffic that can be generated with some frequency NF. This traffic can be realized if the flights are placed optimally throughout the day, in which case the sum of the time-of-day preference factors is given by F1(NF). The traffic actually generated is proportional to the actual values of the time-of-day preference factors LD for each flight or their sum for the entire route.

The function SERLEV is characterized by an s-shape. While the first frequency will attract a relatively small volume of traffic, additional frequencies will attract increasing volumes corresponding to the penetration of the market. From a certain frequency onward, the increase in traffic volume will start to decrease, indicating beginning saturation. Eventually the curve will become completely horizontal. The width of the s is strongly dependent on the length of the route and the shape of the time-of-day preference curve. Obviously, the longer the route, the steeper the ascent. For extremely long routes the first frequency can attract all the traffic that can be generated on the route, and additional frequencies can only be justified for capacity reasons. A similar observation can be made for a route with a very pronounced peak in the time-of-day preference curve.

The limited aircraft capacity is simply treated as a restriction on the traffic that can be carried on one flight. In order to take into account the random day-to-day variations of traffic, it is reasonable to reduce the true aircraft capacity by some maximum average load factor. Any traffic that cannot be accommodated is assumed to be lost. We do not believe that in the local air service environment, at least in operations below the point of beginning saturation, it would be reasonable to reassign this demand to flights at other departure times. Excess traffic is removed in increasing order of the per capita revenue.

The last part of this module, the calculation of cost and revenues, is just a lot of multiplication and addition. The only thing that deserves mentioning is that any conceivable cost function can be handled by it. Along with cost and revenue data, statistics on seat kilometers offered, revenue seat kilometers, and average load factors are compiled per aircraft type.

SCHEDULE EDITOR AND REPORT GENERATOR

The schedule editor permits the user to develop a schedule on a terminal without having to perform any calculations in his or her head or on the side. Thus for any flight with a given departure time, it automatically calculates the arrival time and the earliest possible departure time for the following flight. The schedule is developed in the form of aircraft rotations, and the user can insert or delete flights from a string of flights without having to redefine the whole string. The schedule editor also performs a number of elementary feasibility checks. At the time of this writing, the schedule editor is still not in its final form, and we therefore prefer not to give any details.

The report generator produces a report of the economic results of each flight. For multistop flights, traffic figures are given for each origin-destination (O-D) pair as well as for the flight segment. Also shown are the passengers by O-D pair that could not be accommodated. For interregional flights it is possible to show the traffic originating or terminating in the region without concern for other traffic or cost and revenue figures.

In addition, a summary report is printed. All the intermediate results from the route generation and demand generation modules can be displayed optionally.

RESULTS AND VALIDATION

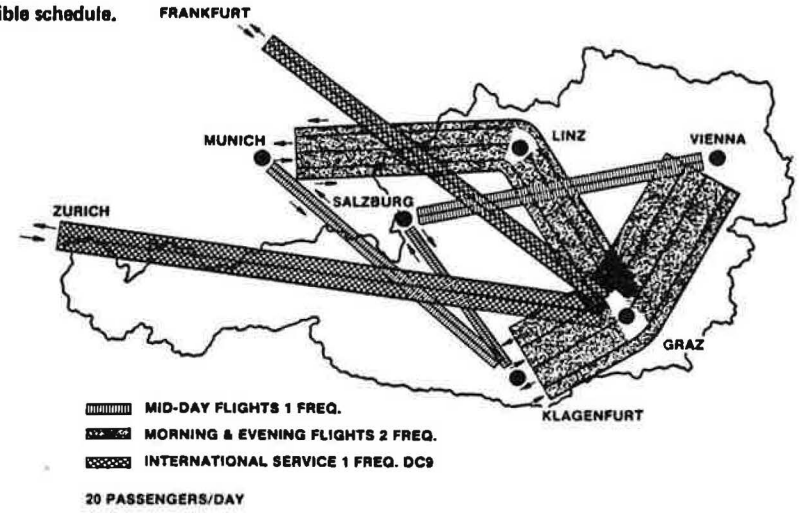
The objective of this study was to demonstrate if and how a viable local air service for Steiermark could be developed. The objective was not satisfied by producing some form of optimum schedule. Rather, a lot of judgment and restraint had to be used to develop a reasonable schedule that would be attractive to all parties concerned. Reasonable meant not only keeping any kind of financial risk within limits but also passing the minimum threshold that would make future growth possible.

Following this, a number of different schedules were produced. All these schedules offered a maximum of two daily frequencies on any route. The results for one of the most attractive schedules in the sample printouts using Fokker F27 equipment are shown graphically in Figure 9. The table below gives a summary of the economic results for that schedule, including some sensitivity analysis.

	Year					
Variable	1975			1985		
Fare	1.00	1.25	1.25	1.00	1.25	1.25
Driving cost	1.00	1.00	1.25	1.00	1.00	1.25
Load factor	52	46	52	56	45	56
Revenue: DOC	1.03	1.12	1.27	1.12	1.08	1.38
Including fuel tax	0.81	0.89	1.00	0.87	0.87	1.09

It can be seen that revenue in all cases covers the direct operating cost so long as the domestic fuel tax is not levied. If the fuel tax has to be paid, it is almost impossible for the revenues to cover the direct operating cost. It is interesting to note that the highway projects, which are expected to be completed by 1985, have a stimulating effect on air traffic. Not only do they de-

Figure 9. Proposed possible schedule.



crease the airport access times, but they increase the attraction between districts, leading to a general increase in travel activity.

The results obtained appear quite reasonable and realistic. Since the proposed air service has not yet been realized, it is not possible to check the model results against reality. We were, however, fortunate that at the end of our study a completely independent proposal for local air service was developed by Austrian Airlines (AUA).

	Load Factor	
Schedule	AUA	PLATO
I	50	46
II	55	43
III	45	46

They were considering three schedule alternatives. Their traffic predictions were made without sophisticated models but using the best judgment of the airline. We evaluated all three schedules by means of PLATO. A comparison of results given in Table 2 shows a reasonably good agreement. We should add, however, that these three schedules were economically much less attractive than schedules we developed.

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Model to Estimate Commuter Airline Demand in Small Cities

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This paper considers the factors indicating a community's potential demand for commuter air carrier service, compares these factors to a profile of commuter airline passenger characteristics, and reports the results of an extensive regression analysis to develop a model to estimate commuter airline demand in small cities. The final regression model was nonlinear in nature and incorporated community populations and measurements of isolation from the certificated air carrier transportation system. This model was the basis of a recommended program to integrate commuter air carriers into Iowa's total transportation system.

Historically, commuter air carrier service has had a general public image of instability. This image resulted from operational failures and discontinuing service to cities along system routes. Primary reasons for such failures and service interruptions are associated with financing, operations, and marketing. Specifically, the aircraft being used have been too large for the markets being served; the operators have not been able to fi-