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Marvin Kottke
University of Connecticut - Storrs

Stephen Libera
University of Connecticut - Storrs

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Marvin Kottke and Stephen Libera
Department of Agricultural Economics and Rural Sociology

STORRS AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES
THE UNIVERSITY OF CONNECTICUT, STORRS, CONNECTICUT 06268

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EFFECT OF TRAVEL CONSTRAINTS ON THE DISTRIBUTION OF SKIING IN NEW ENGLAND

Marvin Kottke and Stephen Libera [1]

INTRODUCTION

The Problem

New England skiers are fortunate in having ski areas within a few hours of automobile travel from home. Of course, there are some problems mixed with the good fortune. Quite often skiers have to cope with long lift-lines on weekends while, on the other side of the market, ski area managers have to cope with a severely erratic demand. Skiers and managers alike have to contend with uncertain snow conditions due to the vagaries of weather. Now a new economic disturbance looms on the horizon in the form of increased travel costs for skiers. If the energy shortage becomes a constraint on travel, then some shifting in the distribution of skiing may occur.

Although much has been done recently by the ski industry to improve the seasonal and spatial distribution of skiing, the distribution problem continues to be of major concern. A fluctuating pattern of demand due primarily to prevailing work-leisure time schedules is typical of many recreation activities.[2] On weekends and holidays, ski areas are frequently over-crowded and profitable while on "work-days" they are usually uncrowded and unprofitable. To achieve a more steady flow of business, ski areas have developed night skiing, special weekly lift rates, reduced midweek lift rates and other economic inducements. To insure against inadequate natural snowfall, many ski areas have invested in artificial snow-making. These kinds of improvements will continue to be needed, but now attention may also have to be given to a potential travel problem. Will travel constraints cause the demand for skiing to shift to ski areas located more closely to population centers? The purpose of this report is to present the results of an analysis aimed at answering this question.

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[1] The authors are Professor of Agricultural Economics and former Graduate Assistant, respectively. This report is based on research reported in a paper by Libera [11]. The helpful comments by Carlos Stern and David Miller are gratefully acknowledged. The linear programming computation was done at the University Computer Center which is supported in part by a NSF Grant GJ-9.

[2] For an analysis of the seasonal variation in demand for another recreation activity, see Kottke [8], and Kottke-Gardner [9].

Objectives

The objectives of the study are:

1. To determine the effect of travel constraints on the spatial distribution of skiing among New England ski areas.

2. To estimate the potential gasoline-saving effect of a "least-travel" pattern by skiers.

DIMENSIONS OF THE NEW ENGLAND SKI MARKET

To provide background for the analysis, we estimated the region's skier population and the aggregate capacity of ski areas. For purposes of this study, we define the geographic scope of the New England ski market as including all six New England states on the supply side and the same area plus Southeasteru New York and Northern New Jersey on the demand side.[1]

Volume of Skiing

One dimension of a ski market is volume of skiing as measured in skier-days (number of skiers in the market multiplied by the average number of days skied per skier per year). The volume of skiing in New England was estimated to be about 6,000,000 skier-days in 1970-71 (Table 1).[2]

To establish a perspective on the potential intensity of skiing demand, it should be emphasized that the skier population is only about 4-5 percent of the total population (1.3 million skiers out of 30.4 million population in the New England skiing demand region). On a "full-capacity" day, the New England ski areas can absorb approximately 10 percent of the region's skier population, or 27 percent if the New York and New Jersey areas are excluded (New England alone has an estimated 516,559 skier population). These data imply that on any given day when over 10 percent of the region's estimated skier population decides to go skiing, ski areas in New England are likely to become over-crowded. On the other hand, if skier participation (6,000,000 skier-days), occurred evenly over 120 days, then the daily participation would be only about 50,000 persons and New England ski areas' lift facilities would be used at 37 percent of capacity.

Obviously, it is impractical for the ski industry to build sufficient capacity to accommodate 100 percent of the skier population on a single day. Likewise, it is unrealistic to expect skiers to distribute their skiing so that daily volume was perfectly even through a season. More likely, an optimal demand-supply balance lies somewhere between these two extremes. Our estimate of 6,000,000 skier-days for New England in 1970-71 represents such an in-between balance and may be close to an optimal volume for the industry.

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[1]Southeastern New York includes U. S. Census Economic Areas F (Albany vicinity), G (Metro New York and Long Island), and 9 (Lower Hudson Valley). Northern New Jersey includes Economic Areas Metro A, B, C and Sussex and Hunterdon Counties.

[2]Based on an estimate of 5,890,334 skier-days using a demand approach and 6,086,174 skier-days using a supply approach (Table 1).

Table 1. Estimated Skier Population and Ski Industry Capacity, the New England Ski Market, 1962-63 and 1970-71.

	Unit	1962-63	1970-71 1/	Percent Average Annual Change 1962-70
Skier population (demand) 2/				
Total population	Persons	27,721,300 3/	30,441,000	1.2
Skier population 4/	Persons	693,000	1,308,963	11
Season participation 5/	Skier-days	2,772,000	5,890,334	14
Skier capacity (supply) 2/				
Ski areas 6/	Number	73	110	6
Cable lifts 6/	Number	180	361	13
Lift capacity 6/	VTF/hr	94,399,500	219,319,715	17
Skier capacity per day 7/	Persons	59,000	137,076	17
Season participation 8/	Skier-days	2,619,600	6,086,160	17

1/ See Appendix Tables 1 and 2 for data by states and for sources of data.
2/ The geographic area for demand includes the New England states, Southeast New York and Northern New Jersey. The geographic area for supply includes only the New England states.
3/ Source: U. S. Census [14].
4/ Based on an assumed 2.5 percent of the population for 1962-63 and on 4.3 percent for 1970-71 based on Erickson [4] and a NEM-42 study [12].
5/ Based on an assumed 4 days per skier per year for 1962-63 and on an average of 4.5 days per skier for 1970-71 as reported by Erickson [4].
6/ Sources: A Sno-Engineering study [15] for 1962-63 and a study by Hill [5] for 1970-71. VTF/hr = vertical transportation feet per hour.
7/ Calculated on the basis of 1600 VTF/hr per skier per day.
8/ Based on 120 days operation per season and a 37 percent of capacity operating rate.

Growth of the Ski Industry

Between 1962 and 1970 the New England ski industry grew at an average rate of about 16 percent per year in skier-day volume (Table 1). This rapid growth has undoubtedly helped spread skier distribution both spatially and through the season. In 1962-63, New England had 73 ski areas with an average of 2.5 cable lifts per area. Eight years later the number was 110 ski areas with an average of 3.3 cable lifts per area. During the same period, skiing demand grew from about .7 million to about 1.3 million skiers.[1]

Skiing demand grew rapidly during the 1960's and began to slow down in the 1970's, especially in 1972-73 and 1973-74, with poor snow conditions topped off with an energy crisis in 1973-74. At the same time, the growth in skiing capacity supplied by ski areas appears to have leveled-off in the 1970's with inflation and environmental regulations dampening interest in expansionary investment. Accordingly, we expect that the New England ski market dimensions presented here have remained nearly constant since 1970-71 and are representative of the demand and supply situation that exists at present.

A LINEAR PROGRAMMING MODEL OF SKIER TRAVEL IN THE NEW ENGLAND SKI MARKET

In order to test the potential effects of travel constraints on the spatial distribution of skiing, a comparison was made between a benchmark distribution and a "least-travel" distribution. The benchmark serves a purpose similar to that of a "control" in an experiment. It represents the existing travel pattern and is used as a "before" situation in the test. The "least-travel" distribution represents an "optimal" travel pattern that should prevail in order to minimize travel in the region as a whole and is used as an "after" situation in the test. It does not represent what might actually happen; however, the travel pattern would probably tend to move in the direction of the "optimal" pattern if constraining conditions similar to those specified in the model were to actually occur. An assumption is made that the primary objective of all skiers as a group choose ski areas to minimize aggregate travel costs.[2] Given these conditions for the test, we hypothesized that the "least-travel" distribution of skiing would result in appreciably less skier-miles of travel than the benchmark distribution, thereby reducing the aggregate expenditure for gasoline.

Formulation of the Linear Programming Travel Minimization Model

Computation of the "least-travel" distances between population centers and ski areas was facilitated with the use of linear programming.[3] Mathematical formulation

[1] Although data in Table 1 suggest that supply has expanded more rapidly than demand, we refrain from drawing that conclusion because the 1962-63 data are based partly on indirect information on participation rates. The 1970-71 skier population and volume estimates are considered fairly reliable since the participation rates are based on documented research.

[2] Obviously, this assumption does not hold for all skiers. Preference of certain ski areas for other reasons may dominate over consideration of travel costs. On an aggregate basis, however, distance may be an important factor on ski area selection especially if travel constraints become severe.

[3] For a basic reference on linear programming, see Danzig [2] or Baumol [1, pp. 70-190]. For examples of other applications of linear programming, see Kottke [6, 7].

of the model involves the minimization (or maximization) of some objective function subject to a set of constraints. The objective function for this model was:

To minimize

$$A = \sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij}X_{ij}$$

subject to

$$\sum_{i=1}^{m} X_{ij} \leq S_j$$

$$\sum_{j=1}^{n} X_{ij} = D_i$$

$$X_{ij} \geq 0$$

where

A = aggregate miles traveled by skiers in skier miles.

M_{ij} = miles traveled from population center i to ski area j.

X_{ij} = number of skiers traveling from population center i to ski area j.

S_j = supply of skier capacity at ski area j.

D_i = demand as represented by the skier population in population center i.

By using this linear programming formulation, we obtained the minimum skier-miles that would permit skiers to distribute themselves among the New England ski areas subject to two conditions, namely, that none of the ski areas' capacities be exceeded and that the entire skiing demand for a weekend day from all population centers be allocated to ski areas. In a sense, these conditions ensured that aggregate demand equal aggregate supply. The focus was on possible re-arrangement of travel patterns with aggregate demand and supply held constant. The model was not formulated to determine whether or not demand would fall off as a consequence of travel constraints.

It should also be noted that the units minimized in the model are skier-miles--not travel costs. However, once we had determined skier-miles it was a simple matter to translate the solution into travel costs in the form of expenditures for gasoline by multiplying skier-miles by average gasoline costs per mile. For the purposes of this study, we defined "least-travel" cost as pertaining only to mileage involved in ski trips. That is, we did not include other travel-connected expenditures such as tolls, lodging, meals and fixed costs of auto ownership or rental.

Market Area Demarcation and Sources of Data

Eight geographical areas were used to represent the demand side of the New England ski market. Overall the demand areas cover essentially the same geographical scope as presented previously in the "Dimensions" section; however, the breakdown of the areas differs slightly with Massachusetts divided on the basis of Western and Eastern areas with Northern New Jersey and Southern New York combined into one area (Table 2). Moreover, the estimated skier population was reduced to 104,491 for a typical weekend day from a potential of 137,076 (see Table 2 footnote).[1]

In order to simplify the specification of distances from demand areas to supply areas, representative cities were designated as population centers for the demand areas. For example, Hartford was designated as the population center for Connecticut and the mileage from Hartford to ski areas was used to represent all ski trips originating in Connecticut.

Fifty-two major ski areas were chosen to represent the supply side of the New England ski market (Table 3). This sample represents only about half of the total number of New England ski areas, but 75 percent of New England skier capacity. Selection of ski areas for the study was influenced largely by availability of data and size of operations.

Lift capacity of a ski area is most commonly measured in vertical transportation feet per hour, VTF/hr. Each lift's vertical rise is multiplied by its rated safe carrying capacity in skiers per hour.[2] Summation of VTF/hr for all lifts gives the ski area's total lift capacity. The daily skier capacity of a ski area is obtained by dividing the area's total VTF/hr by 1600.[3] Data used in calculating each area's VTF/hr were obtained from Hill [5], The Eastern Ski Map [16], and directly from the ski areas to some extent.

BENCHMARK SPATIAL DISTRIBUTION OF SKIING

The estimated distribution of skiing shown in Table 4 was judged as being reasonably close to the actual situation and as such provides a benchmark. It shows that skiers from Connecticut and Metro NY & NJ spread over all of New England with a heavy concentration in Vermont (60-70 percent). Togetner these two population centers have a significant impact on the skiing industry because of the large number of skiers living in these areas. Maine and Vermont skiers, as might be expected, stay close to home (85-96 percent). Those living in the Boston vicinity, Eastern Massachusetts and Rhode Island head for New Hampshire mostly (55 percent) but some also go farther to Vermont and Maine (34 and 6 percent), while some ski in their home state (5 percent).

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[1] This "less-than-full-capacity" estimate of demand remains representative of the region except that it gives relatively less weight to the demand from Metro-New York areas than that from the New England states which may be appropriate because of the New York and New Jersey skiing alternatives available to Metro-New York skiers.

[2] For example, a double chair lift with a 1400 foot vertical rise and a safe carrying capacity of 900 persons per hour would have a capacity of 1,260,000 VTF/hr.

[3] According to the Sno-Engineering study [15, pp. 63-64], a skier averages 8000 vertical feet of skiing per day (7-10 runs per day). Based on 5 hours of skiing per day, the VTF skied per hour is 1600.

Table 2. Demand Areas, Population Centers and Estimated Skier Population on a "Weekend Day," 1970-71.

Demand Area	Population Center	Skier Population on a "Weekend Day" 1/
Connecticut	Hartford	16,158
Maine	Augusta	6,788
E Mass & RI	Boston	26,222
W Massachusetts	Springfield	7,571
New Hampshire	Concord	10,032
Vermont	Rutland	9,076
Metro NY & NJ	New York City	22,120
Capitol Region NY	Albany	6,524
Total		104,491

1/ Based on the distribution of skier demand reported by the 1964 Sno-Engineering study [15, pp. 14-42]. The 1962-63 data were projected to 1970-71 by use of the growth formula:

$$V_{70} = V_{62}\, e^{rt}$$

where V_{70} is the projected skier population,

V_{62} is the 1962-63 skier population,

e is the natural exponential function base (2.71828),

r is the rate of growth (assumed 10%), and

t is time (8 years).

Then the 1970-71 skier population data were converted to a "weekend day" basis by:

$$V^* = 2.3[(V_{70}\, f)/w]$$

where V^* is the skier population on a "weekend day,"

f is the average number of skiing days per year per skier,

w is the length of skiing season (160 days), and

2.3 is a weighting for weekend skiing, based on reported daily skiing data.

Next the data were adjusted downward from 119,384 to 104,491 skiers to set demand equal to the supply capacity of the ski area sample.

Table 3. Estimated Lift Capacity for a "Weekend Day," New England Ski Areas, Test Sample, 1970-71.

State	Ski Area	Lift Capacity per "Weekend Day" (no. of skiers)	Ski Area	Lift Capacity per "Weekend Day" (no. of skiers)	Total
Connecticut	Powder Ridge	1,000*	Mt. Southington	750	
	Ski Sundown	465	Mohawk Mtn.	600	2,815
Maine	Pleasant Mtn.	1,000	Sunday River	750*	
	Mt. Abram	800*	Saddleback Mtn.	1,712	
	Squaw Mtn.	1,155	Enchanted Mtn.	550*	10,390
Massachusetts	Bousquets	1,290	Butternut Basin	1,300	
	Brodie Mtn.	1,418	Jiminy Peak	1,457	
	Mt. Tom	961*	Berkshire East	1,875	8,301
New Hampshire	Waterville Valley	3,137	Cannon Mtn.	2,759	
	Mt. Sunapee	2,736	Wildcat Mtn.	2,717	
	Loon Mtn.	1,932	Attitash	2,094	
	Skimobile	2,070	Tyrol	770*	
	Black Mtn.	1,076	Gunstock	2,500	
	Whittier	1,208	King Ridge	1,576	
	Moose Mtn.	525	Ragged Mtn.	670	
	Crotched Mtn.	867	Onset	750*	
	Pat's Peak	1,000*			28,387
Vermont	Mt. Snow	6,388	Stratton Mtn.	4,176	
	Magic Mtn.	1,267	Bromley Mtn.	3,363	
	Okemo Mtn.	3,474	Ascutney Mtn.	2,108	
	Round Top Mtn.	1,125	Pico Peak	1,737	
	Killington	6,971	Middlebury Snow Bowl	1,198	
	Glen Ellen	2,106	Sugarbush Valley	3,173	
	Mad River Glen	1,705	Stowe	5,504	
	Madonna Mtn.	2,831	Jay Peak	4,386	
	Burke Mtn.	1,638	Haystack Mtn.	1,448	54,598
Total Lift Capacity in Number of Skiers					104,491

* Data were not directly available for these ski areas, therefore these estimates were based on indirect information.

Table 4. Estimated Distribution of Skiing in New England, Benchmark Situation for a "Weekend Day," 1970-71. 1/

Origin Area	Destination Area						
	Conn	Maine	Mass	New Hamp	Vermont	Outside New England	Total
				(number of skiers)			
Connecticut	1,616	323	2,108	646	11,142	323	16,158
Maine		5,770		679	203	136	6,788
E Mass & RI		1,573	1,347	14,422	8,880		26,222
W Massachusetts			1,764	909	4,747	151	7,571
New Hampshire		100		7,624	2,107	201	10,032
Vermont		91	91	91	8,803		9,076
Metro NY & NJ	885	221	912	442	13,688	5,972	22,120
Capitol Reg NY			1,175		4,958	391	6,524
Total	2,501	8,078	7,397	24,813	54,528	7,174	104,491
				(percent)			
Connecticut	10	2	13	4	69	2	100
Maine		85		10		2	100
E Mass & RI		6	5	55	34		100
W Massachusetts			23	12	63	2	100
New Hampshire		1		76	21	2	100
Vermont		1	1	1	97		100
Metro NY & NJ	4	1	4	2	62	27	100
Capitol Reg NY			18		76	6	100

1/ Based on the distribution of skier demand reported by the 1964 Sno-Engineering study [15, pp. 14-42] with the percentage distribution applied to the 1970-71 estimate of skiers by origin area.

The Boston area also has a significant impact on skiing demand because of the large number of skiers living in that area. Residents of Western Massachusetts ski mostly in close-by Southern Vermont and the Berkshire Mountains (63 and 23 percent). People living in the Albany NY vicinity, in a similar situation, go mainly to Vermont and Western Massachusetts.

RESULTS OF COMPUTING THE "LEAST-TRAVEL" SPATIAL DISTRIBUTION OF SKIING

Application of linear programming to find the "least-travel" solution resulted in a distribution interestingly different, in one respect, from the benchmark (Table 5). According to tne "least-travel" solution skiers would not spread out as much among various destinations.[1] Connecticut skiers would travel to Vermont (82 percent) and to Massachusetts (18 percent). Likewise, skiers from Eastern Massachusetts and Rhode Island would go mostly to New Hampshire (76 percent), to Maine (14 percent) and to Vermont (10 percent). Oddly, none from either of these origin areas would ski in their home locations.

One way of interpreting the solution is that if Connecticut skiers, for example, would all go to the Berkshire and Southern Vermont areas, then there would be room for New York skiers in Connecticut. Another interpretation is that if New Yorkers would crowd the close-by ski areas in Connecticut, then the local skiers may be driven to seek out-of-state less-crowded places. Both interpretations contain elements of unreality; however, the direction of the shift in distribution seems plausible. While the extreme change of all Connecticut skiers going out-of-state is unreal, the shift toward a narrower distribution of skiers from all origins when constraints become effective seems reasonable.

The pattern for Maine, New Hampshire and Vermont skiers would remain virtually unchanged. This is not surprising since over 70 percent of the New England ski areas are located in these three states. Eastern Massachusetts and Rhode Island skiers would continue to go mainly to New Hampshire but would also shift somewhat from Vermont to Maine. Metro NY & NJ would similarly continue to go mostly to Vermont, but some would shift to Massachusetts and Connecticut.[2]

EFFECT OF THE "LEAST-TRAVEL" SKIER DISTRIBUTION ON TRAVEL COSTS

It turns out that the difference in aggregate mileage and gasoline cost between the "least-travel" solution and the benchmark situation is negligible. The solution value for the linear programming model was 14,994,412 skier-miles which is only

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[1] Although the "Destination Areas" are presented as states in Table 4, the actual destinations in the linear programming model were 52 ski areas. The results were consolidated into state totals for ease of presentation. To some extent such consolidation masks the extent of a wider distribution as seen in the breakdown by ski areas within a state.

[2] A procedural difference between the benchmark and the "least-travel" test was the exclusion of ski areas outside of New England in the latter. Therefore, the shift for the Metro NY & NJ skiers, in particular, cannot be explained on the basis of travel constraints alone. However, as explained in the "Area Demarcation" section, the skier population used for the Metro NY & NJ area was weighted less than that for the New England areas which, in effect, offsets the exclusion of ski areas outside of New England in the "least-travel" test.

Table 5. "Optimal" Distribution of Skiing in New England, the "Least-travel" Solution for a "Weekend Day," 1970-71.

Origin Area	Destination Area					
	Conn	Maine	Mass	New Hamp	Vermont	Total
	(number of skiers)					
Connecticut			2,836		13,332	16,158
Maine		6,788				6,788
E Mass & RI		3,662		19,993	2,567	26,222
W Massachusetts					7,571	7,571
New Hampshire				8,394	1,638	10,032
Vermont					9,076	9,076
Metro NY & NJ	2,815		5,465		13,840	22,120
Capitol Reg NY					6,524	6,524
Total	2,815	10,450	8,301	28,387	54,538	104,491
	(percent)					
Connecticut			18		82	100
Maine		100				100
E Mass & RI		14		76	10	100
W Massachusetts					100	100
New Hampshire				84	16	100
Vermont					100	100
Metro NY & NJ	13		25		62	100
Capitol Reg NY					100	100

169,118 less than for the benchmark situation (Table 6). In gasoline cost, this amounts to a saving of $3839 (or approximately 7700 gallons of gasoline) for a weekend of skiing in New England.

The reason for this slight difference can perhaps be explained by referring to the changes in average miles that would be travelled by skiers according to the test (Table 7). As pointed out in the previous section, some skiers would have to travel to further destinations in order for other skiers to travel shorter distances thereby accomplishing a net aggregate reduction in mileage. For example, Connecticut skiers would on-the-average have to travel 154 miles one-way to their destination areas. This would be a 9 mile increase over their benchmark average distance. On the other hand, skiers from the Metro NY & NJ area would travel 15 miles less than their benchmark distance. Half of the origin areas would increase their average mileage on a weekend trip and the other half would decrease their average mileage. The net effect would be a reduction from a 145 mile average to a 143 mile average for all skiers in the region.

Location of ski areas in relation to population centers apparently has an important bearing on the existing pattern of skiing travel and on the outcome of the test. About 100 ski areas form somewhat of an arc stretching in a northeasterly direction from Western Connecticut to Maine. About 150 miles southeast of this arc lies a band of three major population centers which provide the dominant source of demand for skiing. Therefore, the tendency towards 143-145 average miles for ski trips seems to be heavily influenced by the particular form in which sources of supply and demand are spatially oriented. With the exception of Metro NY & NJ, most population centers in the region have an opportunity to choose a ski area within 150 miles from home. As a consequence, skiers apparently have already developed close to "optimal" travel patterns in times relatively free of travel constraints.

SUMMARY AND CONCLUSIONS

The ski industry is faced with a new economic disturbance in the form of travel constraints due to a predicted long-lasting energy shortage. This raises the question of whether or not the pattern of skiing distribution in New England will shift. The purpose of this study was to analyze the potential effect of travel constraints on the spatial distribution of skiing. It was expected that an improvement in arrangement of travel patterns would reduce skiers' aggregate mileage and travel costs.

New England ski areas have an advantage of being within a few hours travel distance from major population centers. Although only about 5 percent of the population participates in skiing annually, demand for skiing can exceed supply of skiing facilities on a holiday or weekend day. An estimated 1.3 million skiers participate in the New England ski market, but naturally not all ski on the same day. Instead they ski an average of 5 days within a 150 day season, but mostly on weekends or holidays. The New England ski industry has an estimated capacity for about 137,000 skiers per day which means that on any given day the ski areas can accommodate 10 percent of the skiing population. Perhaps the most appropriate measure of a ski market is the number of skier-days for a season. On this basis, New England skiing demand essentially equals skiing supply at around 6 million skier-days per season.

To test the effects of travel minimization on skiing distribution, a linear programming model of the New England ski industry was developed. The "least-travel" solution thus obtained was compared with a benchmark situation for 1970-71. Eight geographical areas including the New England states, Metro New York-New Jersey and the

Table 6. Estimated Skier-Miles and Expenditures for Gasoline on a Weekend Trip, New England, 1970-71.

	Benchmark Situation	"Least-travel" Solution	Difference
Total skier-miles (one-way)	15,163,530	14,994,412	-169,118
Total skier-miles (round-trip)	30,327,060	29,988,824	-338,236
Automobile miles 1/	8,196,502	8,105,088	-91,414
Gasoline cost ($) 2/	344,253	340,414	-3,839
Gasoline cost per auto ($) 3/	12.19	12.05	-.14

1/ Based on 3.7 persons per car. Source: Sno-Engineering study [15, pp. 25a, 26a].
2/ Based on $.042 cost per mile for gasoline.
3/ Number of automobiles = 28,240.

Table 7. Estimated Average Miles Travelled by Skiers on a Weekend, New England, 1970-71.

Origin Area	Benchmark Situation	"Least-travel" Solution	Difference
	(average one-way miles to destination areas)		
Connecticut	145	154	+ 9
Maine	90	76	-14
E Mass & RI	154	156	+ 2
W Massachusetts	106	118	+12
New Hampshire	88	79	- 9
Vermont	63	58	- 5
Metro NY & NJ	237	222	-15
Capitol Region NY	103	118	+15
Total Region	145	143	- 2

capitol region of New York comprised the demand side of the ski market. Fifty-two major ski areas in New England represented the supply side. A time dimension of a weekend day was specified. The linear programming model was formulated to minimize skier-miles subject to the condition that none of the ski areas' capacities would be exceeded and that the entire skiing demand for a weekend day be allocated to ski areas.

The results of the "least-travel" solution was interestingly different in terms of distribution but only slightly different in terms of aggregate skier-miles. The linear programming allocation of skiers resulted in a narrower or more concentrated distribution than the benchmark distribution. For example, Connecticut skiers would go to only two states compared to six in the benchmark situation. Accompanying the change in distribution was a slight reduction in aggregate skier-miles. The solution value of the linear programming objective function was 14,994,412 skier-miles which is only 169,118 less than for the benchmark situation. In gasoline cost, this amounts to an aggregate savings of about $3800 for New England skiers for one weekend.

The results suggest that rearrangement of skier travel patterns in order to minimize aggregate mileage would reduce fuel consumption only slightly. Of course, this conclusion is subject to all of the qualifications stipulated in the procedures for the test. For example, total skiers were held constant so that we could emphasize the effect of constraints on shifts and rearrangement. Conceivably, travel constraints could discourage some skiers from making any trips. Another possibility is that "doubling-up" in the use of automobiles could reduce aggregate mileage. Moreover, expansion of capacity of closer-by ski areas was not included in the test. All of these possibilities, if included in the test would probably have altered the conclusion. Nevertheless, we submit that the locational distribution of New England ski areas in relation to population centers has an important bearing on travel patterns and with a choice of ski areas within 150 miles of most of the population centers it could be that a nearly "optimal" travel pattern may already exist.

APPENDIX

Appendix Table 1. Estimated Skier Population Residing in New England, SE New York and N New Jersey, 1971.

Area	Total Population 1/	Skier Population 2/	Seasonal Participation in Skier-days 3/
Connecticut	3,068,000	131,924	593,658
Maine	1,012,000	43,516	195,822
Massachusetts	5,762,000	247,766	1,114,947
New Hampshire	758,000	32,594	146,673
Rhode Island	959,000	41,237	185,567
Vermont	454,000	19,522	87,849
Total	12,013,000	516,559	2,324,515
Metro NY	12,405,000	533,415	2,400,368
New Jersey	5,185,000	222,955	1,003,298
Capitol Region NY	838,000	36,034	162,153
Total	18,428,000	792,404	3,565,819
Market Total	30,441,000	1,308,963	5,890,334

1/ Source: U. S. Census [13, pp. 10, 27, 29, 41, 43, 44, 53 and 63].

2/ Assuming 4.3% of the population participates in skiing (5.4% adjusted for population under age 10). Based on a report by Erickson [4, p. 5]. A nationwide study of households in 1973 by NEM-42 reported 5% of the households participated in skiing [12].

3/ Assuming an average of 4.5 days per year per skier. Based on a report by Erickson [4, p. 5].

Appendix Table 2. Estimated Skier-Capacity of New England Ski Areas, 1970-71.

Area	No. of Ski Areas 1/	No. of Cable Lifts 1/	Average VTF/hr per Lift 2/	VTF/hr Supply	Skier Capacity per Day 3/	Seasonal Supply of Skiing in Skier-days 4/
Conn	5	17	500,000	8,500,000	5,313	239,085
Maine	16	38	600,000	22,800,000	14,250	641,250
W Mass	13	39	500,000	19,500,000	12,188	584,460
E Mass & RI	13	20	500,000	10,000,000	6,250	281,250
New Hamp	27	105	600,000	63,000,000	39,375	1,771,875
Vermont	36	142	672,674	95,519,715	59,700	2,686,500
Total New England	110	361		219,319,715	137,076	6,204,420

1/ Hill [5, pp. 43-44, 57].

2/ Vermont VTF/hr rate from Hill [5, p. 57]; VTF/hr rates for other states estimated.

3/ VTF/hr capacity divided by 1600 VTF/hr per skier [15, p. 63-64]. It is estimated that skiers average 8000 vertical feet per day of skiing (approximately 7-10 runs per day). An average 5 hour day of skiing is assumed (8000 ÷ 5 = 1600 VTF/hr per skier per day).

4/ Seasonal supply based on 150 days of operation and an average operating rate of 30% of capacity for the 150 day period. The seasonal "% of capacity" operating rate is calculated from Vermont data by Donovan [3, p. 3].

Appendix Table 3. Inter-Area Travel Distances, New England Ski Market.

Destination Ski Areas	Origin Areas - Population Centers: Conn (Hftd)	E Mass & RI (Boston)	Metro NY & NJ (NYC)	W Mass (Springfield)	N H (Concord)	Vt (Rutland)	Me (Augusta)	Capitol Reg NY (Albany)
Vermont								
Mt Snow	112	145	229	87	100	69	260	68
Magic Mtn	133	166	250	108	82	49	242	81
Okemo Mtn	136	161	253	111	80	24	235	96
Round Top	147	174	264	122	93	30	253	107
Killington	156	173	273	131	92	17	252	112
Glen Ellen	221	214	338	196	133	59	228	154
Mad River Gl	226	219	343	201	138	49	233	149
Madonna Mtn	240	233	358	215	152	98	248	193
Burke Mtn	231	227	348	206	136	128	188	224
Stratton Mtn	121	154	238	96	109	47	269	79
Bromley Mtn	130	163	247	105	91	40	251	72
Ascutney Mtn	137	146	254	112	66	49	226	120
Pico Peak	167	181	264	142	100	9	260	104
Middlebury	207	200	324	182	119	36	273	131
Sugar Bush	212	205	329	187	124	54	233	149
Stowe	232	225	349	207	144	90	240	185
Jay Peak	292	285	410	267	204	150	323	245
Haystack Mtn	109	142	226	84	97	66	257	65
New Hampshire								
Waterville	220	151	337	195	70	117	148	213
Mt Sunapee	150	125	267	125	34	80	185	143
Loon Mtn	210	160	327	185	79	107	136	203
Skimobile	249	145	366	224	118	146	99	242
Black Mtn	254	164	371	229	123	151	104	247
Whittier	231	124	348	206	71	131	121	224
Moose Mtn	210	103	324	185	50	131	109	253
Crotched Mtn	141	80	258	116	32	130	192	134
Pat's Peak	143	80	260	118	19	98	180	136
Cannon Mtn	218	167	335	193	86	115	150	211
Wildcat Mtn	269	183	386	247	102	166	125	255
Attitash	242	155	359	217	111	139	106	235
Tyrol	251	161	368	226	120	148	101	244
Gunstock	177	109	294	152	28	109	165	170
King Ridge	156	122	273	131	31	77	180	149
Ragged Mtn	175	117	292	150	36	82	162	168
Onset	136	85	253	111	37	130	197	129

Appendix Table 3. (continued)

Destination Ski Areas	Origin Areas - Population Centers: Conn (Hftd)	E Mass & RI (Boston)	Metro NY & NJ (NYC)	W Mass (Springfield)	N H (Concord)	Vt (Rutland)	Me (Augusta)	Capitol Reg NY (Albany)
Maine								
Pleasant Mtn	266	162	383	255	100	162	72	253
Mt Abram	307	221	424	285	140	204	64	293
Squaw Mtn	395	291	512	384	267	352	107	420
Sugarloaf Mtn	358	254	475	347	217	304	70	399
Sunday River	299	213	416	277	132	196	72	285
Saddleback Mtn	346	242	463	335	205	292	80	387
Enchanted Mtn	383	279	500	372	255	340	95	408
Massachusetts								
Bousquets	78	149	158	53	163	93	320	41
Brodie Mtn	86	157	166	61	165	85	328	44
Mt Tom	36	107	153	11	119	123	281	104
Butternut	58	140	138	44	183	113	320	48
Jiminy Peak	90	161	170	65	175	84	330	34
Berkshire E	82	112	199	57	106	110	280	67
Connecticut								
Powder Ridge	27	134	90	52	180	184	313	143
Ski Sundown	24	131	125	36	164	147	310	94
Mt Southington	24	131	95	49	177	177	310	130
Mohawk Mtn	42	149	118	60	195	149	325	99

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