Evolution of Trip Chaining Patterns in London from 1991 to 2010

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Abstract

Trip chaining, which is the propensity to link a series of activities into a multi-stop tour or journey, potentially leads to greater time efficiency and reduced travel costs. As people's socio-economic activities have become increasingly more complex and diverse, it can be conjectured that trip chaining is likely to become increasingly prevalent and complex over time. To test this hypothesis, this paper uses data from the 1991 and 2001 London Area Travel Survey, and the 2006-2010 London Travel Demand Survey to examine the evolution of the trip chaining patterns in London. Since work-based trip chaining is expected to be different in nature as compared to non-work-based trip chaining, both types of trip chains are investigated separately. The former is classified into 5 patterns (simple work, complex to work, complex from work, complex to and from work, and complex at work), and the latter into 2 patterns (simple non-work and complex non-work). Using a nested logit model to permit the interdependency between trip chaining patterns and mode choice, trip chaining patterns are modeled to identify and quantify the impacts of influencing factors. By comparing the modelling results across the survey years, insights can be gained on how trip chaining behaviour in London has changed over time. The results of this study are expected to help policymakers to predict people's future trip chaining behaviour, and facilitate development or impact analysis of relevant transportation policies, land use planning and the assessment of infrastructure investments.

Key words: Trip chaining; Travel behaviour; Mode choice; Trend; London; Nested logit

1. INTRODUCTION

Trip chaining involves the linking of spatially and temporally interrelated trips to undertake activities at multiple destinations within a single journey. Given the limited time and income constraints faced by an individual, trip chaining potentially leads to greater time efficiency and reduced travel costs. The overall utility of an individual's trip chain thus increases with the number of trip links (1). At the household level, trip chaining arises when household members gain from arranging activities such that overall travel distances and times are shortened and disutility minimized across all travel activities (2).

In most academic research, a trip chain (also known as tour or journey) is conventionally defined as a sequence of trips that starts at home, involves one or more intermediate stops, and ends back at home (3). No intermediate home stop is present within the trip chain, which means a chain is formed whenever the home location is reached. The aforementioned definition of a trip chain is adopted in this paper, as almost all journeys commence and end at home. This definition is also consistent with research on activity chains and the underlying assumption that travel is a derived demand (4). Strathman and Dueker further distinguished the complexity of trip chains by classifying them as "simple" or "complex" (5). Simple trip chains are home-to-home tours with one intermediate stop while complex trip chains are home-to-home tours with two or more intermediate stops. Hence, a trip chain of the form home-work-home is considered simple whereas a trip chain of the form home-work-shop-home is complex.

Over the past few decades, people's socio-economic activities have become increasingly more complex and diverse. Thus, it may be conjectured that trip chaining is likely to become increasingly prevalent and complex over time because the ability to chain multiple activities together in a single chain may provide greater efficiency and convenience than a series of single-stop simple chains. Interestingly, not many studies have analyzed trip chaining trends using robust statistical methods, possibly due to the rarity of comparable data over time.

This paper examines trip chaining trends in London between 1991 and 2010. Specifically, this study seeks to achieve the following objectives:

(1) Develop the indicators for activity complexity, and describe the activity complexity change over the decades.

(2) Investigate the change of trip chaining patterns over time, and identify possible causes that may be responsible for the observed trend.

(3) Model trip chaining using nested logit model to identify and quantify the impacts of core determinants.

2. LITERATURE REVIEW

A review of previous research has identified numerous influences that impact trip chaining patterns. The majority of these studies have focused on socio-economic factors contributing to the propensity to make stops within a trip chain, such as gender (5-9), age (7, 8, 10), personal income (1, 2), household structure and life cycle (6, 11-13), presence of children (2, 10), household size (2, 5, 11) and household income (6, 8, 10). Other researchers have focused on the effects of technology advancements (6) and trip-specific attributes such as commute distance (7), travel times and costs (8) and day of the trip (4).

The impacts of trip chaining have also been discussed in prior literature. If complex trip chains arose from embedding non-work activities in the work commute, the relative shift of non-

work trips to peak commuting periods would cause an increase in peak period travel demand and exacerbate congestion (3, 11). In addition, as cars provided the flexibility to pursue multiple activities within a single journey, complex trip chaining could result in a higher reliance on car usage and hence greater traffic congestion. Complex trip chaining might thus serve as a barrier to public transportation usage as travellers would be constrained by routes, schedules and issues of access and egress (2, 3).

Ye et al. argued that trip chaining complexity could be a driver of mode choice (3). However, one could also argue that mode choice has an impact on the number of stops within trip chains. This conjecture was affirmed by Strathman et al. who found that mode choice was a significant factor influencing a household's trip chaining behaviour (10). Bhat also described that the lower travel time usually associated with using the car could help to ease time constraints and result in more stop-making (8). Furthermore, the carpooling option, which forms part of the total car mode share, tended to produce more complex trip chains due to the varying trip purposes and destinations of the driver and passengers (3).

Ye et al. investigated the interdependency between trip chaining complexity and mode choice and their findings gave credence to the assumption of a significant and positive bidirectional causal relationship between trip chaining complexity and auto mode choice (3). In this spirit, our study incorporates trip chaining and mode choice within a combined decision framework and adopts a nested logit approach for model development.

Another objective of this research is to investigate the trend in trip chaining patterns over time within the same metropolitan area. Prior empirical research of such nature mostly adopted descriptive methods in their analyses. McGuckin et al. described trends related to work-related trip chains in the United States and found a 9% increase in chained trips[1] among weekday workers between 1995 and 2001 (9). Likewise, Levinson and Kumar discovered a rise in trip chaining activity[2] when household travel survey data from the 1968 and 1987-88 metropolitan Washington, DC, were analyzed (11).

[1] McGuckin et al. (2005) defined a trip chain as a sequence of trips bounded by stops of 30 minutes or less.
[2] Levinson and Kumar (1995) defined a trip chain as a connected sequence of trips between home and work, with stops for nonwork activities along the way.

TABLE 1 Trip chaining behaviour comparison between London 1991, 2001, 2006-2010

	London 1991	London 2001	London 2006-2010
Socio-economic characteristics			
Total households	59678	29973	37310
Average family size	2.47	2.23	2.29
Household in inner London	35.0%	34.8%	34.4%
Household with children younger than 5 yr old	13.4%	12.3%	11.7%
Household with annual income greater than £25,000	24.9%	37.7%	44.6%
Household with access to car	37.1%	61.6%	61.4%
Total respondents	149448	67252	85912
Male	48.1%	48.1%	48.0%
Youth(<16 yr old)	20.9%	20.4%	20.4%
Senior(>=60 yr old)	18.9%	18.0%	18.8%
Trip Information			
Total trips	354983	176447	208205
Average number of trips / day	3.24	3.36	3.21
Average trip distance	4.12km	5.70km	6.08km
Average trip duration	26.46min	26.93min	27.58min
Trip purpose			
Work	29.2%	28.7%	22.9%
Education	9.5%	10.0%	7.7%
Shopping/service	23.9%	28.2%	31.3%
Leisure	23.3%	20.3%	25.4%
Tour Information			
Total tours	146106	70547	83430
Average number of tours in one day	1.36	1.37	1.32
Average number of trips in one tour	2.37	2.45	2.43
Average tour distance	8.33km	12.62km	12.73km
Average tour time	58.42min	64.18min	64.28min
Share of work based tours	43.7%	46.9%	37.0%
Share of complex chains	21.1%	25.9%	26.1%
Mode share			
Car	47.9%	43.3%	41.9%
Bus	12.3%	12.6%	14.2%
Rail	10.1%	12.4%	11.8%
Work based tours			
Share of complex chains	25.9%	29.2%	28.4%
Share of auto based tours	41.09%	38.69%	34.51%
Nonwork based tours			
Share of complex chains	18.2%	23.0%	24.8%
Share of auto based tours	52.97%	47.42%	46.28%

3. DATA DESCRIPTION

This study uses data from the 1991 and 2001 London Area Travel Survey (LATS), and the 2006-2010 London Travel Demand Survey (LTDS), made available by Transport for London. In addition to gathering household data, both LATS and LTDS involve trip-diary surveys, in which respondents are invited to complete a self-completion trip diary for one day during the following week.

A descriptive summary of the travel behaviours across the survey years is provided in Table 1. A trip chain is classified as work-based if it included at least one trip with a work-related purpose. In instances where multiple modes were undertaken within the same trip chain, a single mode was assigned based on the mode with the longest travel time.

According to the comparison of trip purpose distribution, it seems that London residents' activity become more diverse. 20 years ago, people travel for work in most cases, while nowadays a larger portion of trips are made for purpose that are not related to work, such as shopping and leisure. Thus the variance of trip purpose distribution may be a good indicator of activity complexity. Another potential indicator is the number of destinations for each person/household in one day. It can reflect people's destination choice regardless of the purpose. Together, these two indicators are expected to provide more insights into activity complexity.

The table also shows that the share of complex chains increased over the years. Although both work-based tours and non-work-based tours have become more complex over time, the change for non-work-based tours is more pronounced. Car usage decreased and transit usage rose over the past two decades, possibly resulting from improvements in transit infrastructure and the implementation of congestion charging policies. The car usage decrease in work based tours is much greater than in nonwork based tours. The average tour distance and duration also increased over the years, particularly between 1991 and 2001.

4. METHODOLOGY

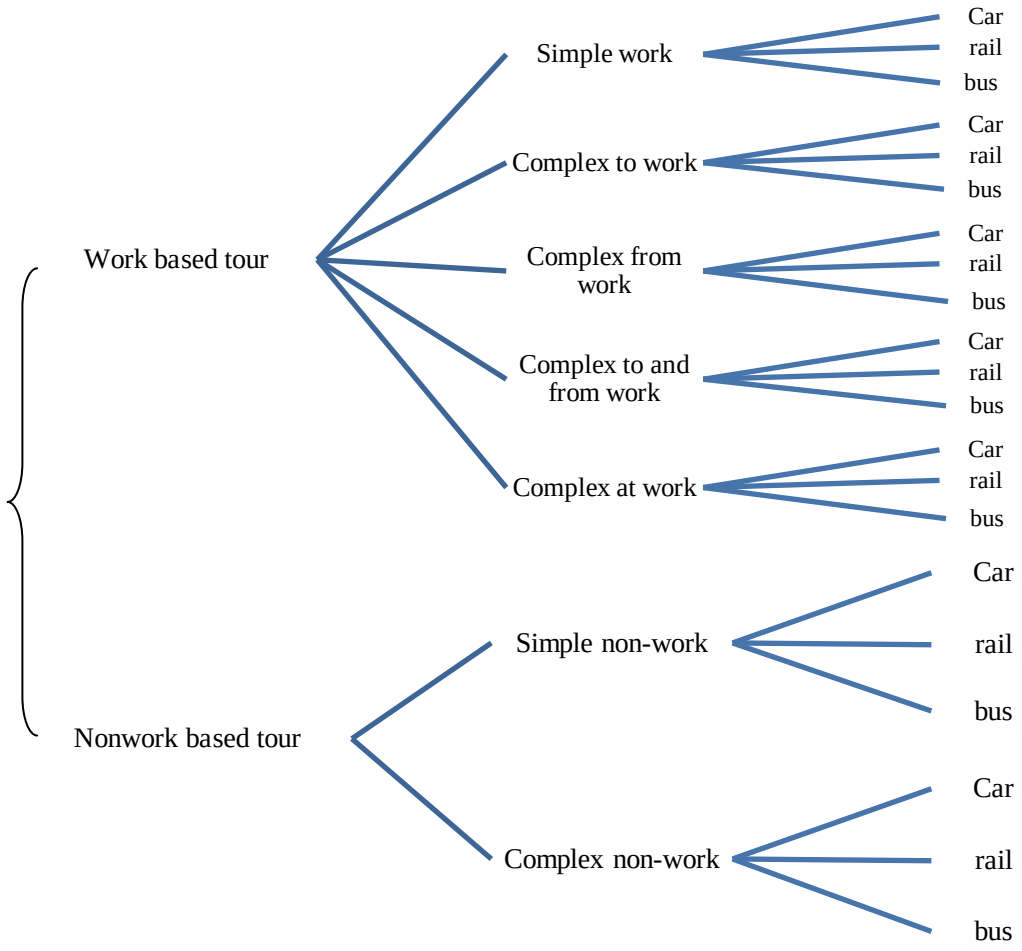
In this study, the nested logit specification is adopted as the benchmark model to permit the interdependency between trip chaining patterns and mode choice. The model is estimated separately for work-based and non-work-based tours. This segregation between work-based and non-work-based trip chains was made to account for possible differences in mode choice behaviour. For example, time constraints may be more of an influencing factor for work-based trip chains due to inflexible travel times.

The structure of the nested logit model is outlined in Figure 1. Work-based tours are categorized into five patterns: simple work, complex to work, complex from work, complex to and from work, and complex at work trip chain. And nonwork-based tours are categorized into two patterns: simple non-work and complex non-work trip chain. This classification of trip chain patterns is similar to that adopted by Hensher and Reyes (2).

In both structures for work-based and non-work-based tours, individuals who need to travel simultaneously decide on the trip chaining pattern and the travel mode. The utility of each trip chain pattern is a combination of factors affecting the pattern and an "inclusive value" constructed from the systematic utilities of the decision of whether to use car, rail or bus. It is to be noted that the model structure where trip chaining in upper level and mode choice in lower level is just a tentative structure, it is not necessarily the case. The inverse structure where mode

choice in upper level and trip chaining in lower level will also be tested, and a better one may be determined through comparing model fit. The choice of variables for potential inclusion in this model will be driven by past theoretical and empirical work on mode choice modeling and trip chaining analysis, as well as logical hypotheses on the impacts of independent variables.

FIGURE 1 Nested logit model structure



In estimating the nested logit models, the simultaneous estimation (full information maximum likelihood) method will be used. To verify that modeling each survey year separately provides the best fit to the data, the Swait-Louviere test will be performed (13). Scale parameters will be estimated using Biogeme to account for the different scales of the three surveys. Wald tests of coefficient equality would then be carried out to assess whether the relative influence of explanatory factors has changed for each survey year. This then allows us to identify possible causal factors that may be responsible for the observed trip chaining trends.

Mode choice and trip chaining pattern will be considered as dependent variables in the model. The independent variables that will be included in the model are listed in Table 2. All of them will be examined through modelling, but only some with significant coefficients will be used in the final models.

TABLE 2 List of possible explanatory variables

	London 1991	London 2001	London 2006-2010
Household size	√	√	√
Presence of children	√	√	√
Household structure		√	√
Area of household address	√	√	√
Household income	√	√	√
Car ownership	√	√	√
Fare zone of household address			√
Congestion charging zone			√
Gender	√	√	√
Age	√	√	√
Disability	√	√	√
Family role	√	√	√
Employment status / profession	√	√	√
Driver license possession	√	√	√
Transit pass possession	√	√	√
Parking type at work place	√	√	√
Commute distance	√	√	√
Mobile possession		√	√
Access to internet		√	√
Travel time of the day (peak vs. off-peak)	√	√	√

5. EXPECTED RESULTS

Based on the descriptive summary, the share of complex trips increased between 1991 and 2010 for both work-based and non-work-based trip chains, although there was a marginal decline between 2001 and 2010 for work-based tours. This is broadly consistent with our conjecture of complex trip chains becoming increasingly prevalent over time, brought about by greater efficiency and convenience arising from linking multiple activities together in a single chain.

We would also expect the influences of various factors affecting trip chaining patterns to change over time. For instance, past studies have found that women's propensity to form complex trip chains was significantly greater than that for men (5, 6, 9). With the emergence of online shopping in the early 2000s, this effect could be diminished as women who typically chained shopping trips to their work commute in the past can now meet some of their needs through means of the Internet.

Furthermore, since the advent of the "second generation" (2G) mobile phone systems in the 1990s, there had been a sharp increase in mobile phone usage. We would expect a more widespread ownership of mobile phones to facilitate scheduling flexibility and result in the creation of more complex trip chains between 1990 and 2010. This postulation was corroborated in Schmöcker et al.'s study which discovered a significant positive effect of mobile phone possession on tour complexity among older people (6).

6. POLICY IMPLICATIONS

A better understanding of trip chaining trends would also help policymakers to predict people's future trip chaining behaviour, and facilitate development or impact analysis of relevant transportation policies, land use planning and the assessment of infrastructure investments. A key implication is in increasing public transportation ridership and controlling car use. When trip chaining complexity is expected to increase in the future and the goal of policymakers is to make public transportation a more attractive option to commuters, they should strive to improve the public transportation service to accommodate the increasing need of trip chaining. More emphasis should be placed on interchange quality at micro level and system connectivity at macro level, which may substantially reduced total journey time and improve the comfort of transfer. In addition, transit agencies should also focus on the development of a more accessible and reliable passenger information system which may provide assistance for people's trip chaining decisions. In the age of mobile phone and internet, many trip chaining decisions are made during travel. Therefore, accurate real time passenger information will be greatly appreciated. Besides, the ticketing system should also be adjusted to limit marginal cost of transit service. This would allow bus and rail passengers to satisfy multiple needs and carry out a wider array of activities within a trip chain without incurring monetary penalties. On the other hand, trip chaining trend may also provide insights into how to control car use because car use is the major source of air pollution and traffic congestion. As trip chaining patterns becoming more complex, parking will become an even bigger concern for car users. Thus, increasing parking cost and limiting parking spaces may be more efficient solutions in the future.

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