Understanding Trip Chaining

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Acknowledgments

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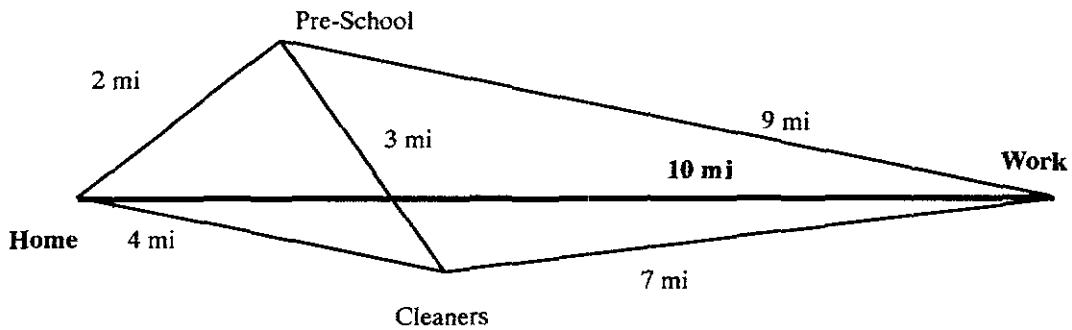
Introduction and Overview

Person trips are a basic unit of measurement in the Nationwide Personal Transportation Survey (NPTS). The "trip" element in this measure is defined as "one-way travel from one place (address) to another by any means of transportation," while the "person" element identifies the subject. In many instances, person trips are a valid indicator of travel. Sometimes, however, they are not. A hypothetical example offers the most convenient way to illustrate how trips are coded in the NPTS and the problems that arise when these trips are combined ("chained") into multiple stop journeys. Figure 1 presents a simple two dimensional map of a person's commuting network. The network is anchored at one end by the worker's home and at the other end by his place of work. Two stops that are sometimes made between home and work are identified. Distances between the various locations on the network are also given.

Figure 1: HYPOTHETICAL COMMUTING ROUTES



The worker's commuting itinerary in a typical week is as follows:

	AM Commute Stops	*PM Commute Stops*
Monday	Pre-School	Pre-School
Tuesday	None	None
Wednesday	Pre-School; Cleaners	Pre-School
Thursday	None	Cleaners
Friday	None	Pre-School

As coded in the NPTS, the worker's commute contains both work and non-work trips. For example, the Monday AM commute consists of a two mile *family and personal business* trip to the pre-school, followed by a nine mile *to work* trip. The Monday PM return commute begins with a nine mile *family and personal business* trip to the preschool, followed by a two mile *from work* trip home.

The non-work trips in this example are treated as independent in the NPTS, which in the above illustration clearly complicates attempts to analyze the work commute. For example, if we were to ask how long this person's commute is based on his coded work trips, the answer would be "it depends." Coded work trip distances vary both by day and direction, as shown in Table 1. As the table indicates, AM work trips average 9.2 miles, while PM work trips average 4.0. Moreover, the daily one-way average ranges from 4.5 (Wednesday) to 10 miles (Tuesday). The overall average work trip distance of 6.6 miles is 34 percent *less* than the "shortest path" commuting route between the person's residence and work place. What this example reveals is that trip purpose as coded in the NPTS can cause problems in analyzing total commute travel. Also, the deviations of work trip and commuting distances in this example are all in the same direction.

Table 1: WORK TRIP DISTANCES FOR A HYPOTHETICAL COMMUTER (MILES)

Day	AM Commute	PM Commute	AM/PM Average
Monday	9	2	5.5
Tuesday	10	10	10.0
Wednesday	7	2	4.5
Thursday	10	4	7.0
Friday	10	2	6.0
Daily Average	9.2	4.0	6.6

This indicates that when the commute involves stops between home and work, coded work trip distances in the NPTS will be shorter than the actual distances between these two points.

An exact portrayal of the journeys in this example can be obtained by linking the trips in the commute, forming *trip chains*. When a journey is comprised of a single non-home destination, the trip chain is termed "simple" in the sense that it is equivalent to the coded trip. Alternatively, "complex" trip chains represent journeys involving multiple non-home destinations. It may also be important to know, as in the commuting example, whether the complexity of a journey exists in the outbound or homeward portion. Below, we again portray the hypothetical weekly commuting itinerary, but this time we depict each commute as its trips would be coded in the NPTS, and (in parentheses) as it would be characterized in trip chaining terminology.

	AM Commute	*PM Commute*
Monday	Personal Business; Work ("Complex to Work")	Personal Business; Work ("Complex from Work")
Tuesday	Work ("Simple Work")	Work ("Simple Work")
Wednesday	Personal Bus.; Personal Bus.; Work ("Complex to Work")	Personal Business; Work ("Complex from Work")
Thursday	Work ("Simple Work")	Personal Business; Work ("Complex from Work")
Friday	Work ("Simple Work")	Personal Business; Work ("Complex from Work")

The trip chain framework permits a less ambiguous response to the commuting distance question. For example, if one is interested in commuting distance to represent the spatial separation of home and the work place, only work trips in the NPTS comprising "simple work" chains should be employed.

Analyzing trip chaining activity may lead to better understanding of travel behavior and provide a more appropriate framework for examining some transportation policy issues. For example, it has been observed that non-work trip-making has been growing rapidly during peak commuting times (1). Such growth would seem surprising in a context of unlinked trips because one would not expect people to schedule so-called "discretionary" travel during the most congested periods. Alternatively, if peak non-work trips are frequently linked to commutes, then a basis for the apparently illogical travel behavior can be established. For example, it has been observed that single person and multiple adult worker households have a greater tendency to combine work and non-work trips than do commuters from family households in which only one adult is employed (2). Since the former household types have been growing in number more rapidly than the latter during the past twenty-five years, we can infer that household composition changes have contributed to the growth of non-work travel during peak commuting hours, and observed increases in the complexity of trip chains over time (3).

Moreover, the 1990 NPTS reveals the predominant reliance on automobiles for the journey to work (4). Since the automobile provides enhanced flexibility in organizing daily activities, non-work activities can be more easily coordinated with the work commute. Thus, the shift of commuters from public transit to automobiles contributes to traffic congestion directly (in the growth of work-based vehicle trips) and indirectly (in the growth of non-work vehicle trips made in conjunction with the commute).

What are the policy implications of the links between work and non-work trips, and trip chaining more generally? First, the non-work trips in the commuting example are probably not as discretionary as one might think, and they may well constrain the scheduling of commutes. Experience indicates a fairly strong resistance to rescheduling work periods (5, 6). Workers' reluctance to re-schedule their commutes is understandable considering that non-work obligations often must be satisfied in these journeys.

Second, single occupant vehicle commuting coupled with changing household structure have stimulated peak period non-work travel, exacerbating congestion. Household demographics fall outside the transportation policy arena, but vehicle occupancy clearly can be influenced, with potentially important consequences. For example, an increase in vehicle occupancy or a switch to transit resulting from congestion tolls or parking price increases would, holding the number of person trips constant, reduce the number of vehicle trips during peak commuting periods. What is not recognized in the "independent" trip perspective is that an additional shifting of non-work trips linked to commuting is likely to occur when the convenience of SOV travel is given up.

Shifting non-work elements of the commute to off-peak periods contributes in principle to more efficient use of transportation infrastructure. However, it may also stimulate some undesirable environmental side effects. It has been estimated that non-work trips made independent of the work commute are 10 to 20 percent longer, and about two-thirds of these journeys involve trips to a single destination (7). Thus, if trip chaining in conjunction with the journey to work was discouraged, vehicle emissions and the proportion of "cold starts" would probably increase.

For at least the past 15 years transportation researchers have stressed the importance of the work commute as an organizing element of household travel. Empirical studies of trip chaining support this view, indicating that 10 to 20 percent of all non-work trips are linked to the work commute. Studies indicate that activities other than employment also provide an organizational focus for multi-trip journeys (8, 9, 10).

Trip chaining studies have usually relied on travel data from specific metropolitan areas. The problems of generalizing the findings of local studies are well known. Most researchers in this field would acknowledge that without analysis of trip chaining at the national level, our understanding of travel behavior suffers and our ability to devise wise policies is more limited.

In the following sections we define the trip chaining typology employed in the report, and describe the procedure used to generate trip chains from person trips in the NPTS. We then present trip chaining patterns distinguished by travel purpose, geographic, socio-economic and demographic factors. We also estimate the bias associated with equating work trips with work commutes. The report concludes with a discussion of research needs and opportunities.

Derivation of Trip Chains

The trip chain typology employed in this report is based on person trips reported in the day trip file of the 1990 NPTS, and identifies two general travel purposes—work and non-work. Second, the typology distinguishes between simple journeys, involving a person trip from home to a given destination and then returning home, and complex journeys, involving a sequence of more than two person trips that begins and ends at home. The greatest amount of detail involves distinguishing among four types of complex work chains, based on the point(s) in the commute where non-work trips might occur: (1) on the way to work; (2) on the return from work; (3) both on the way to and the return from work; and (4) during the work day. The typology is illustrated in Figure 2.

Figure 2: TRIP CHAIN TYPOLOGY

Trip Chain Type	Configuration*
Simple Work	H - W { - W - } - H
Complex To Work	H - NW { - NW/W - } - W - H
Complex From Work	H - W { - NW/W - } - NW - H
Complex To & From Work	H - NW { - NW/W - } - W - { - NW/W - } - NW - H
Complex At Work	H - W { - NW/W - } - NW - { - NW/W - } - W - H
Simple Non-Work	H - NW - H
Complex Non-Work	H - NW { - NW - } - H

*H = Home; W = Work; NW = Non-Work. The bracketed terms represent additional trips which may be present in the chain.

Some of the subjects to be discussed in the following sections of the report call for a more detailed breakdown of the trip chaining types than others. In these instances we will employ the full breakdown of the seven trip chaining types listed in Figure 2. In other cases less detail is necessary, and there we aggregate the four complex commuting chain types. Finally, in selected instances we focus exclusively on the five work chain types. The seven category breakdown will be referred to as the **Main** typology. The **Grouped** typology will refer to the four category set including simple/complex work/non-work chains, and the **Commute** typology will refer to the five work-related chain categories in Figure 2.

It was not possible to link all the trips reported in the day trip file into the various trip chains. Trips contained in sequences that did not begin and end at home were not included. These sequences represent individuals who typically either began or ended their travel day away from home. Also, trips in "broken" chains, in which a given destination address was not coded as the subsequent origin address, were not included. Chains representing over 93% of the nearly 250 billion person trips in the 1990 NPTS were constructed (see Table 2).

Table 2: DISTRIBUTION OF TRIP CHAINS AND TRIPS

	Trip Chains (Millions)	Trips (Millions)
Valid Trip Chains	89,262	232,317
Invalid Trip Chains	8,333	17,245
Total	97,595	249,562

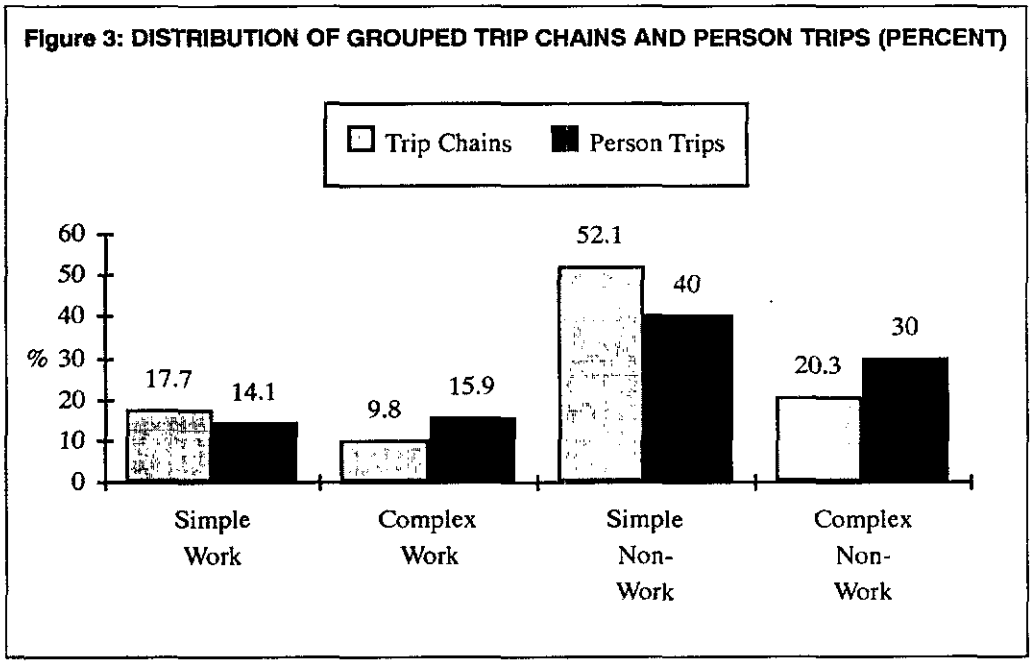
Contributing Elements

In this section we examine trip chaining patterns through a number of cross tabulations involving trip chaining, household and urban characteristics, mode of travel and commuting. The approach is necessarily discursive given the number of topics covered, and in that we do not seek to determine whether the trip chaining patterns are significant statistically.

Distribution of Trip Chains and Person Trips

Trip chains related to work commuting account for 27.5% of all Grouped chains and contain 30% of all person trips (see Figure 3). By comparison, the *Summary of Travel Trends* (11) reports that work travel accounted for 21.6% of the person trips in the 1990 NPTS. The journey to work is thus a more important organizational element of household travel activity than trip-based statistics tend to indicate. Work commutes are also more likely to be comprised of multiple trips than are non-work journeys: 35.6% of all work related trip chains are complex, as compared to 28.0% of non-work chains.

Figure 3: DISTRIBUTION OF GROUPED TRIP CHAINS AND PERSON TRIPS (PERCENT)



A more detailed portrayal of the work commute is provided in Table 3. The likelihood of a commute containing non-work trips in the *to home* portion only is nearly five times the likelihood of a commute containing non-work trips in the *to work* portion only. Moreover, commutes which are complex only in the *to home* portion account for more chains (6.4%) and person trips (9.7%) than the other three complex commuting alternatives combined. The number of trips per chain is reported in the right-hand column of Table 3. Simple commutes, for example, average a trip *to work*, a trip *to home* and, in one of ten instances, a work related trip. Complex to Work, Complex from Work and Complex Non-Work chains contain nearly two more trips than a simple chain. Chains that are complex both to and from work contain the greatest number of trips. Finally, although chains which are complex during the work day comprise a fairly small percentage of all trip chains (0.6%), they average three trips in addition to the trips to and from work.

Table 4 provides a more detailed breakdown of trip chaining activity within the Main typology with respect to non-work trip purpose. Given non-work activities are more likely to be contained in some types

Table 3: DISTRIBUTION OF MAIN TRIP CHAIN TYPES AND PERSON TRIPS (MILLIONS)

	Trip Chain Type							
	Work					Non-Work		
Trip Category	Simple	Complex To	Complex From	Complex To & From	Complex At	Simple	Complex	Total
Trip Chains	15,834	1,184	5,724	1,354	562	46,479	18,126	89,262
Percent	17.7	1.3	6.4	1.5	0.6	52.1	20.3	100.0
Person Trips	32,856	4,337	22,474	7,240	2,792	92,962	69,656	232,317
Percent	14.1	1.9	9.7	3.1	1.2	40.0	30.0	100.0
Trips Per Chain	2.1	3.7	3.9	5.3	5.0	2.0	3.8	2.6

Table 4: TRIPS PER CHAIN BY PURPOSE AND MAIN TRIP CHAIN TYPE

	Trip Chain Type						
	Work					Non-Work	
Trip Category	Simple	Complex To	Complex From	Complex To & From	Complex At	Simple	Complex
Work	2.00	2.04	2.05	1.98	2.08	0.00	0.00
Work-Related Business	.08	.15	.09	.17	.67	0.00	0.00
Shopping	0.00	.23	.54	.62	.41	.48	.99
Other Family/ Personal Bus.	0.00	.77	.79	2.06	1.48	.40	1.20
School/Church	0.00	.17	.04	.12	.02	.44	.31
Doctor/Dentist	0.00	.01	.04	.03	.08	.02	.05
Vacation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Visit Friends/Relatives	0.00	.10	.15	.16	.05	.24	.49
Pleasure Driving	0.00	0.00	0.00	0.00	0.00	.02	.02
Other Social/ Recreational	0.00	.18	.21	.19	.18	.38	.73
Other	0.00	.01	.01	.02	.02	.02	.04
Trips Per Chain	2.08	3.66	3.92	5.35	4.98	2.00	3.83

of trip chains than others. Shopping trips predominate in complex non-work chains and are relatively infrequent in complex *to work* chains. Trips whose purpose is other family/personal business are most heavily represented in chains that are complex both to and from work. School and church related trips are most heavily represented in simple non-work chains, and visits to the doctor or dentist are most often made during the work day. Visits to friends and relatives and other social and recreational trips are most likely to be contained in complex non-work chains.

Trip Chaining and Gender

In both work and non-work travel women exhibit a greater tendency to organize their trips into chains (see Figure 4 and Table 5). Within the Grouped typology the likelihood that a woman's commute will be complex is 37% greater than a man's (.42 for women versus .306 for men). For non-work travel, the likelihood of a complex journey for women (.299) is 15% greater than the likelihood for men.

Figure 4: PERCENTAGE OF WORK AND NON-WORK TRIP CHAINS FOR MEN AND WOMEN THAT ARE COMPLEX

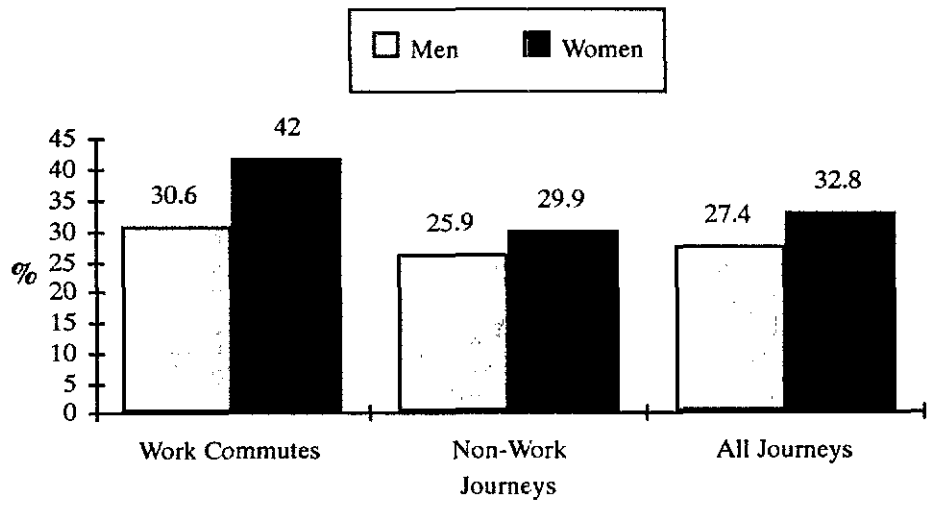


Table 5: GROUPED TRIP CHAINS OF MEN AND WOMEN (MILLIONS)

	Trip Chain Type				
Gender	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
Men	9,305	4,095	21,899	7,663	42,951
Women	6,527	4,729	24,578	10,462	46,295
N.A.*	2	0	12	2	16
Total	15,834	8,824	46,489	18,127	89,262

*Not Ascertained/Refused.

Table 6: DISTRIBUTION OF GROUPED TRIP CHAINS BY HOUSEHOLD INCOME (PERCENT)

Income Category	Trip Chain Type: Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
L. T. $5,000	8.5%	4.2%	61.4%	25.9%	100.0%
$5,000-9,999	12.1	5.4	61.3	21.2	100.0
$10,000-14,999	15.4	7.4	55.6	21.6	100.0
$15,000-19,999	17.1	9.4	53.0	20.5	100.0
$20,000-24,999	19.0	10.1	50.7	20.2	100.0
$25,000-29,999	17.1	9.4	52.7	20.8	100.0
$30,000-34,999	17.4	10.8	50.8	21.0	100.0
$35,000-39,999	18.5	11.5	50.0	20.0	100.0
$40,000-44,999	17.9	11.3	49.0	21.8	100.0
$45,000-49,999	18.4	10.9	50.0	20.7	100.0
$50,000-54,999	18.5	12.4	50.0	19.1	100.0
$55,000-59,999	18.2	11.8	50.9	19.2	100.0
$60,000-64,999	18.0	12.8	47.7	21.5	100.0
$65,000-69,999	18.0	13.2	49.2	19.6	100.0
$70,000-74,999	18.1	13.2	46.2	22.6	100.0
$75,000-79,999	15.9	15.0	49.8	19.2	100.0
$80,000+	18.9	11.1	47.8	22.2	100.0

Trip Chaining and Income

The share of simple non-work journeys declines as household income increases. Over 60% of the Grouped trip chains of households with incomes less than $10,000 are simple non-work, as compared to less than 50% for households with incomes over $30,000 (see Table 6). Higher income households exhibit a greater tendency to combine work and non-work trips. Nevertheless, the share of simple work chains is greater for higher income households.

Trip Chaining and Time of Travel

Based on the Grouped typology, Figure 5 shows that complex chains are more likely than simple chains to occur during the peak period. For commute chains, 87 percent of complex chains occur in the peak period compared to 77 percent of simple chains. Complex chains may be more peak oriented due to a need to meet scheduled stops, or possibly because complex chains have longer durations.

Figure 5: TIME OF TRAVEL: GROUPED TRIP CHAINS (PERCENT)

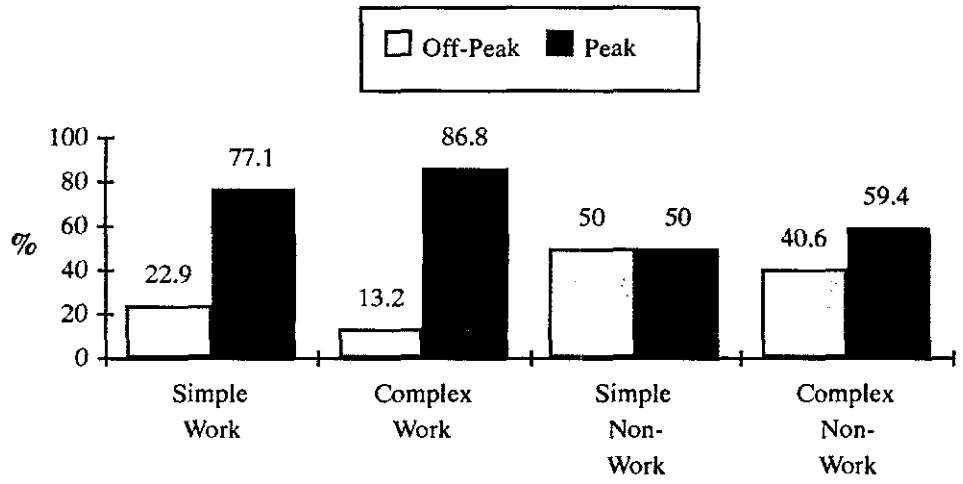
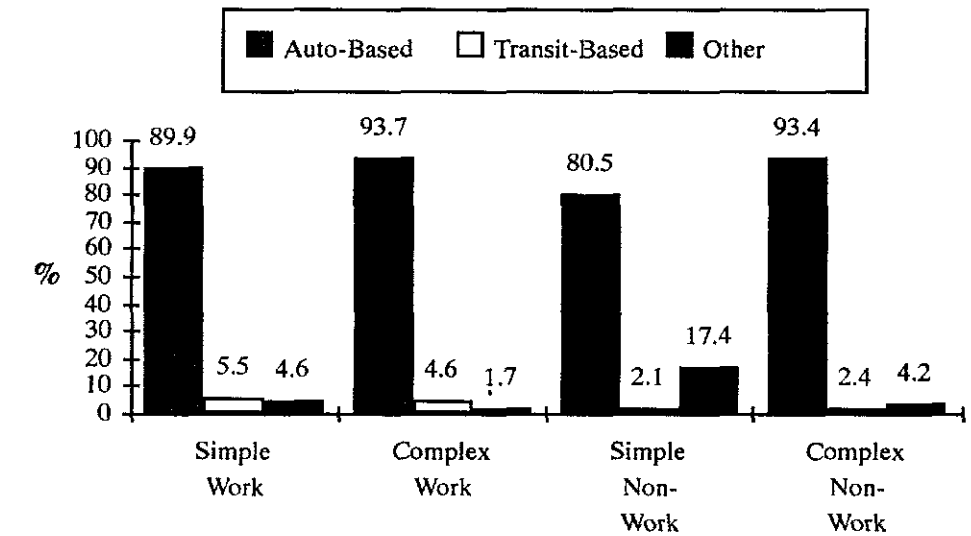


Figure 6: GROUPED TRIP CHAIN DISTRIBUTION BY PRINCIPAL MODE OF TRAVEL (PERCENT)



Trip Chaining and Travel Mode

Based on the Grouped typology, Figure 6 shows that complex trip chains tend to be more auto oriented. The cause of this shift is not unilaterally evident, however. Is it the choice of the auto mode that makes the journey more likely to be complex, or are complex travel activity itineraries contributing to a higher likelihood that a person will choose the automobile?

Table 7: GROUPED TRIP CHAIN DISTRIBUTION BY TIME OF TRAVEL (MILLIONS)

	Trip Chain Type				
Travel Period	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
Peak*	12,200	7,662	23,229	10,767	53,858
Off-Peak	3,633	1,160	23,250	7,360	35,404
Total	15,833	8,822	46,479	18,127	89,262

* The peak periods are 6:30 to 9:00 AM and 3:30 to 6:00 PM.

Table 8: DISTRIBUTION OF GROUPED TRIP CHAINS BY TRAVEL MODE (MILLIONS)

	Trip Chain Type				
Mode	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
Auto Only	14,113	7,801	36,593	15,730	74,237
Transit Only	628	45	710	47	1,430
Auto/Transit	133	112	108	101	453
Auto/Other	128	470	838	1,192	2,628
Transit/Other	73	175	102	236	586
Auto/Transit/Other	26	73	4	52	155
Other	728	149	8,102	769	9,749
N.A.*	4	0	20	0	24
Total	15,833	8,825	46,477	18,127	89,262

* Not Ascertained

Table 9: DISTRIBUTION OF GROUPED TRIP CHAINS BY LOCATION OF RESIDENCE (PERCENT)

	Trip Chain Type				
Metropolitan Status	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
MSA Central City	17.9	9.8	52.3	20.1	100.0
MSA Suburban	17.8	10.5	51.0	20.8	100.0
Non-Metropolitan	17.5	8.8	53.8	19.9	100.0

Trip Chaining and Urban Status

The distribution of Grouped trip chain types is not strongly related to residential location status, broadly defined. Metropolitan suburban residents have a somewhat smaller share of simple non-work chains and a slightly larger share of complex work chains than do central city and non-metropolitan residents. Non-metropolitan residents have the largest percentage of simple non-work chains (see Table 9).

The percentage of simple work chains becomes progressively larger as urban population increases (see Table 10). This upward trend is offset by declines in the shares of both simple and complex non-work chains. Hence, the share of work based trip chains is positively related to metropolitan size.

Table 10: DISTRIBUTION OF GROUPED TRIP CHAINS BY METROPOLITAN SIZE (PERCENT)

	Trip Chain Type				
MSA/CMSA Size	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
L.T. 250,000	15.7%	10.1%	52.7%	21.5%	100.0%
250,000-499,999	16.5	10.4	51.7	21.4	100.0
500,000-999,999	17.5	10.3	51.6	20.6	100.0
1,000,000-2,999,999	18.5	9.7	50.7	21.1	100.0
G.T. 3,000,000	18.5	10.4	51.7	19.3	100.0

Trip Chaining and Household Size

Single person households have the greatest likelihood of forming complex trip chains (see Figure 7). Based on the Grouped typology, the share of complex work chains declines and the share of simple non-work chains grows with increases in the number of persons per household (see Table 11).

Figure 7: PERCENTAGE OF GROUPED TRIP CHAINS THAT ARE COMPLEX, BY HOUSEHOLD SIZE

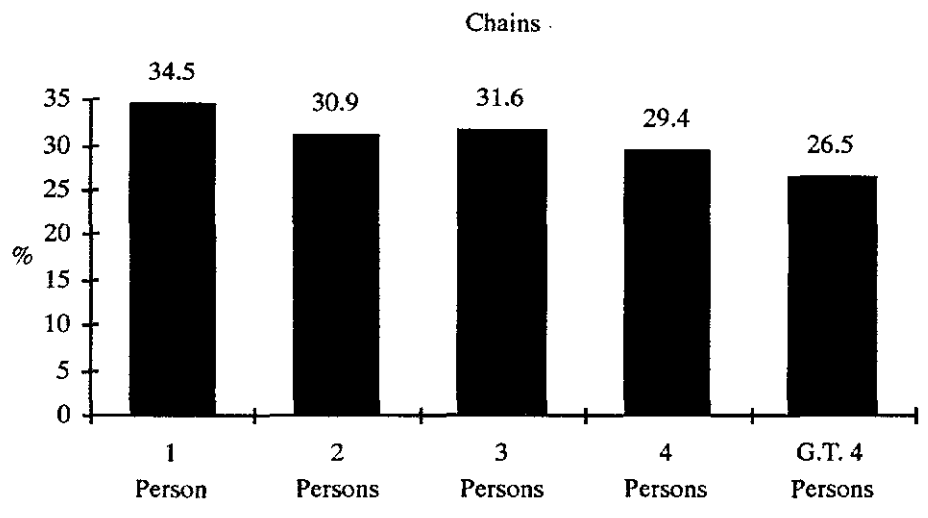


Table 11: DISTRIBUTION OF GROUPED TRIP CHAINS BY SIZE OF HOUSEHOLD (PERCENT)

	Trip Chain Type				
Household Size	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
1 Person	15.5%	12.1%	50.0%	22.4%	100.0%
2 Persons	20.1	10.7	48.9	20.2	100.0
3 Persons	20.2	11.4	48.2	20.2	100.0
4 Persons	16.9	9.0	53.6	20.4	100.0
G. T. 4 Persons	14.4	7.3	59.0	19.2	100.0

Trip Chaining and Life Cycle

Trip chaining patterns vary considerably with respect to household life cycle stage (see Table 12). Based on the Grouped typology, single and multiple adult households—the first two life cycle categories in Table 12—account for the largest percentage of work related chains (38.6% of all chains for households comprised of two or more adults, and 35.5% for single adult households), while the percentage of trip chains linked to the commute is smallest for single adults with children age 15 and less (16.8% for single adults with children age 0-5, and 17.6% for households with children age 6-15).

For non-work travel the relative likelihood of complex trip chaining is greatest for single adults with children age 16-21 and single adults (33.5% and 31.8% of these respective group's non-work chains are complex), while the relative likelihood of complex chaining is least for households comprised of two or more adults with children age 6-15 (24.5%) and households with two or more retired adults (25.2%).

Table 12: DISTRIBUTION OF GROUPED TRIP CHAINS BY HOUSEHOLD LIFE CYCLE STAGE (PERCENT)

	Trip Chain Type				
Life Cycle Category	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
1 Adult	20.0%	15.5%	44.0%	20.5%	100.0%
2+ Adults	25.9	12.7	42.6	18.8	100.0
1 Adult; Ch. 0-5	7.9	8.9	57.6	25.6	100.0
2+ Adults; Ch. 0-5	16.4	10.6	52.0	21.0	100.0
1 Adult; Ch. 6-15	9.4	8.2	58.5	23.9	100.0
2+ Adults; Ch. 6-15	14.8	7.9	58.3	18.9	100.0
1 Adult; Ch. 16-21	16.7	8.6	50.0	25.2	100.0
2+ Adults; Ch. 16-21	24.0	10.8	45.9	19.4	100.0
1 Retired Adult	1.3	.6	70.1	28.0	100.0
2+ Retired Adults	7.9	3.2	66.6	22.4	100.0
Not Ascertained	22.3	9.1	48.2	20.4	100.0

Commuting Chains and Urban Area Size

Cross tabulation of duration, distance, and speed of work trips contained in the various types of commute chains are reported in Table 13. Note that the figures in the table are for work trips and do not reflect non-work trips that are present in complex commute chains. Focusing on work trips in this way reveals more clearly how the presence of non-work trips in the commute affects work trip characteristics, as coded in the NPTS.

Table 13 shows that work trip distance and duration increase and speed decreases with respect to urban area size. Simple commute chains follow this pattern more than do complex commute chains. For simple commute chains, work trip length and duration in metropolitan areas with more than three million residents are 27 and 49 percent greater than in metropolitan areas with less than 250,000 residents, while average speed is about 15 percent lower. Work trip lengths in non-metropolitan areas are generally greater than lengths in all but the largest metropolitan areas. Work trips in simple commute chains are 26% slower in the largest metropolitan areas than in non-metropolitan areas (29.4 versus 39.5 mph).

Table 13: COMMUTE TRIP CHAINS, BY METROPOLITAN SIZE*

	Trip Chain Type					
MSA/CMSA Size	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Row Av.
			I. Distance (Miles)			
L. T. 250,000	9.5	11.7	8.3	8.0	—	9.2
250,000-499,999	9.5	7.6	10.1	9.5	—	9.6
500,000-999,999	11.3	7.9	10.2	12.9	9.8	10.9
1,000,000-2,999,999	10.8	9.3	11.3	9.6	9.0	10.8
G. T. 3,000,000	12.1	12.1	12.5	9.9	14.2	12.2
Non-Metropolitan	11.7	10.8	10.9	9.9	8.6	11.3
			II. Duration (Min.)			
L. T. 250,000	16.6	19.5	14.9	14.4	—	16.2
250,000-499,999	17.0	14.2	17.0	17.0	—	16.8
500,000-999,999	19.8	16.5	18.0	19.9	17.8	19.2
1,000,000-2,999,999	20.8	19.0	20.0	18.0	16.9	20.3
G. T. 3,000,000	24.8	23.8	24.6	19.0	25.8	24.4
Non-Metropolitan	17.8	15.6	17.3	15.5	13.2	17.4
			III. Speed (MPH)			
L. T. 250,000	34.5	36.1	33.3	33.6	—	34.3
250,000-499,999	33.5	32.3	35.7	33.4	—	34.1
500,000-999,999	34.3	28.6	33.9	38.7	33.2	34.3
1,000,000-2,999,999	31.2	29.2	34.0	32.2	31.9	31.8
G. T. 3,000,000	29.4	30.5	30.5	31.3	33.1	29.9
Non-Metropolitan	39.5	41.3	37.8	38.4	39.1	39.1

* Blank cells represent fewer than 30 observations, and their values are thus not reported.

The relative importance of simple commute chains generally increases with metropolitan area size (see Table 14). The trend in increasing simplicity does not hold for metropolitan areas with more than three million residents, due to the greater percentage of complex commutes on the return leg in that size category. Non-metropolitan areas had the largest percentage of simple commutes.

Table 14: DISTRIBUTION OF COMMUTE TRIP CHAINS BY METROPOLITAN SIZE (PERCENT)

	Trip Chain Type					
MSA/CMSA Size	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Total
L. T. 250,000	61.7%	5.2%	25.3%	5.0%	2.8%	100.0%
250,000-499,999	61.6	4.2	26.0	6.0	2.2	100.0
500,000-999,999	62.2	5.0	23.8	6.0	3.0	100.0
1,000,000-2,999,999	65.0	4.8	23.0	4.9	2.4	100.0
G. T. 3,000,000	63.5	5.1	25.7	3.8	1.9	100.0
Non-Metropolitan	66.2	4.3	22.2	5.2	2.1	100.0

Commuting Chains and Life Cycle

Cross tabulation of work trip distance, duration and speed by commute chain type and life cycle category shows that work trip distances and speeds are generally lower for single adults with pre-school and school age children than for their two adult household counterparts (see Table 15). This distinction was not evident for households with children age 16-21.

Table 16 decomposes household commuting according to life cycle category and commute chain type. Single adults with young children are the most likely to have complex commute chains both to and from work (32% of single adult households with children 0-5 years of age, and 12.5% of single adult households with children 6-15 years of age as compared to 4.9% for all complex commute chains for all households). Similarly, single adult households with pre-school and adolescent children exhibit the lowest rate of simple work commute chaining (44.8% and 49.5% as compared to 64.0% for all simple commute chains).

Table 15: COMMUTE TRIP CHAINS, BY LIFE CYCLE CATEGORY*

Life Cycle Category	Trip Chain Type: Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Row Av.
			I. Distance (Miles)			
1 Adult	9.5	12.8	10.8	9.9	—	10.1
2+ Adults	11.4	10.5	11.5	11.4	13.3	11.4
1 Adult; Ch. 0-5	8.7	—	—	6.7	—	8.0
2+ Adults; Ch. 0-5	13.1	10.2	12.7	10.1	12.5	12.5
1 Adult; Ch. 6-15	10.1	—	10.0	10.6	—	10.1
2+ Adults; Ch. 6-15	12.0	10.6	11.4	8.8	9.0	11.5
1 Adult; Ch. 16-21	12.1	—	—	—	—	11.4
2+ Adults; Ch. 16-21	11.3	13.0	10.7	—	—	11.3
1 Retired Adult	—	—	—	—	—	—
2+ Retired Adults	9.7	—	8.9	—	—	9.8
Not Ascertained	11.5	—	—	—	—	9.8
Column Average	11.6	10.9	11.4	9.9	11.1	11.4
			II. Duration (Min.)			
1 Adult	17.3	19.5	19.0	16.3	—	17.9
2+ Adults	19.9	19.0	19.1	18.3	21.3	19.7
1 Adult; Ch. 0-5	15.1	—	—	15.3	—	15.3
2+ Adults; Ch. 0-5	21.3	19.0	20.7	17.4	18.8	20.5
1 Adult; Ch. 6-15	18.9	—	16.5	18.5	—	18.1
2+ Adults; Ch. 6-15	19.8	19.0	19.7	15.3	16.1	19.4
1 Adult; Ch. 16-21	18.4	—	—	—	—	17.6
2+ Adults; Ch. 16-21	19.3	22.7	18.4	—	—	19.2
1 Retired Adult	—	—	—	—	—	—
2+ Retired Adults	18.8	—	17.5	—	—	18.6
Not Ascertained	20.2	—	—	—	—	17.9
Column Average	19.8	19.4	19.2	17.1	18.0	19.4
			III. Speed (MPH)			
1 Adult	33.0	39.2	34.0	36.5	—	33.8
2+ Adults	34.2	33.3	36.3	37.3	37.4	34.8
1 Adult; Ch. 0-5	34.5	—	—	26.3	—	31.2
2+ Adults; Ch. 0-5	36.9	32.1	36.7	34.7	39.9	36.4
1 Adult; Ch. 6-15	32.2	—	36.5	34.3	—	33.5
2+ Adults; Ch. 6-15	36.2	33.5	34.7	34.8	33.6	35.6
1 Adult; Ch. 16-21	39.4	—	—	—	—	38.7
2+ Adults; Ch. 16-21	35.4	34.5	34.8	—	—	35.3
1 Retired Adult	—	—	—	—	—	—
2+ Retired Adults	31.0	—	30.6	—	—	31.2
Not Ascertained	34.2	—	—	—	—	32.9
Column Average	35.1	33.8	35.5	34.9	37.0	35.1

* Blank cells represent fewer than 30 observations, and their values are thus not reported.

Table 16: DISTRIBUTION OF COMMUTE TRIP CHAINS BY LIFE CYCLE CATEGORY AND CHAIN TYPE (PERCENT)

	Trip Chain Type					
Life Cycle Category	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Total
1 Adult	55.6%	4.4%	34.8%	3.0%	2.2%	100.0%
2+ Adults	67.2	3.1	24.3	2.8	2.6	100.0
1 Adult; Ch. 0-5	44.8	6.5	15.4	32.0	1.3	100.0
2+ Adults; Ch. 0-5	60.5	6.2	22.0	9.1	2.1	100.0
1 Adult; Ch. 6-15	49.6	4.9	31.8	12.5	1.2	100.0
2+ Adults; Ch. 6-15	64.1	6.0	22.6	5.5	1.9	100.0
1 Adult; Ch. 16-21	66.5	4.2	25.4	3.0	0.9	100.0
2+ Adults; Ch. 16-21	70.0	4.8	20.6	2.1	2.6	100.0
1 Retired Adult	72.6	0.0	15.9	0.0	11.5	100.0
2+ Retired Adults	71.1	4.9	21.4	2.3	0.3	100.0
Not Ascertained	60.5	5.5	34.0	0.0	0.0	100.0
Column Average	64.0	4.7	24.2	4.9	2.2	100.0

Commuting Chains and Travel Mode

Work trips in complex commute chains by transit or mixed modes cover greater distances and are considerably longer in duration and slower in speed than simple commutes (see Table 17). Chaining has a substantial effect on duration and, consequently, speed. The auto only mode has an average speed of 35.1 mph, while the transit mode has an average speed of 19.1 mph.

Table 17: COMMUTING CHARACTERISTICS BY MODE AND COMMUTE CHAIN TYPE*

Mode	Trip Chain Type: Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Row Av.
			I. Distance (Miles)			
Auto Only	11.7	11.1	11.4	10.4	11.3	11.5
Transit Only	14.0	—	—	—	—	13.9
Auto/Transit	20.4	—	13.8	—	—	17.1
Auto/Other	5.6	7.5	9.5	5.9	—	7.9
Transit/Other	6.9	—	9.7	—	—	7.8
Auto/Transit/Other	—	—	—	—	—	9.0
Other Only	1.7	—	1.1	—	—	1.6
Average Distance	11.3	10.4	11.1	10.0	10.7	11.1
			II. Duration (Min.)			
Auto Only	20.0	19.5	19.3	17.6	18.2	19.6
Transit Only	42.9	—	—	—	—	43.5
Auto/Transit	37.9	—	35.8	—	—	35.7
Auto/Other	14.9	16.0	18.3	16.3	—	17.2
Transit/Other	27.1	—	37.7	—	—	33.0
Auto/Transit/Other	—	—	—	—	—	20.7
Other Only	12.1	—	12.8	—	—	11.8
Average Duration	20.6	19.4	20.1	17.4	18.8	20.2
			III. Speed (MPH)			
Auto Only	35.1	34.2	35.3	35.5	37.1	35.1
Transit Only	19.6	—	—	—	—	19.1
Auto/Transit	32.3	—	23.1	—	—	28.7
Auto/Other	22.5	28.0	31.1	21.9	—	27.7
Transit/Other	15.4	—	15.5	—	—	14.2
Auto/Transit/Other	—	—	—	—	—	26.0
Other Only	8.3	—	5.1	—	—	8.0
Average Speed	32.8	32.3	33.2	34.4	34.1	33.0

* Blank cells contain fewer than 30 observations, and their values are thus not reported.

Transit only commute chains are predominantly simple (94%), with only 5.1% of transit-based chains being complex from work to home (see Table 18). When auto and transit modes are mixed the rate of complex commute chaining from work to home increases to 28.2% and the rate of simple commute chains drops to 50.4%. When transit is combined with modes other than auto (principally walking), the rate of complex commute chaining from work to home increases again to 58.1%, and the simple commute chaining rate declines to 24.7%.

Table 18: DISTRIBUTION OF WORK TRAVEL BY MODE AND COMMUTE CHAIN TYPE (PERCENT)

	Commute Chain Type					
Model	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Total
Auto Only	64.6%	4.7%	23.7%	4.9%	2.1%	100.0%
Transit Only	94.0	0.5	5.1	0.0	0.4	100.0
Auto/Transit	50.4	8.2	38.2	3.3	0.0	100.0
Auto/Other	21.8	7.7	51.5	9.3	9.8	100.0
Transit/Other	24.7	11.5	58.1	0.0	5.6	100.0
Auto/Transit/Other	22.7	13.5	39.0	8.5	16.3	100.0
Other Only	82.5	4.6	10.2	1.5	1.1	100.0

Work Trip Time, Distance and Speed

The time, distance and speed of work trips contained within alternative commuting chains is presented in Table 19. Note that the figures in the table refer only to the work trip links in commuting chains.

A baseline for comparison is work trips in simple commute chains, represented by rows a and b in Table 19, which show work trip duration to be longer in the *to home* than the *to work* commute and, consequently, a lower speed on the *to home* commute. Trip lengths and total commuting distance are equivalent by definition for this chain type. As a result, there is a fairly close correspondence of the distances *to work* and *to home.*

Table 19: DURATION, DISTANCE AND SPEED OF WORK TRIPS IN ALTERNATIVE COMMUTE CHAINS

Chain Type	Time (Mins.)	Distance (Mi.)	Speed (MPH)
Simple Work			
a. To Work	20.0	11.1	33.3
b. To Home	21.2	11.2	31.7
Complex to Work			
c. To Work	15.9	8.5	32.1
d. To Home	18.3	9.4	30.8
Complex from Work			
e. To Work	20.1	11.1	33.1
f. To Home	15.1	7.7	30.6
Complex to & from Work			
g. To Work	16.0	9.4	35.2
h. To Home	12.4	6.6	31.9
Complex at Work			
i. To Work	18.2	11.0	36.3
j. To Home	19.7	10.6	32.3

The first category of complex work commutes is classified as chains that are "complex from home to work and simple from work to home" (rows c and d). The average work trip distance in the *to work* portion of the commute is 8.5 miles, which is nearly one mile shorter than the simple work-to-home return trip of 9.4 miles. The fastest component of this commute chain is the *to work* leg, with a speed of 32.1 mph.

The mirror of the first category is commute chains that are "simple from home to work and complex from work to home" (rows e and f). The *to work* trip component of the commute has a mean distance of 11.1 miles and a speed of 33.1 mph, whereas the final *from work* trip to home is only 7.7 miles with a speed of 30.6 mph.

The commute chains that are complex to and complex from work (rows g and h) have comparatively short but fast *to work* and *to home* trips. These work trip lengths can be compared to chains that are complex in the midday period but simple to and from work. These chains have work trip distances similar to simple commute chains but, for some reason, have faster speeds.

Effect of Trip Chaining on Work Trip Length

Estimates of the distance from home to work based on work trip data from the NPTS are downward biased when commute chains are complex because only the last leg to work or the last leg to home of complex commute chains are coded as work trips in the NPTS.

Chains that are simple-to-work and complex-to-home, and chains that are complex-to-work and simple-to-home provide the most direct evidence of the reduction of work trip distance due to chaining. For *Complex from Work* chains, the data in Table 19 indicate that the average work trip length in the *to home* portion is 31 percent shorter than its *to work* counterpart. Alternatively, in *Complex to Work* chains the average work trip length in the *to work* portion of the commute is nearly 10 percent shorter than the *to home* portion.

Two adjustments are made to reflect the composite downward effect of complex chaining on work trip distance and time in the NPTS. Chains that are complex on one end only are adjusted by using the direct home-to-work trip length for both ends. Chains that are complex both to-and-from are the most problematic. These are adjusted by using the average home-to-work trip length of *Complex from Work* commute chains and the *from work* average work trip length from *Complex to Work* commute chains.

Trip chaining-related adjustment factors for home-to-work distances and travel times are reported in Table 20. The distances and travel times of work trips in *Simple Work* and *Complex at Work* chains are unaffected because non-work trips are not contained in these chains' commutes. The distances and times of the *to work* trips in *Complex to Work* chains are increased by 10.6 and 15.1 percent, while the distances and times of the *to home* trips in *Complex from Work* chains are increased by 44.2 and 33.1 percent respectively. In the *Complex to & from Work* chains, *to work* trip distances and times are increased by 18.1 and 25.6 percent, and *to home* trip distances and times are increased by 42.4 and 47.6 percent.

Table 20: WORK TRIP DISTANCE AND TRAVEL TIME ADJUSTMENT FACTORS

Commute Chain Type	Distance	Time
Simple Work Chains		
To Work Trips	N.C.*	N.C.
To Home Trips	N.C.	N.C.
Complex to Work Chains		
To Work Trips	+10.6%	+15.1%
To Home Trips	N.C.	N.C.
Complex from Work Chains		
To Work Trips	N.C.	N.C.
To Home Trips	+44.2%	+33.1%
Complex to & from Work Chains		
To Work Trips	+18.1%	+25.6%
To Home Trips	+42.4%	+47.6%
Complex at Work Chains		
To Work Trips	N.C.	N.C.
To Home Trips	N.C.	N.C.

* No Change

These adjustments increase the mean distance and duration of work trips from 10.46 to 11.05 miles (5.64%) and 19.34 to 20.36 minutes (5.25%). The average work trip distance and duration in our analysis is slightly less than the averages reported in the *Summary of Travel Trends* (10.6 miles and 19.7 minutes) because work trips contained in invalid chains were not included, in addition to trips returning to work following mid-day non-work trips (which are coded as work trips in the NPTS). The percentages thus reflect the amount one should adjust work trips to account for trip chaining. Applying these adjustments (5.64% for miles and 5.25% for time) increases the averages reported in the *Summary of Travel Trends* to 11.2 miles and 20.7 minutes.

Conclusions

This report has examined trip chaining in the 1990 NPTS, noting patterns in three broadly defined categories: a) journey purpose and related travel characteristics; b) metropolitan characteristics; and c) characteristics of the traveler and his or her household. Regarding the first category, the trip chaining framework highlights the role of the commute as an organizing element in consolidating work and non-work activity. Trip chaining researchers commonly reach this conclusion, and its implications warrant emphasis: focusing solely on work trips understates their importance in household travel.

Examining work commutes in greater detail, we found that non-work stops were twice as likely to be contained in the homeward leg as in the commute to work. The apparent preference of the return commute for non-work travel activities is consistent with the contention that the penalties for late arrival at work are greater than late arrival on the return home (5, 12).

We observed that non-work chains were also more likely to be complex during peak commuting periods, which leads us to hypothesize that certain non-work activities also provide an organizational focus for other non-work trips. The scheduling of these journeys also favors the peak commuting periods, thus contributing to traffic congestion.

Complex chains are relatively more reliant on the automobile. Coupled with the evolving dispersion of work and non-work activities in metropolitan areas, conventional pedestrian and transit systems face a growing disadvantage in serving the mobility needs of a population that is increasingly engaging in complex trip chaining.

Regarding metropolitan characteristics we found the share of commute-related chains to increase with urban size. This increase is confined to simple commuting chains, and its causes are not evident. If congestion is positively related to metropolitan size, there would be a tendency for households to forego travel for purposes other than work. Also, households in larger metropolitan areas may be more likely to substitute in-home activities for out-of-home activities. Alternatively, transit accounts for a larger share of work trips in large metropolitan areas. Transit riders who make non-work stops in the course of their workday are more likely to be on foot, and the under-reporting of such walking trips has been a long-standing concern. A final possibility is that the demographic composition of large and small metropolitan areas is somewhat different. In particular, larger metropolitan areas have a greater share of households without children, whose trip-making is more work-oriented.

Trip chains in larger metropolitan areas were found to be neither more nor less complex than those in smaller metropolitan areas. However, metropolitan area residents are more likely to form complex trip chains than residents of non-metropolitan areas. The commutes of suburban residents were more likely to be complex than those of their central city and non-metropolitan counterparts, which may reflect differentials in commute distance and greater exposure to intervening non-work activities.

Increases in metropolitan size corresponded with increases in commuting distance and duration, and decreases in speed. Commuting distances in large metropolitan areas were not appreciably greater than distances in small metropolitan areas. This is consistent with the contention that large metropolitan areas are more likely to have a polynuclear form and, as a consequence, have similar commuting levels as smaller mononuclear cities (13).

Trip chaining patterns were quite distinct with respect to demographic factors. Generally, the share of complex chains is negatively related to household size. The presence of children in the household is also negatively related to complex chaining, and contributes to increases in the relative importance of non-work travel as well. As their children mature, the trip chaining patterns of family households more closely resemble those of single and multiple adult households.

Higher income households are more likely to form complex trip chains, and they also tend to organize a larger share of trips around the commute. This could reflect greater trip making frequency and corresponding opportunities for consolidating travel. It may also imply a greater marginal opportunity cost of time spent in travel for higher income households.

Women are more likely to form complex commute and non-work chains than men. Whether these differences can be explained in a household utility optimization framework is unclear. The "new home economics" perspective (14, 15) does not directly consider household travel activities, and doing so may yield fruitful insights on chaining differences between men and women, as well as trip chain patterns related to life cycle stage.

Work trips are representative of the distance between home and work only in simple commute chains. The inclusion of non-work trips in the commute results in work trip distances underestimating home-to-work distances by about 5 percent. Because complex commuting has become more prevalent, we can infer that this bias has increased over time.

In his evaluation Kitamura (16) distinguished the contributions of trip chaining research to better understanding of travel behavior from those which improved urban transportation models. He concluded that the former contributions were considerable, while the latter were scant. One possible reason for this disparity is that, until recently, there has been little incentive for urban transportation professionals and researchers to move beyond the established planning process and modeling framework. However, the focus of urban transportation planning is shifting toward travel behavior, and is becoming increasingly concerned with modifying travel behavior rather than reacting to it. Legislative and legal mandates addressing economic efficiency, land use, and environmental quality issues indicate that the days of the behaviorally anemic four-step models are numbered.

The path from models in current practice to their successors, however, is not clearly defined. Undoubtedly, the next generation models will need to be more capable of dealing with both the traditional transportation facility planning objectives and newly emerging policy issues. The need for more interplay between these two arenas will almost certainly require greater ability to derive travel outcomes from household, activity and transportation system conditions, as well as greater ability to project complex travel activity on a given system. Research on the former would be facilitated by an activity based survey of households rather than the current trip based format. This would permit more careful assessment of the substitutability among in-home work and non-work activities, for which travel is not required, and out-of-home alternatives, for which travel is required.

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