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An Empirical Analysis of the Impact of Energy Restrictions on the Execution of Activity Patterns

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ABSTRACT

In this paper, activity pattern analysis is employed to quantitatively assess the potential impact of (1) the introduction and use of a special purpose urban vehicle, and (2) gasoline rationing on the daily activities of individuals. The results obtained are based on a study both of the actual activity patterns of 664 individuals from Orange County, California as well as of simulated responses to the energy-constrained environment. Two of the most easily implemented user-related options: (1) tripchaining (the formation of multiple-sojourn tours) and (2) activity site substitution were analyzed in detail under varying degrees of constraint severity imposed by the two scenarios. The results obtained from this study indicate that those segments of the population that are characterized by long distance trips to activities of a highly inflexible nature (i.e., work or school) and large numbers of medium distance trips will experience severe difficulty in carrying out their current activity patterns when energy-constraint policies are introduced. With respect to potential remedies for transportation policy-induced restrictions on daily activity patterns, it is shown that most of the strategies evaluated offer some relief to the latter population group but little, if any, to the former.

I. Introduction

The possibility of serious changes in the availability and cost of energy, particularly gasoline, has resulted in increased emphasis on transportation policy formulation, evaluation and selection. The implementation of effective policies must be preceded by quantitative estimates of the likely impacts these policies will have on individual travel behavior. Unfortunately, current estimates are deficient, both in terms of the range of impacts examined (too narrow) and the nature of the estimates (too qualitative).

Most of the previous quantitative studies of traveller responses to transportation policies have suffered from the same malady--the use of the individual trip as the basic analysis unit. It is this narrow focus that has contributed to the difficulty in estimating to what extent an individual's current travel behavior would be rendered infeasible as a result of energy restrictions.

In this study, travel behavior is viewed as a collection of responses which depend not only on the physical space/time constraints of movement, but also on the spatial/temporal distribution of activity sites and the location-specific properties of these sites. In this context, the use of activity patterns (the entire set of trips, activities and the interrelationships between them) as the primary unit of analysis is presented as both logical and theoretically consistent and an integrated analysis of complex travel behavior (via activity pattern analysis) is developed as the framework to assess the impact of various transportation policies on the individual's ability to interact with the environment. In addition, the effectiveness of potential short-term user responses to these policies are examined.

II. Methodology

The methodology used in this study involved a synthesis of the path traced by human movement through time and space to access and participate in desired (or needed) activities. This synthesis is comprised of two distinct phases--specification and classification. In the first phase the individual's collection of daily activities and the travel by which they are linked are specified in terms of the image they cast on the space/time/activity continuum. This image is digitized in the form of a two-dimensional matrix with elements consisting of the spatial location of the individual (distance from home) and the activity being performed by the individual (classified into 9 distinct categories including travel and "in home" activities) at approximately 9 minute intervals. The resulting matrix thus represents a digitized time history of the individual's activities, their locations and the travel required to access them. An essential feature of this specification of human movement is the inherent representation of both activity and travel linkages as inseparable entities.

The second phase of the methodology involves the classification of individuals with similar activity/travel profiles (as specified in the first phase). Because of the complexity of the images that characterize each individual's activity pattern (a total of 256 pieces of information were used, equivalent to 2 x 128 sampling periods) techniques of pattern recognition theory were employed to enhance identification and classification of similar activity patterns. Specifically, the two-dimensional matrix associated with each individual's activity pattern was first transformed by a Walsh-Hadamard transformation algorithm (Welchel and Guinn, 1968); the resulting two-dimensional images were cluster analyzed in Walsh-Hadamard transformation space using a K-means algorithm (Ball and Hall, 1967). The transformed images associated with the transform coefficient centroids were inverted by Walsh-Hadamard inversion formulae to reconstruct the activity patterns that are representative of the distinct travel/activity behavior of individuals in each group.

This procedure was applied to the travel/activity diaries of 664 individuals from Orange County, California. These diaries were randomly selected from the 1976

Southern California Association of Governments (SCAG) and California Department of Transportation (CALTRANS) Urban and Rural Travel Survey. The results of the classification phase (based on pseudo F-ratios) indicated that the activity patterns of the respondents are best classified into 9 distinct groups. These groups represent the unit of analysis for the energy impact assessment detailed in subsequent sections of this paper. To provide a better understanding of the composition of these groups, Table 1 summarizes the travel/activity characteristics associated with each representative activity pattern, together with the general socio-economic characteristics of the individuals that display the pattern and the type of urban form reflected by their place of residence.

TABLE 1. SUMMARY MEASURES OF REPRESENTATIVE ACTIVITY PATTERNS

REPRESENTATIVE ACTIVITY PATTERN (RAP) Number (%)	Travel/Activity Characteristics	Socio-Economic Characteristics	Urban Form
A 32 (4.8)	Single work trip of about 25 miles No evening travel	Predominantly employed, male household heads Age (25-34) 97% Drivers	Low density/ high income
B 56 (8.4)	Single work trip of about 7 miles Evening shopping trip	Predominantly employed, male household heads Age (35-44) 93% Drivers	Low density/ high income
C 83 (12.5)	Work/school activity within 3 miles of home, evening social/recreation activity	Non-employed spouses and children, even sex and age distributions 57% Drivers	High density/ low income
D 62 (9.3)	Multiple non-work sojourns within 5 miles of home, no evening travel	Predominantly female non-employed Age (> 25) 71% Drivers	Low density/ high income
E 47 (7.1)	Single work trip of about 15 miles Evening work/school activity within 2 miles	Predominantly employed male household heads Age (25-54) 96% Drivers	Low density/ high income
F 6 (0.9)	Single work trip of about 2 miles Multiple non-work evening sojourns (no return trip home before 12:00 A.M.)	NA	NA
G 306 (46.1)	Single school/work trip of about 1 mile, no evening travel	Predominantly female 50% employed adults 50% school aged children 47% Drivers	High density/ low income
H 66 (9.9)	Single work trip of about 7 miles No evening travel	Predominantly employed even sex distribution Age (25-54) 76% Drivers	High density/ low income
I 6 (0.9)	Extremely long travel (not identified)	NA	NA

These data should be understood to be generalizations of the predominant characteristics that surfaced in a multiple discriminant analysis of group membership (Groups F and I did not contain sufficient membership to permit such analysis).

III. Present Energy Impacts

The usefulness of activity pattern analysis in assessing the potential impact of policy options on travel behavior is illustrated by two scenarios involving the imposition of travel restrictions caused by: 1) a special purpose urban vehicle and 2) gas rationing.

One transportation alternative offered as a partial solution to the "energy crisis" is the special purpose urban vehicle (e.g., electric or hybrid-powered vehicle). Prior to the construction of this vehicle a set of design criteria (e.g., range, speed, recharge time) must be developed, however, at present, the vehicular technology has been proceeding almost independently from any demand characteristics that affect the acceptance and use of such vehicles.

There is a paucity of information concerning the potential market demand for special purpose urban vehicles (SPUVs). The characteristics of future electric cars were estimated using parametric models of weight, cost and performance in a comprehensive study by General Research Corporation (Hamilton, 1978). However, the focus of the research was on supply constraints and market potential analysis was brief and at an aggregate level.

A multinomial logit model developed by Lave and Train (1979) served as the basis for a demand study by Cambridge Systematics (1978). The problems of introducing a new alternative to the choice set is not fully realized, and this model defined a SPUV based on predicted technology advances.

Bevilacqua and Maslanka (1979) approached market analysis by applying statistical distributions to cross-sectional household data, and developed market responses for a range of SPUV characteristics. While not restricted by explicit vehicle technology definition, only market potential for various scenarios may be developed, and not market penetrations as in the logit formulations. Bernard

(1979) summarizes other quantitative attempts to forecast SPUV market acceptance, but characterizes the majority of research as limited and in need of further study.

The lack of a sound data base has limited the analysis of market demand for SPUVs as a partial substitute for automobile travel. Design criteria that allow SPUVs to meet various household and business travel demands are needed and should be determined based on those demands.

As one example, various maximum travel ranges were investigated to determine the number of individuals that could execute their activity patterns using a SPUV with a particular range. It should be noted that travel range represents only one level-of-service parameter and to obtain an accurate estimate of user potential factors such as travel speed and recharge time ("down" time) must also be considered. In addition, the results that follow are based on the individual's activity pattern reported on the survey day, which may not accurately reflect an individual's travel/activity recurring needs.

Over two-thirds of the sample (70.9 percent) are not able to complete activity patterns (on the day surveyed) using a SPUV with a maximum travel range of 5 miles. This percentage decreases to 57.9 percent and 41.0 percent when the range is doubled and tripled, respectively. As the maximum travel range increases beyond 20 miles, the subsequent changes in the percentage of the sample that cannot execute activity patterns decreases steadily, indicating 20 miles may be an effective design range. A SPUV designed with a travel range of 20 miles will be able to accommodate the travel needs of almost 70 percent of the total sample, on the analysis day.

Since a SPUV offers a highly specialized level-of-service, it will accommodate certain travel needs much more effectively than others. Therefore it is useful to analyze each of the representative activity patterns individually to determine which sub-groups of the population have travel needs most coincident with the level-of-service provided by the urban vehicle.

An examination of Figure 1 reveals that a SPUV with a range of 15 miles could be utilized by at least half of the individuals associated with activity pattern profiles C,G or H. The latter two are characterized by a single sojourn tour (for either work or school purposes) of relatively short distance (15 miles or less). RAP C, although characterized by two single sojourn tours (home-work-home and home social/recreation-home), also involves a small total travel distance (12 miles). These three RAP's comprise 68.4 percent of the total sample. The other RAP's (A,B,D and E) are not easily accommodated by the SPUV because of large total distance traveled (resulting from either single or multiple sojourn tours).

Increases in the potential SPUV market could be achieved through increasing the design range to accommodate activity patterns with larger total distances. If, for example, the design range were expanded to 30 miles, at least 70 percent of the those individuals with RAP B or D and 80 percent in Groups C, G and H could have used a SPUV on the survey day. The design range at which each group has at least 50 percent of its members possessing activity patterns of total distance less than the design range appears in Table 2. The absence of Group A from this table indicates that even if the SPUV was designed to travel a total distance of 55 miles, less than 50 percent of those people in Group A would be able to carry out their travel/activity needs using such a vehicle.

The second scenario considered involves gas rationing. A wide range of rationing policies is possible, with each differing in degree and/or focus. (For example, fuel constraints may be applied to individual drivers, registered vehicles or households.) As a preliminary step to analyzing more complex rationing schemes, specific allotments to licensed drivers were examined in detail. Trip diaries of drivers were matched to a corresponding record of individual vehicle usage by type, to determine estimates of high and low fuel consumption. The fuel required to

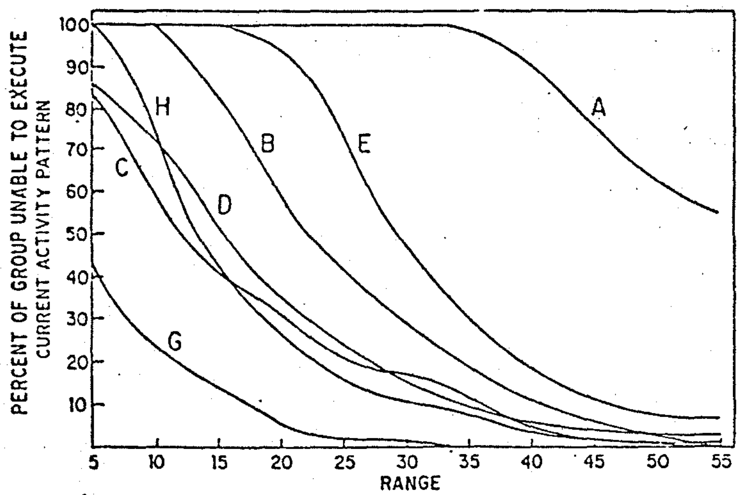

FIGURE 1. PERCENT OF GROUP UNABLE TO EXECUTE CURRENT ACTIVITY PATTERN DUE TO URBAN VEHICLE DESIGN RANGE

Table 2. Design Range at which Majority of Group Can Utilize Urban Vehicle

Range	Group	% of Total Sample	Cumulative % of Total Sample
5	G	46.0	46.0
10			46.0
15	C,H	22.4	68.4
20	D	9.3	77.7
25	B	8.4	86.1
30			86.1
35	E	7.1	93.2
40-55			93.2

complete a tour was estimated (and summed if more than one tour was reported) to yield individual driver fuel demands (i.e., the fuel consumption necessary to execute the individual activity patterns). A range of daily fuel limitations was applied to each driver on the basis of estimated fuel requirements. The percentage of respondents affected by each ration level is illustrated (Figure 2).

Since each activity pattern profile exhibits different travel characteristics, the impact of gas rationing is not uniform. Figure 3 depicts the results for the seven representative groups, identified by their size as a percentage of all drivers in the sample. In Table 3, the original cluster size (with the proportion of drivers and driver trips) is shown to illustrate which groups are more auto dependent (i.e., more sensitive to rationing programs).

A greater sensitivity to gas rationing is associated with groups A,B and E (those groups which are characterized by employed heads of households residing in low density, high income areas). The potential impact of rationing policies on

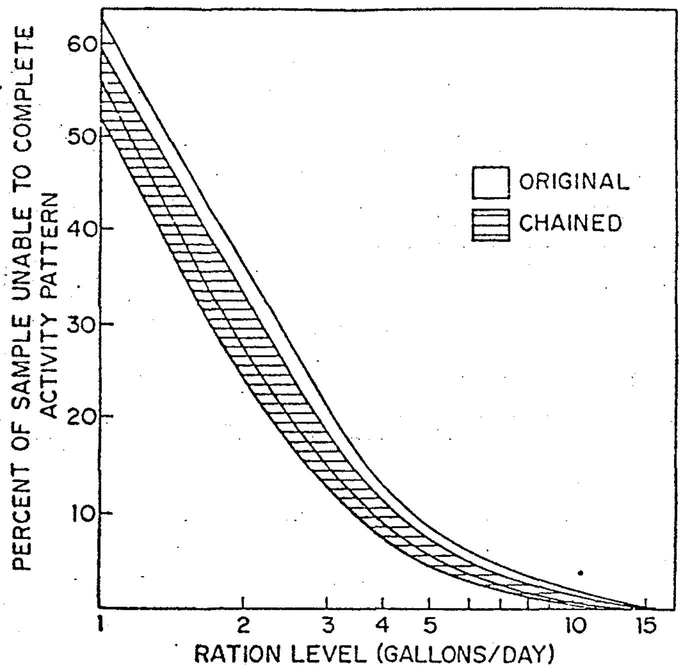

FIGURE 2. EFFECTS OF RATIONING ON SAMPLE

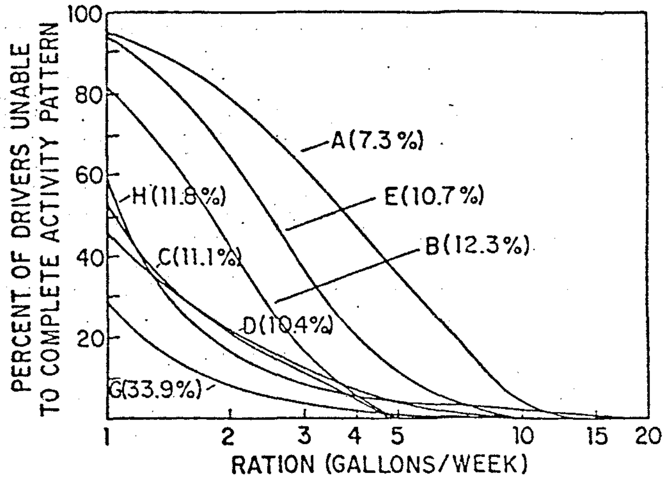

FIGURE 3. IMPACT OF GAS RATIONING ON GROUPS

Table 3: Group Membership of Driver Subsample

Cluster Group[1]	Full Sample N	Full Sample Trips	Drivers N (Pct)	Drivers Trips (Pct)
A	32	170	31 (.97)	108 (.64)
B	56	333	52 (.93)	214 (.64)
C	83	573	47 (.57)	237 (.41)
D	62	432	44 (.71)	247 (.57)
E	47	264	54 (.96)	196 (.74)
G	306	1483	143 (.47)	527 (.36)
H	66	292	50 (.76)	171 (.59)
Total	652	3547	412 (.63)	1700 (.48)

(1) Cluster groups F and I are omitted from the ration analysis due to insufficient size. Totals reflect this reduction.

these groups may severely restrict present work trip commuting patterns. The decreased reliance on car use in groups C,D and G (those individuals with the highest flexibility in trip making) is associated with a potential decrease in impact of rationing. Group H, while similar to the other employed groups, would not experience the severity of a rationing constraint due to proximity to place of employment.

IV. User Strategies in an Energy-Constrained Transportation Environment

There are many user-related options that may be invoked in response to constraints imposed by an energy-constrained environment. Of these various options, trip chaining (the linking of consecutive trips) and activity site substitution (the substitution of closer activity sites for those farther away) are potentially the most easily implemented. Trip chaining requires a higher level of planning/scheduling but allows the individual to perform activities at the originally selected sites (as opposed to performing these activities at alternative sites). Depending on the spatial and temporal distribution of desired activity sites and the severity of the travel restrictions, trip chaining may not allow an individual to execute the desired activity pattern. This situation may force the individual to substitute alternate activity sites (which involve less traveling) for those originally selected.

The impact of trip-chaining behavior on energy consumption was assessed through two simulations that generated multiple-sojourn tours from single-sojourn tours. This was accomplished by replacing the individual's intermediate trips to and from home with trips to subsequent non-home activities. In the first simulation, trip chains were constructed for each individual with the constraint that each of the following must be maintained:

(1) performance of the complete set of activities,

(2) observed durations of each activity,

(3) observed location of each activity, and

(4) temporal sequence of the activity set.

In addition, constraints on the timing of specific activity types were introduced into the simulation. These temporal constraints restricted the times when various activities could be performed. Subject to these restrictions, multiple-sojourn tours were constructed to reduce the total travel distance associated with each individual's activity pattern. A second simulation was also performed that removed the constraint regarding observed temporal sequencing of activities. The resulting "trip chaining" patterns (referred to as "chained/original sequence" and "chained/optimal sequence" patterns) were then analyzed to determine the effectiveness of these strategies in counteracting the restrictions imposed by the transportation-related policies that impact travel behavior.

First, trip chaining only marginally decreases the percentage of the total sample that cannot execute their activity pattern (original activity sequence) with the use of a SPUV when the design range is 15 miles or less (Figure 4). For ranges between 15 and 35 miles, the decline in the percentage of infeasible patterns is approximately 1 percent, while ranges in excess of 35 miles experience percentage changes of less than one percent.

Additional decreases resulting from an optimal rearrangement of activity sequence coupled with the linking of trips is illustrated in Figure 5. A comparison

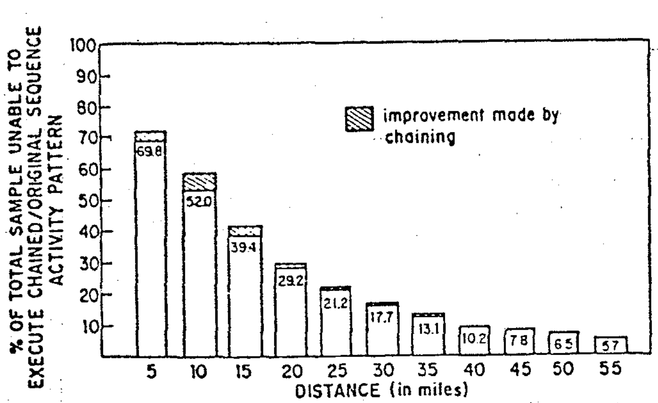

FIGURE 4. PERCENTAGE OF TOTAL SAMPLE UNABLE TO EXECUTE CHAINED/ORIGINAL SEQUENCE ACTIVITY PATTERN DUE TO TRAVEL DISTANCE RESTRICTION

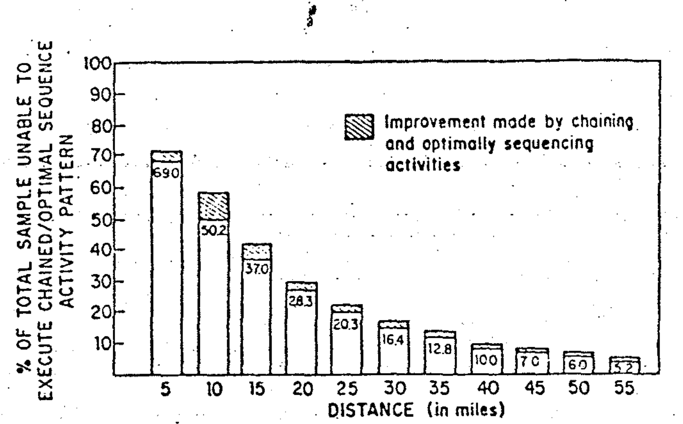

FIGURE 5. PERCENTAGE OF TOTAL SAMPLE UNABLE TO EXECUTE CHAINED/OPTIMAL SEQUENCE ACTIVITY PATTERN DUE TO TRAVEL DISTANCE RESTRICTION

of Figures 4 and 5 reveals that the combination of changes in activity sequence and chaining enables a larger percentage of the sample to execute their activity patterns for the entire span of design ranges and causes larger percentage changes in the range of 0-15 miles. However, chaining (with or without optimal sequencing), does not significantly decrease the optimal design range of the special purpose urban vehicle.

The effectiveness of trip chaining will also not be uniform across the entire sample, with certain sub-samples of the population experiencing more benefits than others (Figure 6). These figures indicate that those individuals possessing RAP's A, B or E do not benefit substantially (with respect to usage of SPUV) when trip chaining and optimal sequencing of activities are carried out. Again, this illustrates the ineffectiveness of chaining and sequencing when it is applied to either single sojourn tours or to multiple-trip patterns involving fixed activities (both spatially and temporally).

Alternatively, Groups C, D, G and H experience sizeable increases in the percentage of individuals who can use a SPUV with a design range between 5 and 25 miles, indicating large reductions in distance traveled brought about by chaining and optimal sequencing. Of the four groups, Group C experiences the largest increase in potential users (Table 4).

The chained/original and the chained/optimal sequence patterns were also subjected to the gas rationing analysis. As an example, the reductions in the percentage of drivers unable to complete activity patterns after chaining with optimal sequencing is illustrated in Figure 7 (a, b, c).

Groups A and H were unable to chain, therefore the original curves are depicted. The reductions associated with Group B are significantly greater than those of Group E, corresponding to the increased chaining potential (temporal flexibility) of the shopping trips associated with B over the work-related and education activities associated with E.

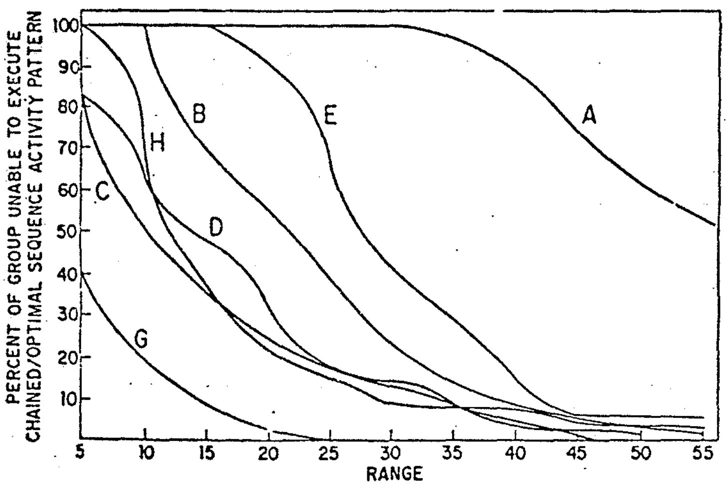

FIGURE 6. PERCENT OF GROUP UNABLE TO EXECUTE CHAINED/OPTIMAL SEQUENCE ACTIVITY PATTERN DUE TO URBAN VEHICLE DESIGN RANGE

Table 4: Design Range at which Majority of Group can Utilize Urban Vehicle Under Chained Conditions

Range	Group	% of Total Sample	Cumulative % of Total Sample
5	G	46.0	46.0
10	C	12.4	58.4
15	D,H	19.3	77.7
20			77.7
25	B	8.4	86.1
30	E	7.1	93.2
35-55			93.2

The remaining groups (C, D and G) are also able to decrease the negative impacts of rationing through chaining. Reductions in Group D are somewhat less than C or G, due primarily to the relatively efficient nature of the existing travel patterns of respondents in that group. A summary of the potential of trip chaining for reducing the impacts of gasoline rationing is presented in Table 5.

The removal of the restriction that each of the individual's activities must be performed at the original location offers a more realistic approach to the examination of travel/activity behavior. In the short-run, it is reasonable to expect individuals to substitute closer activity sites for those farther away when faced with the imposition of travel limitations. Unfortunately, this increase in realism is also accompanied by an increase in complexity in applied problem solving. The additional complexity is due to the difficulty in determining the substitutability of alternative activity sites. The relative number of opportunities forfeited (or gained) as a result of changes in vehicle usage and rationing levels is dependent

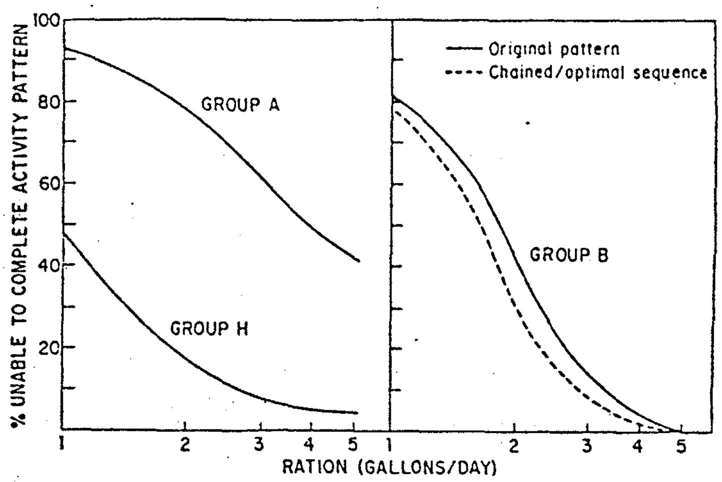

FIGURE 7a. EFFECT OF RATIONING ON VARIOUS GROUPS

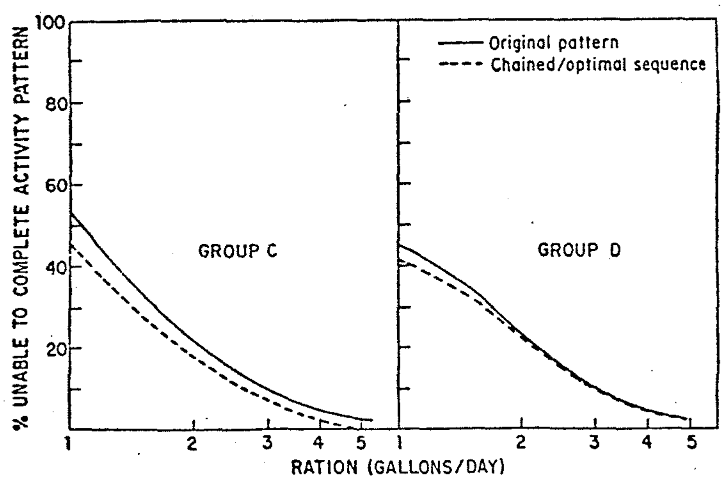

FIGURE 7b. EFFECT OF RATIONING ON VARIOUS GROUPS

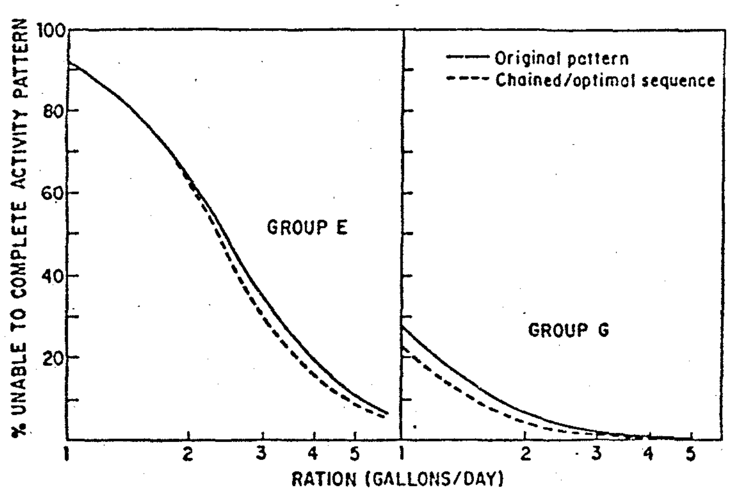

FIGURE 7c. EFFECT OF RATIONING ON VARIOUS GROUPS

in part on perceived as well as actual opportunities which are acceptable to the individual.

Table 5: Summary of Fuel Rationing Impacts

Group	Characteristics	Total Distance Traveled	Impact of Rationing: present	Impact of Rationing: potential reduction by chaining(1)
A	-working household heads -single long trip (work) -low density/higher income residence	60	high	none
B	-working, household heads -single fixed/single flexible activity -low density/higher income residence	10	high	moderate
C	-younger, nonemployed -some workers, short trips -evening flexible trip -high density/lower income residence	15	moderate	moderate
D	-non-employed females -shopping and social-recreational activities -low density/higher income residence	10	moderate	moderate
E	-working, household heads -multiple fixed activity trips -low density/higher income residence	30	high	low
F	(not analyzed)			
G	-primarily students, non-employed -several short trips -high density/lower income residence -no evening trips	5	low	moderate
H	-working household heads -single moderate length trip (work) -high density/lower income residence	15	moderate	none

(1) Reductions are classified in a relative sense--the impact on each group remained in the same general classification--low, moderate and high.

A starting point for the quantification of opportunity space was provided by the representative activity patterns. From these, the maximum potential opportunity area (the continuous and connected set of locations that can be physically accessed by an individual) was determined. This maximum area served as a surrogate for the total number of potential opportunities available to the individual. A combination of automobile fuel efficiency (as defined by vehicle miles per gallon) and gasoline ration level (as defined by the number of gallons/five day work week) was introduced to generate a maximum total travelling distance. A "new" activity pattern profile with the same activity types and durations as the original pattern and a total distance equal to the distance determined by the vehicle mpg and ration level was derived and the number of potential opportunities available was calculated. A comparison between the original number of potential opportunities and the derived number indicated the loss in potential opportunities brought about by the travel restriction. This procedure was carried out for various ration levels and vehicle miles per gallon to measure the sensitivity of an individual's potential opportunity space with respect to the different policy-imposed travel restrictions. This procedure was also applied to each type of activity contained in an individual's RAP to determine which activities are affected most severely.

Table 6 illustrates that individuals in Group A would be unable to reach their places of employment if their gasoline consumption was limited to 10 gallons/week (irrespective of vehicle efficiency). A 50% increase in the ration level would also have to be accompanied by a vehicle efficiency level of 20 miles per gallon to allow members of Group A to travel to their employment sites. In contrast to Table 6, Table 7 shows that Group B is able to execute the work portion of their activity pattern in all cases except the most restrictive (a ration level of 5 gallons/week and a vehicle efficiency of 10 mpg). In addition, over half of the total potential shopping opportunities would still be available to Group B if the ration level exceeded 5 gallons/week and vehicle efficiency was greater than 10 mpg.

Group C's relatively "safe" position with respect to the loss of potential opportunities is illustrated in Table 8. The work-related portion of Group C's activity pattern is unaffected in all cases and over 60 percent of all potential social-recreation opportunities are still present unless gasoline is limited to five gallons and vehicle efficiency is 15 mpg or less. Group D (Table 9) forfeits over 80 percent of its total potential opportunities when the strictest rationing is imposed (independent of vehicle) and at least 55 percent of its opportunities when the most inefficient vehicle is utilized (independent of ration level). If, however, a vehicle with an efficiency of 20 mpg or more is available, the members of Group D will experience no loss in potential shopping/social recreation opportunities with an accompanying ration level of 15 gallons per week or more.

An illustration of Group E's potential opportunity space is provided in Table 10. Neither the work activity nor the school/work-related business activity can be performed with a 5 gallon/week ration level and the same situation exists when the ration level is doubled if the most inefficient vehicle is used. However, a 50 percent increase in efficiency (or ration level) allows Group members to carry out work trips, and a 100 percent increase allows the school/work-related business trip to be carried out as well.

A comparison of Tables 11 and 8 reveals that Group F experiences a greater loss in potential social-recreation opportunities than does Group C. At least 67 percent of their potential opportunities are rendered infeasible when the ration level is set at 5 gallons per week and vehicle efficiency is 25 mpg and this increases to 80.33 percent when vehicle efficiency decreases to 20 mpg (compared to 0.0 and 36.0 percent for Group C). Increased severity caused by rationing results from Group F's execution of multiple social-recreation activities as opposed to a single social-reaction activity in the case of Group C. Group G experiences no loss in potential opportunities for any combination of vehicle efficiency and rationing while Group H is only unable to carry out its RAP under the most severe conditions (10 mpg and 5 gallons/week).

V. Summary and Conclusions

The specific results obtained from this study should only be interpreted as preliminary estimates of transportation-related impacts and are not as important as

TABLE 6: PERCENT OF RELEVANT OPPORTUNITIES FORFEITED BY GROUP A

KEY: WORK

RATION / EFFICIENCY		GALLONS PER WEEK			
		5	10	15	20
MILES PER GALLON	10	100.00	100.00	100.00	100.00
	15	100.00	100.00	100.00	0.00
	20	100.00	100.00	0.00	0.00
	25	100.00	100.00	0.00	0.00

TABLE 7: PERCENT OF RELEVANT OPPORTUNITIES FORFEITED BY GROUP B

KEY: WORK / SHOP

RATION / EFFICIENCY		GALLONS PER WEEK			
		5	10	15	20
MILES PER GALLON	10	100.00 / 100.00	0.00 / 93.75	0.00 / 43.75	0.00 / 0.00
	15	0.00 / 100.00	0.00 / 43.75	0.00 / 0.00	0.00 / 0.00
	20	0.00 / 93.75	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00
	25	0.00 / 75.00	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00

TABLE 8: PERCENT OF RELEVANT OPPORTUNITIES FORFEITED BY GROUP C

KEY: Work School / Soc. Rec.

RATION / EFFICIENCY		GALLONS PER WEEK			
		5	10	15	20
MILES PER GALLON	10	0.00 / 91.00	0.00 / 36.00	0.00 / 0.00	0.00 / 0.00
	15	0.00 / 69.75	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00
	20	0.00 / 36.00	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00
	25	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00

TABLE 9: PERCENT OF RELEVANT OPPORTUNITIES FORFEITED BY GROUP D

KEY: Shop / Soc. Rec.

RATION / EFFICIENCY		GALLONS PER WEEK			
		5	10	15	20
MILES PER GALLON	10	97.25 / 97.25	88.88 / 88.88	75.00 / 75.00	55.55 / 55.55
	15	93.75 / 93.75	75.00 / 75.00	43.75 / 43.75	0.00 / 0.00
	20	88.88 / 88.88	55.55 / 55.55	0.00 / 0.00	0.00 / 0.00
	25	82.64 / 82.64	30.55 / 30.55	0.00 / 0.00	0.00 / 0.00

TABLE 10: PERCENT OF RELEVANT OPPORTUNITIES FOREFEITED BY GROUP E

KEY: WORK / Sch Work-re

RATION / EFFICIENCY		GALLONS PER WEEK			
		5	10	15	20
MILES PER GALLON	10	100.00 / 100.00	100.00 / 100.00	0.00 / 100.00	0.00 / 0.00
	15	100.00 / 100.00	0.00 / 100.00	0.00 / 0.00	0.00 / 0.00
	20	100.00 / 100.00	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00
	25	100.00 / 100.00	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00

TABLE 11: PERCENT OF RELEVANT OPPORTUNITIES FORFEITED BY GROUP F

KEY: WORK / Soc. Rec.

RATION / EFFICIENCY		GALLONS PER WEEK			
		5	10	15	20
MILES PER GALLON	10	0.00 / 96.67	0.00 / 80.33	0.00 / 49.65	0.00 / 0.00
	15	0.00 / 90.20	0.00 / 49.65	0.00 / 0.00	0.00 / 0.00
	20	0.00 / 80.33	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00
	25	0.00 / 67.50	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00

the development and application of the activity analysis methodology. Clearly, household interaction in the form of vehicle reallocation or ridesharing will have impacts on both fuel consumption and the effectiveness of trip chaining and these factors have been ignored here. However, the case study serves as a means by which the policy application of the methodology can be evaluated. It has been shown that approximately one-fifth of the Southern California population (Groups A, B and E in the analysis) will experience severe difficulty in carrying out activity patterns when energy-constraint policies are introduced as a result of their propensity to make long distance trips to activities that are spatially and temporally fixed (e.g., work, school). Another 35 percent of the sample population (Groups C, D and H) can expect to encounter moderate problems in executing activity patterns as a direct consequence of the large number of trips associated with these individuals. This segment of the population will not experience disruption on the order of that experienced by Groups A, B and E because of the short-distance nature of their trips. Although only slightly more than one-half of the individuals were shown to experience some degree of difficulty in performing their daily activities, these individuals were contained in 82.7 percent of the households examined. As a result, it is expected that energy-constraint policies will have a fairly widespread effect on the population of southern California. The remaining 45 percent of individuals (Group G) has been shown to be relatively "immune" to any adverse impacts on their daily routine due to both the relatively small number of trips made and the proximity of activity sites. However, this latter group comprises only 17.3 percent of the households analyzed.

With respect to potential remedies for the activity pattern restrictions imposed by the transportation policies, it has also been shown that most of the remedies evaluated (trip chaining, utilization of more energy-efficient vehicles, activity site substitution) offer little in the way of relief to those segments of the population most severely affected. Exceptions to this are trip chaining (and optimal activity sequencing) in the case of Group B and shifts to more fuel-efficient vehicles in the cases of Groups B and E. In general, however, it appears that long-term decisions (i.e., changes in employment or residential locations) offer the only substantial relief to those individuals most severely affected.

A much wider range of effective strategies is available to those portions of the population that can expect somewhat less severe restrictions on their current travel/activity behavior. Two of the groups in this category (Groups C and D) comprising 41.4 percent of the households are able to either chain their trips or visit alternate activity sites without experiencing much difficulty or loss in potential opportunities. In addition, all three groups (C, D and H; 34.5 percent of households) are able to use a more energy-efficient vehicle (either a special purpose urban vehicle or a conventional automobile with a higher mpg) to carry out their present activity pattern. Lastly, although Group G as a whole is not seriously affected by the energy-constrained environment, any individuals in this group experiencing difficulty in completing their current activity pattern will be able to use any of the optional strategies to full advantage.

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