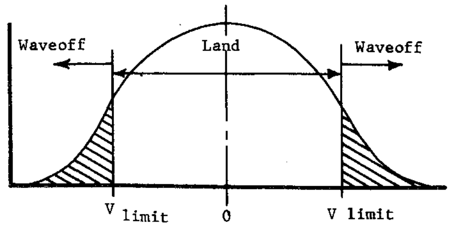

Fig. 11 Crossrunway speed.

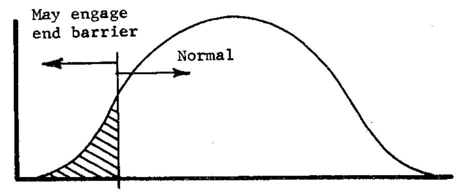

Fig. 12 Braking force on grooved, wet runway.

at the takeoff decision point (see the preceeding Sec. STOL Runway Markings) must be compatible with the V_1 speed definition and requirements.

12) The aircraft operator will define the engine power/thrust deterioration limits he will accept. Acceleration performance will be based upon that minimum value, and propulsion system maintenance quality controls will be established to ensure the limit is not exceeded.

13) The takeoff will be aborted in the event of a sudden thrust loss, normally resulting from a sudden engine failure, occurring before passing the takeoff decision point. Automatic warning devices may be required.

14) The takeoff will be continued in the event of a sudden thrust failure after passing the takeoff decision point. In this event the aircraft must not descend below the flight-path gradient defined in the Sec. STOL System Requirements. Flight test must confirm this capability to within the required probability.

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Intercity V/STOL Service and the Businessman Traveler

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Nondemographic data, including attitudinal and preference structures, are generated for a demand analysis of two feasible V/STOL systems assumed to be suitable for operation in a business travel market composed of New York, Philadelphia, and Washington, D.C. A sample of frequent or potential businessman travelers was surveyed by a comprehensive questionnaire, the results serving as input to a linear, nondemographic factor, mode choice-market share model designed to predict modal splits in a future environment. The model is applied to the selected V/STOL designs and the resulting predictions are assessed with respect to technological planning.

I. Introduction

FORECASTS of the demand for V/STOL aircraft service in the Northeast Corridor and elsewhere generally rely on gravity, interactance, abstract, or utility models of modal split based on historical travel and demographic data. The techniques developed by Howrey and by McLynn and Woronka are typical demographical approaches.[1-2] Most V/STOL demand analyses with demographic foundations present an optimistic forecast; that is, they conclude that fast, short haul, intercity service at reasonable rates and with minimum ground connection delay will lure large volumes of travelers away from other modes of transportation. Critics challenge this optimism by arguing that travelers will not choose an unfamiliar aircraft with a potentially high accident rate, given the unlikely assumption, in their judgment, that V/STOL's will be permitted to land in downtown areas where noise and pollution levels are already unacceptable. The dilemma to the aircraft industry is enigmatic. Should aircraft be developed at great expense on the premise that travelers prefer the service that V/STOL's potentially offer? Suppose travelers are not willing to exchange the relative comfort, low cost, and low risk of conventional systems for the reduced travel time and greater convenience of a V/STOL system? On the other hand, even though travelers may prefer V/STOL's over other modes, local governments may banish them to conventional airports or to other suboptimal landing areas where their advantages are nullified. This latter prob-

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lem is political, and will undoubtedly be influenced by the acceptance of V/STOL technology by ecologists, city planners, urban residents, and the traveling public. Although of great interest and challenge, this problem will not be analyzed here. It is the first problem, that of predicting actual mode choice, that is of immediate importance. If it can be shown that few people will actually choose to use a V/STOL system, then aircraft development will be uneconomic and the problem of community acceptance merely academic.

Predicting user acceptance of a technological innovation is an inexact science.[3] The optimistic nature of V/STOL forecasts based on deomographic data may be due to the trend characteristics of this data and not to a true measure of traveler mode choice behavior. It is easy to correlate gross intercity travel volumes with city populations, mean personal incomes, residential densities, and other independent demographic factors. It is sometimes forgotten that all such variables have followed similar trends for years, always upward, and although one may predict their future values with high statistical confidence, these variables do not explain certain critical phenomena. Why have STOL and helicopter services failed to attract economic volumes? Why is bus travel viewed as low-status, and why does the average citizen become so attached to his automobile? The behavioral puzzles are explainable in terms of traveler attitudes, experience, and travel objectives, all of which are nondemographic variables. One cannot quantify them by simple overt counting procedures. Yet these variables determine mode choice at the level of the individual, and must therefore be included in any valid estimate of V/STOL demand.[4] If travelers will not choose V/STOL service in a future environment, preferring other modes of travel, then such a service will surely be uneconomic regardless of the fact that the environment may be affluent and apparently hospitable to V/STOL service on the basis of demographic indicators.

II. Nondemographic Theory

The prime market for downtown-to-downtown V/STOL service appears to be short haul intercity business travel. V/STOL's offer the opportunity for minimum door-to-door travel time and maximum convenience, but they will probably require a premium fare, at least initially. Time is most important to the businessman traveler and to the individual traveling on urgent personal business, the former constituting the larger group.[5] Companies are generally willing to pay premiums for significant time savings; the cost of unproductive executive time is high and business opportunities may be lost because of delay. Consequently, an analysis of the mode choice behavior of businessman traveling on short haul routes should provide valid insights into any future market for intercity V/STOL service.

Businessman traveler mode choice analyses conducted in the Midwest by Sommers and Leimkuhler provide strong empirical evidence that middle management businessmen traveling for large corporations base their mode choices on the factors of total door-to-door travel time, convenience, safety, weather reliability, comfort, and cost, in that order of importance.[6-7] A mode choice-market share model derived from the Midwest data suggested that mode market shares could be predicted for disaggregate trip purposes, traveler populations, and origin-distination city pairs. This encouraging result led to an expanded validation study conducted during 1969 in Washington, D.C., and designed to identify the mode choice determinants of businessmen traveling to Penn Center, Philadelphia, and to downtown Manhattan, New York City. Two hundred and eighty-seven businessmen completed detailed questionnaires similar to those employed in the earlier Midwestern studies. Semantic differential, constrained choice, and open ended questions attempted to determine how each respondent made mode choices for hypothetical but contemporary business trips to Philadelphia and New York given routine business travel purposes. Again, travel time and convenience were most important, but comfort preceded safety for this Northeastern sample, followed by weather reliability and cost, in that order. The short distances in the Northeast Corridor and the common high level of congestion apparently place an emphasis on speed, convenience, and comfort not to be found in the more spacious, less congested Midwest. Although the comprehensive survey is of intrinsic interest, and reported elsewhere, the main value of the Washington study lies in its application to predictions of V/STOL marketability.[8] The nondemographic data collected therein is adaptable to such forecasting and generates a new approach to the V/STOL marketing problem.

Statement of a mode choice-market share model for predicting the market shares of competing modes in present or future markets is now appropriate. Let a_{ijk} represent a measure of average traveler acceptance of mode i on the basis of some factor j for a trip to destination k. This measure is termed a mean acceptance index, and is derived from survey attitudinal data.[9] In the Washington study of interest, mean acceptance indices were derived for automobiles, trains, airlines, and buses serving New York and Philadelphia. Indices were generated for each of the six nondemographic factors found to be the major determinants of business travel mode choice. Additionally, let K_j represent the mean importance ranking for factor j, a universal value independent of destination. In other words, hypothesize that for a given traveler population faced with a specific trip purpose independent of destination, mode choice is determined by a set of factors one of which is most important to the average traveler, another is second most important, and, finally, one is least important. If levels of factor importance are quantified by a ranking procedure on a questionnaire survey, wherein each respondent ranks his most important factor first, the second most important second, and so on, then on a mean basis the most important factor for the sample population is that factor with the lowest mean rank. For f factors, then

$$K_1 \leq K_2 \leq K_3 \ldots \leq K_f$$

where K_1 identifies the most important factor. The mean rankings K_j are relative quantities which can be measured on a simple linear scale from 1.0 to f. The positive difference between any two adjacent rankings, or $K_{j+1} - K_j$, is therefore a measure of the relative difference in importance between factors j and $j + 1$, where j is more important than $j + 1$.

A nonattitudinal measure of traveler mode preference is actual modal split for a particular trip purpose and destination. This data is available for the Washington sample of businessman travelers, and is defined by a set of m_{ik}, the market share or modal split, for mode i for a business trip to destination k. As expected, airline travel was most preferred, followed by autmobile and train, for both destination cities. Buses were not considered by the sample respondents. This, of course, is a reflection upon the corporate need for high-status travel when traveling on an expense account.

Consider now a market share model given by

$$\sum_{j=1}^{6} a_{ijk}x_j + x_k = m_{ik} \tag{1}$$

where x_j is defined as a weight for factor j, and x_k is an origin-destination constant. Equation (1) states that mode i's market share to destination k for a specific traveler population and trip purpose is a linear sum of a set of acceptance index-factor weight products. This model is an hypothesis, of course, but also a reasonable analogy to traveler behavior. If a traveler assigns mental weights to a particular factor for a particular trip, and if he modifies these subjective weights with a realistic or intuitive assessment of mode acceptability, then Eq. (1) is a logical model of his decision process. For one

Table 1 Good weather acceptance indices

	Time	Convenience	Comfort	Safety	Cost	m_{ik}
1) Washington–Philadelphia						
Auto	.6632	.7387	.6597	.6452	.7631	.296
Air	.6661	.6418	.8124	.8391	.8624	.578
Train	.6202	.6179	.6992	.8461	.8479	.126
2) Washington–New York						
Auto	.5052	.5459	.5709	.5720	.6336	.101
Air	.7491	.7253	.8258	.8026	.8868	.790
Train	.6249	.6585	.6934	.8421	.8438	.109

Table 2 Acceptance index reduction chart

	Percent of good weather index			
Weather condition	Time	Convenience	Comfort	Safety
Automobile				
Intermittent rain	90	100	100	100
Steady light rain	80	100	100	90
Heavy rain	60	85	75	60
Fog	20	50	70	40
Light falling snow	40	75	70	80
Icing conditions	35	70	70	50
Airline				
Intermittent rain	100	100	100	100
Steady light rain	100	100	95	100
Heavy rain	90	60	60	90
Fog	50	80	90	85
Light falling snow	100	85	85	90
Icing conditions	70	80	80	85
Train				
Intermittent rain	100	100	100	100
Steady light rain	100	95	100	100
Heavy rain	90	80	95	95
Fog	80	80	95	85
Light falling snow	100	80	95	100
Icing conditions	90	80	95	85

individual, m_{ik} is a zero-one variable. For a population or market segment, m_{ik} is logically an aggregate market share.

What are the values of x_j and x_k for contemporary markets? If the a_{ijk}, m_{ik}, and K_j are known from survey analysis, then the x_j and x_k may be computed by making the logical assumption that

$$x_j - x_{j+1} = (K_{j+1} - K_j)x_{pk} \qquad (2)$$

where x_{pk} is a proportionality constant for destination k. This is, the difference between factor weights is linearly proportional by x_{pk} to the mean importance rankings. Consequently, according to Eq. (2), $x_1 \geq x_2 \geq x_3 \geq \ldots \geq x_6$ where x_1 is the factor weight for the most important factor. For the six deterministic factors in business travel, and for the three modes used by business travelers in the Northeast Corridor, Eq. (1) generates three equations and Eq. (2) generates five, the combination of eight equations possessing eight unknowns, the x_j, x_k, and x_{pk}. These variables may then be solved by simultaneous equation techniques to deliver a set of factor weights relevant to contemporary travel between Washington, D.C., and New York and Philadelphia. Nondemographic factors are thereby quantified into constants analogous to those appearing in traditional demographic regression analyses.

III. Application to the Corridor

To illustrate the first step in a nondemographic factor V/STOL forecast, Table 1 gives a condensed set of standardized acceptance indices for business travel between Washington, D.C., and New York and Philadelphia. Each index is derived from survey data: each is the mean of a response distribution drawn from a seven-point semantic differential. Note that an index of unity represents total acceptance or maximum satisfaction, whereas an index of zero represents complete rejection or maximum dissatisfaction. For example, it is evident from Table 1 that air travel is slightly more satisfactory than travel by automobile for a trip to Philadelphia on a time criterion. Indeed, the majority chose air travel as their preferred mode, as given in the market share, or m_{ik}, column. In good weather, of course, weather reliability is at its maximum. The corresponding index is therefore unity.

Table 1 represents average businessman traveler mode acceptance in good weather. What are equivalent acceptances for inclement weather, especially the adverse conditions which characterize the Northeast Corridor? Obviously, this is a comprehensive question because of the diversity of ad-

Table 3 Washington–Philadelphia acceptance indices

	Time	Convenience	Comfort	Safety	Weather	Cost	Modal split
1) Intermittent rain							
Auto	.5969	.7387	.6597	.6452	.8107	.7631	.265
Air	.6661	.6418	.8124	.8391	.7991	.8624	.645
Train	.6202	.6179	.6992	.8461	.9379	.8479	.090
2) Steady light rain							
Auto	.5306	.7387	.6597	.5807	.7067	.7631	.223
Air	.6661	.6418	.7718	.8391	.8508	.8624	.662
Train	.6202	.5870	.6992	.8461	.9210	.8479	.115
3) Heavy rain							
Auto	.3979	.6279	.4948	.3871	.4152	.7631	.129
Air	.5995	.3851	.4874	.7552	.6121	.8624	.470
Train	.5582	.4943	.6642	.8038	.8299	.8479	.401
4) Fog							
Auto	.1326	.3694	.4618	.2581	.2073	.7631	.066
Air	.3331	.5134	.7312	.7132	.2178	.8624	.195
Train	.4962	.4943	.6642	.7192	.6568	.8479	.739
5) Light falling snow							
Auto	.2653	.5540	.4618	.5162	.3601	.7631	.098
Air	.6661	.5455	.6905	.7552	.6231	.8624	.544
Train	.6202	.4943	.6642	.8461	.7904	.8479	.358
6) Icing conditions							
Auto	.2321	.5171	.4618	.3226	.0877	.7631	.049
Air	.4663	.5134	.6499	.7132	.3484	.8624	.272
Train	.5582	.4943	.6642	.7192	.6022	.8479	.679

Table 4 Washington–New York acceptance indices

	Time	Convenience	Comfort	Safety	Weather	Cost	Modal split
1) Intermittent rain							
Auto	.4547	.5459	.5709	.5720	.8159	.6336	.087
Air	.7491	.7253	.8258	.8026	.8937	.8868	.833
Train	.6249	.6585	.6934	.8421	.9326	.8438	.080
2) Steady light rain							
Auto	.4042	.5459	.5709	.5148	.7073	.6336	.080
Air	.7491	.7253	.7845	.8026	.8455	.8868	.825
Train	.6249	.6256	.6934	.8421	.9245	.8438	.095
3) Heavy rain							
Auto	.3031	.4640	.4282	.3432	.4425	.6336	.041
Air	.6742	.4352	.4955	.7223	.6400	.8868	.568
Train	.5624	.5268	.6587	.8000	.8304	.8438	.391
4) Fog							
Auto	.1010	.2730	.3996	.2288	.1992	.6336	.031
Air	.3746	.5802	.7432	.6822	.2671	.8868	.262
Train	.4999	.5268	.6587	.7158	.6731	.8438	.707
5) Light falling snow							
Auto	.2021	.4094	.3996	.4576	.3856	.6336	.044
Air	.7491	.6165	.7019	.7223	.6074	.8868	.650
Train	.6249	.5268	.6587	.8421	.8002	.8438	.306
6) Icing conditions							
Auto	.1768	.3821	.3996	.2860	.1156	.6336	.031
Air	.5244	.5802	.6606	.6822	.3717	.8868	.314
Train	.5624	.5268	.6587	.7158	.6336	.8438	.655

verse states of nature, all of which undoubtedly influence user perceptions of mode performance. A satisfactory answer would be derived from survey questions designed to elicit respondent assessments of mode acceptance under a set of representative poor weather conditions. Unfortunately, resource limitations prevented this depth of analysis in the pilot survey of Washington, D.C., businessmen. Although a complete businessman survey covering adverse weather conditions proved to be infeasible, the factor of weather reliability was measured as a function of six conditions: intermittent rain, steady light rain, heavy rain, fog, light falling snow, and surface icing. Survey data is therefore considered valid with respect to the weather reliability factor. What about the other factors, however? Given the exploratory research nature of the survey, and the fact that it demonstrates a methodology rather than presenting a definitive set of predictions, it is reasonable to derive a set of hypothetical respondent reactions to poor weather mode performance. Consequently, for all factors other than weather reliability, a panel of four businessman travelers was asked to judge mode acceptability under the aforementioned six weather conditions and to report their mean assessments as percentages of good weather acceptance. The results appear as Table 2.

It should not be implied that mode weather performance can be adequately assessed by a nonrepresentative respondent panel. It is reasonable to argue in any technological assessment procedure, however, that one judgment is less desirable than many. In many instances, complete data is unavailable to the analyst. He must then attempt to generate data with as much face validity as he can muster. This approach is taken for the generation of Table 2.

It is assumed that cost acceptance is not a function of weather severity. To illustrate the meaning of Table 2, an examination of the column under the factor of total door-to-door travel time shows that, for automobile travel in fog, acceptance is reduced to but 20% of its good weather value. Twenty per cent is the value generated by panel concensus. Comparing this reduction to that for airline travel, given as 50%, and to train travel, appearing as 80%, it is evident that in fog a train is regarded as the fastest mode of transportation. Indeed, 73.9% of the businessman sample would choose a train for a fog-bound ride to Philadelphia. This modal split appears in Table 3, a compilation of acceptance indices computed from Tables 1 and 2. Table 4 is an equivalent compilation for travel to New York. For this longer trip, 70.7% of the sample would choose a train for a trip under fog conditions.

Given Tables 1, 3, and 4, and given survey-derived importance rankings expressed in the restriction set comprising Table 5, it is possible to calculate sets of factor weights characteristic of business travel to Philadelphia and New York. Based on the population samples, computed factor weights emerge as Tables 6 and 7. Since only the factor weights themselves will be used for forecasting purposes, the proportionality and origin-destination constants are omitted from the tabulations. Also, since no restrictions on sign are included in the model, many factor weights are negative. The sign is immaterial. It is the relative position of each weight on a linear scale that is important. Transposition onto a purely positive scale is both feasible and desirable with no loss of information.

Tables 6 and 7 are unusual in that they display nondemographic data in a unique, quantified format. The tabulated factor weights reflect the mode choice preferences of businessman travelers, and no other segment of the traveling public. That is, the weights are unique to a specified market identified by trip purpose, trip origin, trip destination, and socioeconomic group. There is little doubt that traveling students, or migrant workers, would have completely different mode choice structures. Total intercity modal splits, of course, are the sum of the modal splits for each market segment, the former in volumetric units.

IV. V/STOL Aircraft Selections

V/STOL aircraft types selected for a demonstration of nondemographic demand forecasting are a deflected slipstream STOL and a stowed rotor VTOL.[10] The choice of these air-

Table 5 Factor importance restriction set

$$K_2 - K_1 = 2.5819 - 2.2195 = 0.3624$$
$$K_3 - K_2 = 4.0837 - 2.5819 = 1.5018$$
$$K_4 - K_3 = 4.7056 - 4.0837 = 0.6219$$
$$K_5 - K_4 = 5.1586 - 4.7056 = 0.4530$$
$$K_6 - K_5 = 5.9670 - 5.1586 = 0.8084$$

Table 6 Washington–Philadelphia factor weights

	Time	Convenience	Comfort	Safety	Weather Reliability	Cost
1) Good weather	3.5557	3.2374	1.9186	1.3725	0.9747	0.2648
2) Intermittent rain	5.5736	4.9345	2.2862	1.1895	0.3907	−1.0348
3) Steady light rain	4.7348	4.1389	1.6695	0.6469	−0.0979	−1.4272
4) Heavy rain	2.2859	1.9267	0.4383	−0.1780	−0.6269	−1.4281
5) Fog	3.8296	3.0240	−0.3144	−1.6969	−2.7038	−4.5009
6) Light falling snow	1.4271	1.2095	0.3078	−0.0654	−0.3374	−0.8227
7) Icing conditions	26.329	21.759	2.8198	−5.0229	−10.736	−20.930

craft is an arbitrary one. Any design would be equally demonstrable. Table 8 gives aircraft data such as block speed, direct operating cost or DOC, indirect operating cost or INDOC, and landing fee. This data is used for estimating return trip travel characteristics for 1985 as shown in Table 9. Again, the choise of 1985 as a forecasting horizon is arbitrary, but one commonly used by industry forecasters. The following assumptions are also made: 1) total return times are based on the Rand McNally mileages given as 225 miles between Washington and New York and as 142 miles between Washington and Philadelphia. Specific destinations within these cities would be measured by point-to-point mileages or other quantities. 2) V/STOL's in 1985 will have accident records similar to those of certificated air carriers in the 1960's. Airline fatality statistics are reported as deaths per 100 million passenger-miles, a figure which will be used for analysis purposes.[11] Assuming 85% occupancy on any trip, an expected passenger complement is 102 for each V/STOL type. Expected V/STOL fatalities are therefore 0.286×10^{-8} deaths/passenger-mile $\times$ 450 $\times$ 102 passenger-miles = 0.0001312 for a Washington-New York trip, and 0.286×10^{-8} deaths/passenger-mile $\times$ 282 $\times$ 102 passenger-miles = 0.0000828 for a Washington-Philadelphia trip. 3) Fares are estimated from the following formula[12]:

$$\text{Fare} = \text{available seat-mile DOC}/0.5 \text{ load factor} \times \text{stage length} + \text{INDOC} + 10\% \text{ return} + 5\% \text{ transportation tax} + \text{landing fee per passenger}$$

Unproductive travel time for a business traveler in 1985 is taken as $23.44 per hr.[7] Total trip cost is the sum of all fares and out-of-pocket costs and the dollar value of unproductive time.

The preceding three assumptions serve to quantify the factors of time, cost, and safety. Hypothetical 1985 values appear as Table 9. Quantification of the attitudinal factors of comfort, convenience, and weather reliability is far more controversial, but it forms the foundation of a realistic V/STOL forecast.

In order to prepare market share forecasts for 1985, it is necessary to estimate mode acceptance on the basis of each nondemographic factor. Once mode acceptance indices are available, it becomes expedient to make a powerful assumption. Assume that factor weights characteristic of contemporary Northeast Corridor business travel will be characteristic of 1985 travel between the same city-pairs. In other words, assume that basic individual mode choice behavior will not change through 1985. At first glance this may seem to be a dubious assumption. Yet it is not easily disparaged on historical grounds. Travelers have consistently preferred safe, fast, convenient transportation, a preference structure that seems to remain stable in the face of advertising campaigns, government pleas, and economic inflation. Although one may argue that some modification of contemporary factor weights is essential for depicting a 1985 environment, that issue will be avoided for demonstration purposes, leaving the assumption of continuity intact.

As a different line of argument, it may be logical to insist on the assumption that mode choice behavior will change prior to 1985. Consequently, contemporary factor weights will not adequately estimate those weights expected to exist in 1985. New aircraft landing systems, for example, may greatly improve the air mode's reliability and safety over the next decade, a development that could change user attitudes toward air travel. Yet how might these changes be predicted and quantified for a transportation analysis? Any prediction would be required to assess those feasible future developments which are likely to be implemented and which would consequently influence traveler attitudes either positively or negatively. Some future implementations may attact or repel potential users. The required assessment would need to combine all such future effects into a total estimate of expected mode choice behavior change through 1985. The validity of such an estimate would be highly controversial since future technologies are themselves controversial and their effects on traveler preferences are completely hypothetical. To attempt to predict changes in future mode choice behavior would therefore gain little credibility while greatly expanding the scope of the prediction analysis. In fact, controversial predictions of future mode choice behavior could defeat the objective of formulating systematic, unbiased, contemporary market share predictions. Given this possibility, the assumption of stable factor weights becomes a reasonable systems analysis tenet.

What are the factor acceptances for airlines, CTOL's, automobiles, trains, Metroliners, STOL's, and VTOL's operating in 1985 Washington-Philadelphia and Washington-New York business travel markets? Answers are derived from the following reasonings.

1) It is likely that travel in the NEC by most conventional modes will become less acceptable as congestion increases, as facilities become obsolete, and as public pressures mount

Table 7 Washington–New York factor weights

	Time	Convenience	Comfort	Safety	Weather Reliability	Cost
1) Good weather	4.1045	3.3875	0.4161	−0.8143	−1.7106	−3.3101
2) Intermittent rain	4.1478	3.4192	0.3999	−0.8502	−1.7610	−3.3862
3) Steady light rain	3.2845	2.7254	0.4081	−0.5514	−1.2504	−2.4977
4) Heavy rain	4.7549	4.0031	0.8877	−0.4023	−1.3420	−3.0190
5) Fog	2.6145	2.0552	−0.2627	−1.2227	−1.9218	−3.1696
6) Light falling snow	1.3227	1.1013	0.1840	−0.1957	−0.4724	−0.9661
7) Icing conditions	2.3966	1.9067	−0.1234	−0.9640	−1.5764	−2.6692

Table 8 V/STOL aircraft data

	120-Passenger deflected slipstream STOL	120-Passenger stowed rotor VTOL
Block speed, mph	281	359
DOC, $ per seat/mile	0.0147	0.0203
INDOC, $ per passenger		
100 mile/block	6.4	6.4
200 mile/block	8.1	8.1
Landing fee, $ per passenger	3.15	3.15

Table 9 Return trip travel characteristics for 1985

A = Washington, D.C. B = New York C = Philadelphia	120-Passenger deflected slipstream STOL	120-Passenger stowed rotor VTOL
Air time A–B, hr.	1.59	1.24
Air time A–C, hr.	.93	.73
Origin connection A–B, hr.	.75	.75
Destin. connection A–B, hr.	1.00	1.00
Origin connection A–C, hr.	.75	.75
Destin. connection A–C, hr.	1.00	1.00
Total return time A–B, hr.	3.34	2.99
Total return time A–C, hr.	2.68	2.48
Expected fatalities per trip, $+ 10^{-5}$, A–B	13.127	13.127
Expected fatalities per trip, $\times 10^{-5}$, A–C	7.643	7.643
Fares A–B, $	40.30	34.30
Fares A–C, $	30.72	24.72
Time cost A–B, $	78.29	70.09
Time cost A–C, $	62.82	58.13
Connection cost A–B, $	5.00	5.00
Connection cost A–C, $	5.00	5.00
Total cost, A–B, $	123.59	109.39
Total cost, A–C, $	98.54	87.85

against costly, disruptive, conventional transportation construction. Albeit somewhat arbitrary, assume that the time, convenience, and comfort acceptance indices of CTOL's and automobiles will decrease by 20% through 1985. Since train travel is the subject of much contemporary research and development, as much a subject as V/STOL's themselves, it is probably wise to assume that trains will be greatly improved by 1985 on time, convenience, and comfort criteria. Thirty per cent increases in acceptance for these factors are not too far-fetched. Table 10 depicts these estimates for 1985 under good weather conditions.

2) For the selected V/STOL designs, it is logical to compare acceptance indices with the most similar competitor, conventional airliners or CTOL's. By landing in downtown areas rather than on fringe airports, V/STOL's should offer time and convenience savings of at least 25% over CTOL service. Consequently, assume that 1985 acceptance indices for these two factors are 25–30% larger than their CTOL counterparts, the former value for STOL's, the latter for VTOL's. On the other hand, CTOL and V/STOL comfort levels are likely to be similar: their comfort acceptances are therefore taken as identical.

3) With respect to safety, it is reasonable to assume that 1985 automobile and CTOL acceptances will be similar to those found today. As trains improve, however, accidents will be more spectacular and well-publicized, perhaps lowering the high safety image of this mode. A reduction of 10% in safety acceptance is assumed. V/STOL's, in a similar fashion, will be a new experience for passengers. Travelers may well view them with initial caution. V/STOL safety acceptance indices are therefore taken as 80% of the equivalent CTOL measures.

4) Although V/STOL's are expected to require premium fares, time savings will reduce the cost of unproductive travel time, a cost which greatly exceeds out-of-pocket transportation cost. Since air travel has traditionally received high acceptance in business circles, it is assumed that in 1985 VTOL service will have the highest cost acceptance index, followed by STOL's and CTOL's. Changes in automobile acceptance are unlikely, whereas train acceptance will probable increase slightly. It is therefore assumed that CTOL cost acceptance will increase by 10%, and that VTOL's will exceed the CTOL index by 40%, and STOL's by 20%. Train cost acceptance is expected to rise by 10%. All computed indices appear in Table 10.

It should be recognized that the assumptions implicit in Table 10's construction are rough predictions of conditions in a 1985 environment. They are not the result of a thorough systems engineering approach. Rather, they are estimates designed to illustrate the forecasting methodology. The serious forecaster would perform a comprehensive, perhaps Delphic, analysis to determine a set of acceptance indices for each mode operating under diverse environmental restraints. Any mode of interest could be analyzed: the technique is by no means limited to V/STOL designs, although it is particularly well-suited to the variation to be found in this proposed new mode of intercity transportation.

V. Market Share Estimates

Mode market share predictions for 1985 are generated directly by Eq. (1), then standardized to meet the logical requirement that the sum of individual market shares sum to unity. Input data to Eq. (1) computations are factor weights, Tables 6 and 7, and mode acceptance indices, Table 10. Market share estimates, or m_{ik}'s, for good weather conditions appear in Table 10 with their coincident acceptance predictions. Table 11 lists the corresponding market shares for travel under steady light rain conditions, one of many adverse weather conditions analyzed. For computational purposes, negative factor weights are eliminated by a scale shift to the positive quadrant. The sum of the minimum factor weight and 1.0 is added to each factor weight within a city-pair set. The relative position of each factor on a linear scale remains unchanged: standardization forces a set of equivalent m_{ik} predictions for each city-pair market.

Tables 10 and 11 give market share estimates for but two weather conditions. Similar tables may be prepared for each of the conditions listed in Tables 3 and 4. Predictions for each condition, of course, may be based upon different assumptions with respect to safety, convenience, weather reliability, and time. Estimates of mean annual mode market shares would be derived by evaluating historical weather data and weighting each weather condition prediction set accordingly.

Active intermode competition is assumed by Tables 10 and 11. That is, all five modes listed are assumed to be operating

Table 10 1985 Good weather mode market shares

a_{ijk}	Time	Conv.	Comfort	Safety	Cost	m_{ik}
			Washington–Philadelphia			
Auto	.5306	.5911	.5279	.6452	.7631	0.174
CTOL	.5329	.5134	.6500	.8391	.9486	0.182
Train	.8062	.8033	.9089	.7615	.9326	0.241
STOL	.6661	.6418	.6500	.6713	1.0	0.199
VTOL	.6925	.6673	.6500	.6713	1.0	0.204
			Washington–New York			
Auto	.4042	.4369	.4569	.5720	.6336	0.143
CTOL	.5993	.5803	.6608	.8026	.9754	0.192
Train	.8121	.8559	.9013	.7579	.9281	0.240
STOL	.7491	.7254	.6608	.6422	1.0	0.209
VTOL	.7791	.7544	.6608	.6422	1.0	0.216

Table 11 1985 Steady light rain market shares

a_{ijk}	m_{ik}	Time	Conv.	Comfort	Safety	Weather	Cost
			Washington–Philadelphia				
Auto	.192	.5306	.7387	.7257	.5807	.7773	.7631
CTOL	.201	.6661	.6418	.8489	.8391	.9359	.8624
Train	.196	.6822	.5870	.6992	.8461	.9999	.8479
STOL	.207	.7511	.7060	.6792	.7104	.9359	.9999
VTOL	.204	.6870	.7060	.6792	.7104	.9359	.9907
			Washington–New York				
Auto	.144	.4042	.5459	.6280	.5148	.7780	.6336
CTOL	.207	.7491	.7253	.8630	.8026	.9301	.8868
Train	.194	.6874	.6256	.6934	.8421	.9999	.8438
STOL	.232	.9627	.7978	.6904	.7165	.9301	.9999
VTOL	.223	.8505	.7978	.6904	.7165	.9301	.9999

simultaneously. This may or may not be a reasonable assumption for 1985, but it does allow intermode comparisons which are interesting from a planning viewpoint. For example, it is evident from Table 10, which is based upon a different set of assumptions than Table 11, that future train service of the Metroliner type could prove extremely popular for NEC travel. Such service could reduce the marketability of V/STOL aircraft unless they offer clearly advantageous time and convenience performances. Conventional airlines will continue to hold a good share of the market. Likewise, automobile business travel will not disappear. VTOL's will hold an edge over STOL's, but only if their ability to land anywhere is put to efficient use. In this respect, it may be difficult for any aircraft to beat improved intercity train service on time, convenience, and comfort criteria.

It should be evident from the prediction model's derivation that any market share estimates are sensitive to the absolute values of both the expected acceptances indices and the factor weights. Changes in this input data affect market share predictions. In any actual application of the model, sensitivity analyses would be performed to evaluate the dependence of market share estimates on specific acceptance indices, some of which will be quantified on largely speculative evidence. Acceptance indices for the more important factors, of course, play the dominant role in quantifying market shares and would be of greatest interest in a study of model sensitivity. For the purposes of technique demonstration, however, a detailed discussion of model sensitivity is perhaps superfluous.

It would be premature to make sweeping conclusions on V/STOL marketability based on Tables 10 and 11. These tables suggest that STOL and VTOL airlines operating concurrently will seize about 42% of a NEC business travel market. One must remember, however, that business travel is but a part of the total travel market, and V/STOL penetration of this total market could be far less significant. The decision analyst must draw his own conclusions on the future of economic V/STOL service. The nondemographic forecasting methodology presented herein suggests that the V/STOL concept may be seriously challenged by railroad developments, and even by improved CTOL and automobile facilities. Should V/STOL acceptance be low on time, convenience, or comfort criteria, its share of the market would be negligible, as the model structure clearly indicates. This, then, is an argument for model validity, and supports the contention that a demographic approach to V/STOL forecasting is perhaps the most realistic. It is undoubtedly the most cynical of the techniques currently in active use. A degree of pessimism, however, may be most desirable in today's era of conflicting technological and humanistic aspirations.

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