TRIP-CHAINING BEHAVIOUR OF WORKERS FROM A CITY OF A DEVELOPING COUNTRY

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ABSTRACT

Trip-chaining is an indicator of the complexity in travel behaviour of individuals. Trip-chaining has wide policy implications since mode choice is one of predominant factors affecting it. This paper characterises the trip-chaining behaviour of workers from city of developing country with emphasis on simple and complex trip-chains. A comparison of various activity-travel related attributes showed their variation across different mode groups. The analysis also provided a hint on some specific attributes affecting the dependency on personalised modes for undertaking simple as well as complex trip-chains.

Keywords: Trip-chaining, Workers, Public Transport.

INTRODUCTION

Individuals travel for participating in various activities distributed in time and space. Trip maker, as a consumer, obviously tries to optimize his/her itinerary to participate in various activities. The outcome of such a decision-making process is the linking of various activities into a trip-chain having multiple numbers of stops. The linking of activities into single chain offers convenience to the trip makers (Ye et al., 2007). Thus, it is understood that travel behaviour of an individual should be viewed in terms of interlinked trips. Travel demand models attempts to mimic such a complex decision-making behaviour of individuals. The trip-based paradigm views the travel behaviour in terms of independent trips and leads to the biased prediction of modal share under various policy scenarios (Pinjari and Bhat, 2010).

The analysis of travel behaviour from trip-chaining perspective can lead to the efficient analysis of various transportation policies (Ye et al., 2007). Trip-chaining has wide policy implications since mode choice is one of predominant factors affecting it. Spatio-temporal as well as purpose wise complexity of trip chains often requires much flexible modes to move around (Hensher and Rayes, 2000). Thus, it is clear that trip changing has a bearing on transportation planning, as mode choice of travellers is the interest of many of transportation policies. Also, as reported elsewhere (see Bhat, 1997), mode choice has important bearing on stop making behaviour of commuters during commute journey. It has been found that commuters, who use flexible modes (cars), had the higher propensity of making non-work stops during commute (Bhat, 1997). This chaining of non-work stops to commute period adds to the peak period travel and subsequently leads to congestion. In short, we can summarise that there is a dependency between trip-chaining and private mode usage.

It is reported in some case studies that trip-chaining is a barrier to the use of public transport (Hensher and Rayes, 2000; Ye et al., 2007). Some contrary views to the above are also available from other case studies (see Currie and Delbosc, 2011). This calls for analysis of trip-chaining behaviour of commuters to understand the interaction between mode choice and trip linking. Such an analysis is important for Indian cities as the cities have been witnessing decreasing dependency on public transport and increasing shares of private modes (cars and two wheeler) amidst introduction of various sustainable transportation policy measures (See NUTP, 2006).

This paper reports on the trip-chaining behaviour of workers from a city of developing country, India. The behaviour of workers is compared with respect to various activity-travel related attributes for investigating interaction of mode choice on trip-chaining behaviour. The paper is organised as follows. Next part briefly covers the literature study. Following this, an introduction to the study area as well as to the data source is given. Subsequently, the methodological aspects and analysis is presented. The final section draws a summary and conclusion to the study.

LITERATURE REVIEW

As per Wegmann and Jang (1998), a trip-chain is *"a connected sequence of trips to visit more than one destination"*. The different aspects of this phenomenon have been widely acknowledged. McGuckin and Murakami (1999) compared the trip-chaining behaviour of men and women using Nationwide Personal Transportation Survey (NTPS). It was found that working women having children made more number of non-work stops on the way to and from work compared to that of men. However, the authors ignored the impact of mode choice on trip-chaining behaviour of men and women. A similar study by Wegmann and Jang (1998) reported that there was a significance difference in trip-chaining behaviour of men and women (in terms of activity attributes as well as travel resources). They also noted that about 93% of the all trip links in the trip-chains were undertaken using private modes. Studies by Srathman and Dueker (1995) and Srathman et al. (1994) show that commute trip-chaining behaviour is influenced by household structure, gender, income, mode choice, employment status, activity-travel environment characteristics etc. Noland and Thomas (2007) focused on the impact of urban form on trip-chaining patterns of individuals. They found that lower density residential areas lead to a greater reliance on trip-chaining as well as motivated individuals to make more number of stops in tours. Hanson (1980), in her paper analysed the trip linkages on the way to and from work. She used 35 days travel diary data and found that many households combine a large portion of their activities with work trip. The study also summarised that public transport users made relatively less number of stops compared to other mode users. Primerano et al. (2008) introduced trip-chaining typologies and analysed the trip-chaining behaviour of individuals using Adelaide Household Travel Survey. They found that age, gender, household structure etc had a significant impact on trip-chaining behaviour of individuals. They also identified that households having car were involved in complex trip-chains compared to those with no cars.

Studies related to trip-chaining and mode choice interaction are also available in the literature. Hensher and Rayes (2000) developed choice models to identify the influential factors affecting complexity in trip-chaining as well as the mode choice. They found supporting evidence to the general hypothesis that as the trip-chains grow in complexity the utility of public transport tends to be decreasing. Apart from individual sociodemographics, they noted that income and car ownership had a significant impact on complexity of trip-chains as well as on mode choice decisions. Ye et al. (2007) investigated the relationship between mode choice and complexity in trip-chaining patterns. They proposed three casual structures such as mode choice decision preceding trip-chaining, trip-chaining decision preceding mode choice and finally the joint decision of both aspects. Their study using Swiss Travel Microcensus data had revealed that tour complexity was driving mode choice in the case of work and non-work tours. According to them, this finding has an important role in public transport industry. They noted that trip-chaining complexity is a disutility to use public transport, as it is generally very difficult to make multiple stops using public transport when travellers have fixed routes (Ye et al., 2007). This calls for improvements in public transport for catering to complex stop making apart from improving conventional elements. Currie and Delbosc (2011) explored the trip-chaining behaviour of Melbourne residents using Victorian Activity-Travel Survey. It was found that trip-chaining complexity was higher for public transport trips than that for car-based trips. Non-work travel was having higher number of trips legs compared to that of work travel. They suggested that rail based public transport also has opportunities associated with trip linking. Yun et al. (2011) analysed the mode choice behaviour based on trip-chaining using Household Travel Survey data from a city in China. The choice model developed showed that complexity in trip-chains had a significant impact on mode choice behaviour of individuals. As the complexities in trip-chains grow, the utility of public transport was found to be decreasing and that of flexible modes were found to increasing.

Overall, the literature review shows that trip-chaining complexity has a direct bearing on mode choice decision of individuals. In addition, it is clear that flexible modes allow individuals to engage in complex trip-chaining patterns. As found in few studies, public transport offers hindrance to the chaining of trips even though it has the potential for trip linking if proper planning is exercised. All these findings points to the need for analysis of mode choice of individuals from a trip-chaining perspective. Such an analysis is very much important from the perspective of Indian cities as they are witnessing depleting shares of public transport and increasing shares of private modes (especially two-wheelers) amidst the policy interventions for promoting sustainable transportation practices.

CASE STUDY

This paper explores the trip-chaining behaviour of workers from Bangalore Metropolitan Region (BMR), a fastest growing city in India. Emphasis is placed on commute behaviour of workers as commute trips plays a major role in congestion during peak periods. Following subsections briefly discuss about the city context and data.

Study Area

Bangalore is the fifth largest metropolis in India. The population of the city has been growing at over 3% per annum (KUIDFC, 2007). The 2011 population of BMR is 84.4 lakhs as per the information available for Bangalore Metropolitan Region (Census of India, 2011). The city is endowed with a radial pattern of road network with an outer ring road, which cut across various radial roads. As per the Master Plan 2015, about 43% of land use is for residential, 3% for commercial, 7% for industrial and 21% for traffic and transportation for the year 2011 (KUIDFC, 2007). The vehicle population in the Bangalore city shows that two-wheelers hold 69.1% of the total vehicle population (Bangalore City Traffic Police, 2012).

The Comprehensive Traffic and Transportation Studies (CTTS) are undertaken in most of Indian cities for streamlining investments for developing integrated land use transport plans. Since 1963, several CTTS have been conducted in BMR with different urban transportation visions. A comparison of recent studies (KUIDFC, 2007 and BMRDA, 2010) shows that trip distributions by public transport mode has been dropped from 42% to 30% in BMR. This is in line with the findings from a study conducted by Ministry of Urban Development for various Indian cities including BMR (MoUD, 2008).

The Data

The Household Travel Survey data collected for CTTS 2010 (BMRDA, 2010) is used in this study. The data contains information on household socio-demographics, individual socio-demographics and a one-day trip-diary filled by all members of the households in the sample. Every trip is recorded in the form of a stage and each stage is characterised by mode, distance, waiting/transfer time, start and end time, and the location. The purpose of each stage is also recorded in the trip diary. The city was divided into three major zones viz urban, rural (Figure 1) and rest of India for the study. The sample of the households from the urban area (51 zones, 7448 households) is considered for this study.

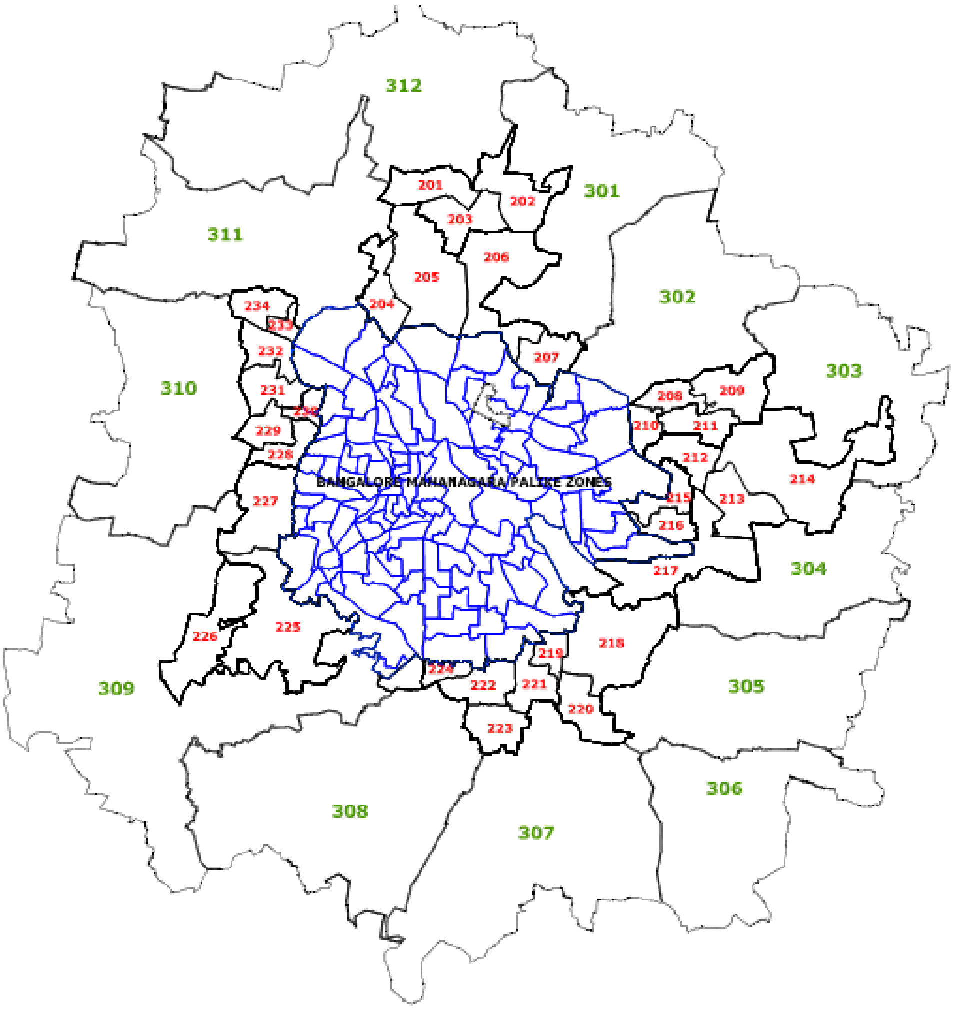

Figure 1 – Traffic Analysis Zones of BMR (Source: KUIDFC, 2007)

METHODOLOGY

The overall methodology adopted in the study is depicted in the figure 1. The Household Travel Survey database was provided to us in MS Excel format. Hence, we used MS Excel and MATLAB for managing the information for further analysis. Since the focus of the study is on the travel behaviour of workers, a database for workers was first generated from the given database.

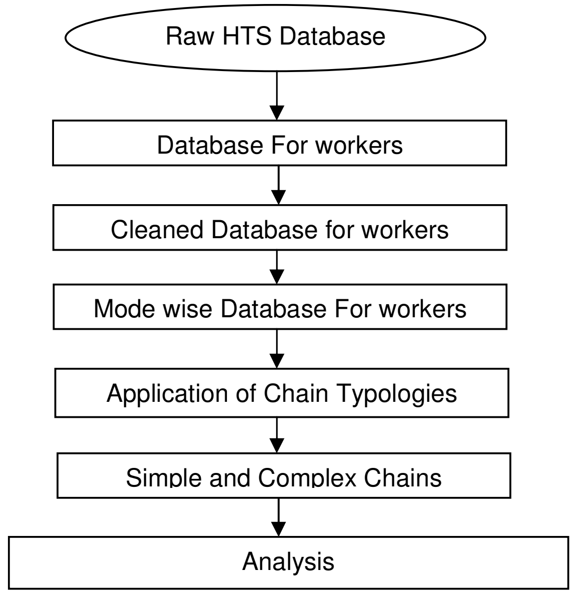

Figure 1 – Methodology

This database was then subjected to a set of screening as well as cleaning procedures. First, we included only those individuals who went out to engage in work activity. The individuals had to start their day from home and had to be back to home at the end of the day for including them in the analysis. Since the time is reported in the form of start and end time for a trip, each trip had to have positive travel time (as well positive duration for other attributes) for considering it for the analysis.

Since the focus the study is on commute behaviour of workers, we define two broad trip - chain typologies, “simple” and “complex” for further analysis. These typologies are based on anchor points as “Home” and “Work location”. “Simple” typology refers to the chain characterised by individual’s movement from home-location to work-location and then back, without making any intermediate stops for any other activities. “Complex” typology refers to the chain characterised by individual’s movement from home location-to work-location and back, with a number of intermediate stops (on the way to, on the way from or both) made for any other activities. These concepts are described in figure 2.

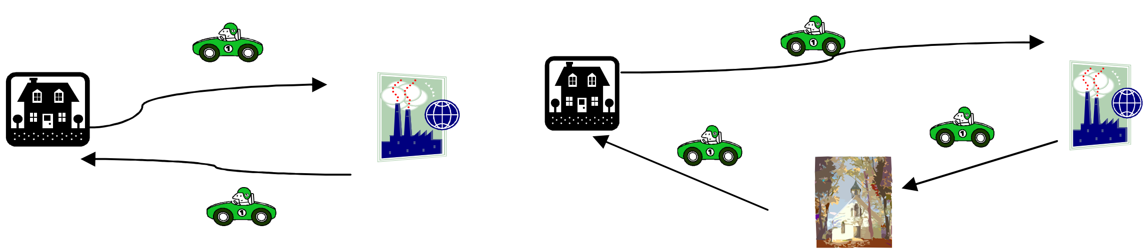

Figure 2 – Illustration of Simple and Complex Trip-Chains

The first part of the figure shows a simple chain, where an individual goes to work and returns to home without participating in any other activities throughout the journey. The second part of the figure shows a complex chain, where the individual participates in an activity at a stop on the way to home from work location. In addition, it can be noted from the figure that there are two trip links/stages in the case of simple chain. The mode used for the overall movement is car. In the case of complex chain, there are three trip links and the mode used for the movement is car.

The above mentioned procedure was applied to capture the commute behaviour of workers travelling with different modes. Two sub-databases were created for simple and complex chains. The analysis strategies, other considerations, and methodological aspects of the study are explained in the upcoming sections.

ANALYSIS AND RESULTS

This section presents analysis of trip-chaining behaviours of workers who commutes with different types of modes. The analysis is undertaken separately for simple and complex chains. The analysis strategies as well as methodological aspects for these two chains are separately addressed in following subsections.

Simple Chain Analysis

As mentioned before, simple chain represents the pattern of movement in which the worker moves from his home to work location and then back without making any intermediate stops for participating in other activities. The screening and cleaning procedure resulted in 3033 simple commute trip-chains. The modal split for these chains is shown in figure 3.

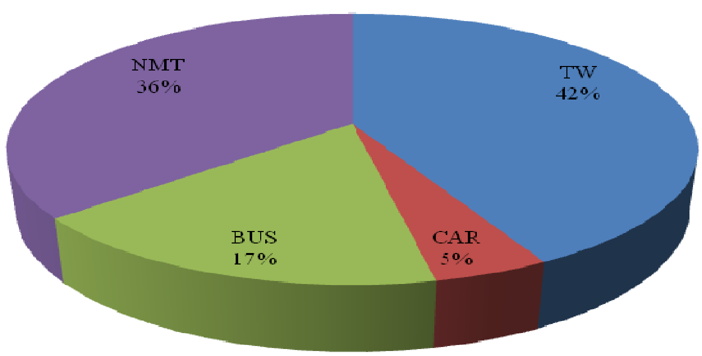

Figure 3 – Modal Split for Simple Commute Chains

As can be seen from the figure, two wheelers hold a major share in simple chains. Please note that NMT share consist of both walk chains and cycle chains. Public transport chain is represented by bus chain, since bus is the only dominant public transport mode in BMR. Shares of other modes (cabs, motorised three-wheeler) were very negligible compared to the above mentioned modes and hence not considered in the analysis. The observation in the figure is in line with the present mode share scenario for Bangalore City where two-wheeler holds a major portion of the traffic.

Analysis of Travel Related Attributes

The objective of this section is to see whether activity-travel related attributes are different for different mode users indulging in simple trip-chains. The various activity-travel related resources considered here are total chain distance, total chain duration, work duration, per stage length and per stage duration. The objective is to see whether these parameters vary across different groups. One-way analysis of variance is conducted to compare the attributes of interest across the groups. For all the samples used in the analysis, the normality assumption was verified by using Kolmogorov-Smirnov (K-S) test at 5% significance level. The null hypothesis (follows normal distribution) was accepted at 5% significance level in all the cases. The homogeneity of variance was checked by using Levene statistic. At 5% significance level, the test revealed that the variances of groups are different in all the cases. Due to this, Welch test for equality (robust test for equality of means) of means was conducted for all samples (5% significance level) for finding the adjusted F-ratio (Welch, 1938, 1947). At 5% significance level, we could see that null hypothesis (equality of means) was rejected in all the cases. Due to unequal sample size and heterogeneity in variance, Games-Howell post hoc procedure (Games and Howell, 1976) is used for identifying which among the group means are significantly different. The analysis is presented in following subsections.

Total Chain Distance

Total chain distance is the overall vehicle distance travelled from fist trip to last trip in a trip chain. A plot of average value of total chain distance is shown in the figure 4. It can be concluded that chain distance is higher in the case of motorised modes compared to that non-motorised modes. Among the motorised modes, public transport chains had higher length followed by car chains and two-wheeler chains.

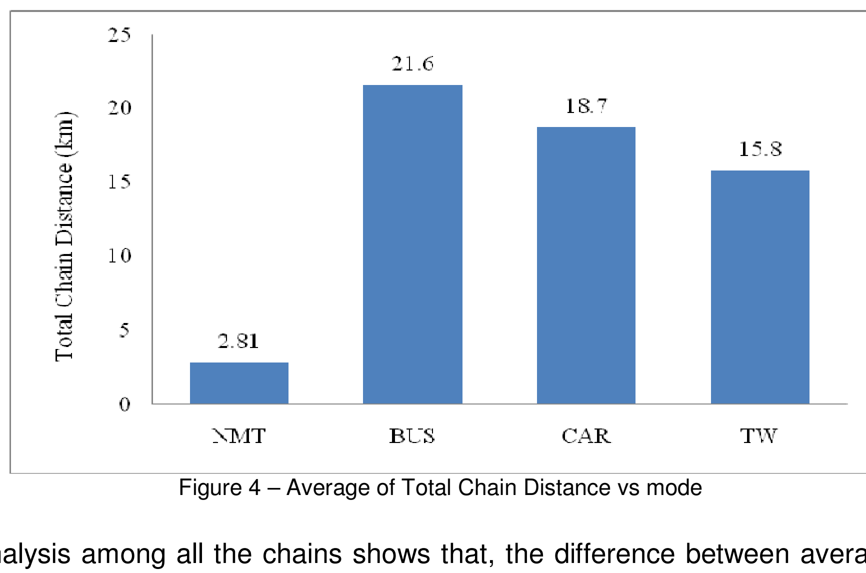

Figure 4 – Average of Total Chain Distance vs mode

Further analysis among all the chains shows that, the difference between averages of total chain distance is statically significant [using one-way ANOVA at 5% significance level, [F (3, 15.21)=29.86]. Public transport users travel longer than car and two-wheeler users to participate in work activity. This finding is also in line with previous studies in the region based on individual trip based analysis (KUIDFC, 2007). In order to see which of the group means are significantly different from each other, we undertook a multiple comparison analysis using Games - Howell's test. At 5% significance level, the test showed that there is a significant difference between means of bus chains and two-wheeler chains and between that of NMT and all other modes. However, the difference between car chains and bus chains, and car chains and two-wheeler were found to be insignificant.

Total Time Spent in a Chain

Other important attribute of interest is the total time spent in a chain. Here, the total chain duration is considered as the sum of time required for travel as well as the time spent at work location. Figure 5 shows a plot of average time spent in chain for different mode users. It can be seen from the figure that two wheeler chains has higher duration followed by car chains and bus chains. NMT chains has lower duration among all chains. A one-way ANOVA shows that these differences are statically significant [5% level, F (3, 32.17) =8.26]. The multiple comparison of average duration using Games - Howell's test shows that there is a statistically significant difference between the mean values for bus and two-wheeler chains. In addition, the difference between NMT and other modes is found to be significant at 5% significance level.

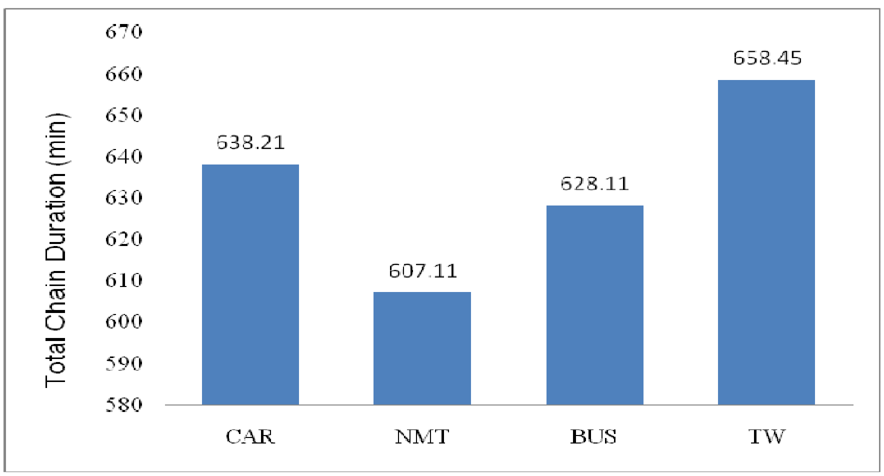

Figure 5 – Average time spent in chain by mode users

Time Spent at Work Location

An analysis of average time spent at work location shows that two-wheeler chains has higher work duration among all the groups (Figure 6). Bus chains have lower work duration compared to all other chains. It can also be noted that the work duration of NMT chains and car chains are nearly equal. The one-way ANOVA shows that the differences between average work durations are statically significant at 5% significance level [F (3, 19.52) =20.56)]. Further analysis using Games - Howell's test reveals that there is a statistically significant difference between the time spent at work location for bus users and other mode users. However, the difference between groups excluding bus is found to the insignificant (5% significance level).

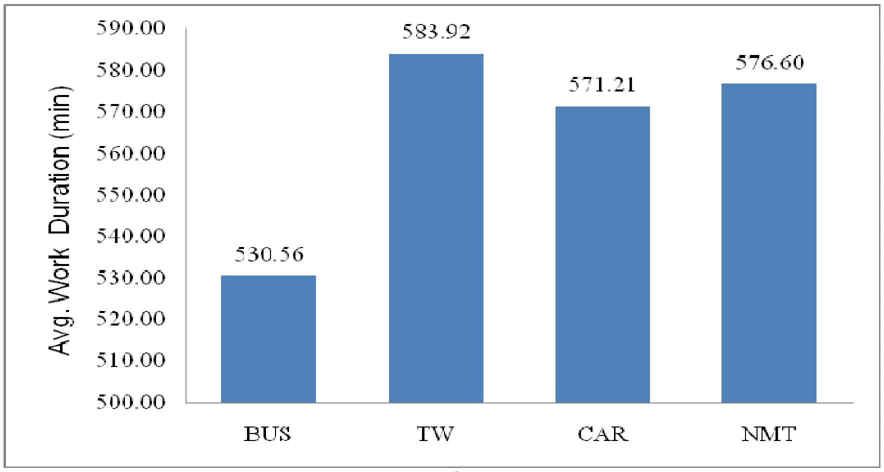

Figure 6 – Avg. Duration Spent at Work Location

Commute Duration

Average commute duration (one-way duration) is another attribute considered for the analysis. Figure 7 shows a plot of average commute duration for different modal chains. Please note that access/egress duration (to reach bus stop) is not included in the case of bus for calculating the commute duration. It can be concluded from the figure that among the motorised mode users, those who travel by bus had highest commute duration followed by car users and then two wheeler users. The average commute duration of NMT chains are found to be lowest among the groups. An extension of comparison using one-way analysis of variance shows that the difference average values are significant at 5% significance level [F (3, 25.76) = 12.29). The multiple comparison analysis using Games - Howell’s test shows that the motorised group means are significantly different from that of NMT. Further, it is evident that the mean values for bus and two wheelers are significantly different (5% level). The difference between mean values for bus and car, and car and two-wheelers are found to be insignificant.

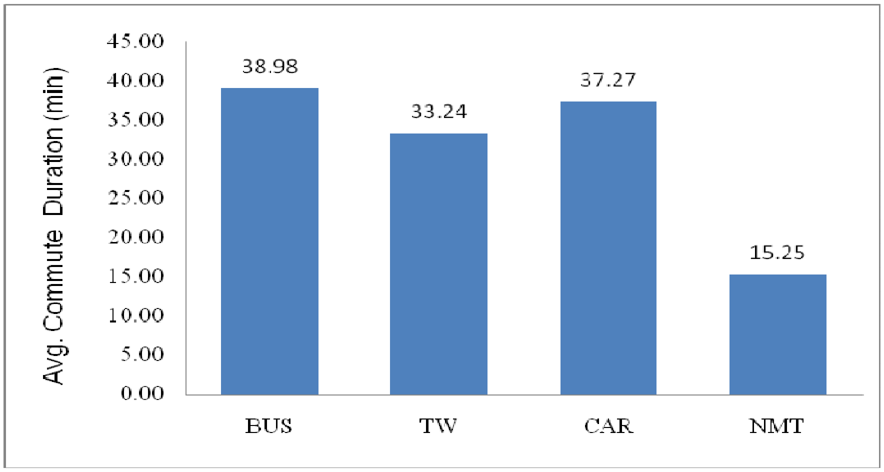

Figure 7 – Average Commute Duration for Different Mode Users

Ratio of Stage Duration to Stage Distance

Other attribute we considered here is the ratio between stage duration and stage distance. Figure 8 shows the comparison of this attribute between various mode users.

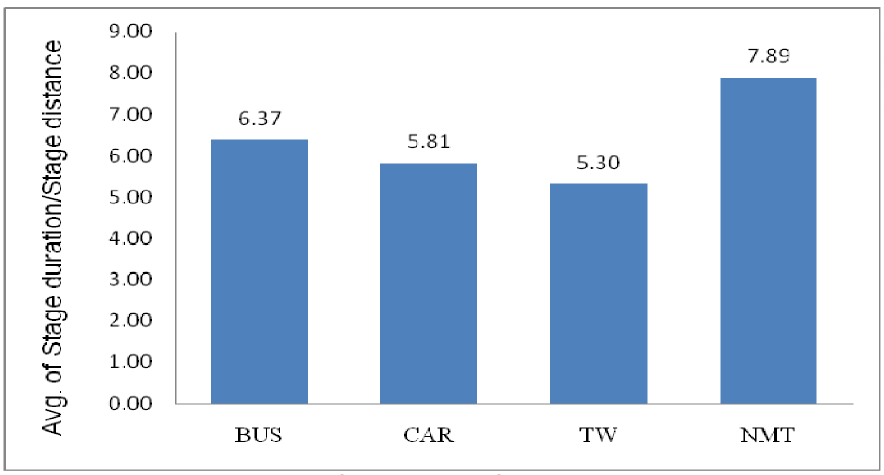

Figure 8 – Average Value of Stage Duration/Stage Distance for Various Modes

As expected, this value is higher for NMT modes (7.9 min/km) compared to all other modes. Among the moterised modes this value is higher for bus followed by car and then two wheelers. A further extension of analysis using analysis of variance shows that these differences are significant at five percent significane level [F (3, 12.7) = 32]. In order to understand which among the groups are significantly different, Games - Howell's test was undertaken. The test revealed that there is a statistically significant difference between group means for NMT and other mode users. Further, the analysis showed that means for bus and Two-wheeler are statistically significant (5% level). The difference between mean values for car and other motorised modes were found to be insiginficant.

Discussion

Analysis of simple work chains were the focus of the previous section. The analysis focused on comparing various activity-travel related attributes for different mode groups. The analysis revealed that attributes of interest were varying across mode groups. A comparison of average chain distance showed that bus chain had higher length compared to other modes. Leaving NMT, there is a significant difference between chain length for bus and two-wheeler. It shows that among the motorised modes, bus is used for traversing long distance. An analysis of overall duration spent in chain showed that the difference between NMT and motorised mode groups are significant. Also, there is a significant difference between total chain duration for bus and two-wheeler chains. An extension of the analysis into work duration revealed that bus chains had lower work duration compared to all other chains. It's also found to be significantly different from other mode groups. It can be seen that two wheeler chain had the highest work duration among all chains. A comparison of average commute duration revealed that bus had the highest commute duration among all the groups. This was significantly different from that of two-wheelers. It should be noted that even omiting the access/egress duration, bus had the highest commute duration. We also compared the ratio between access duration and access distance for various mode groups. It can be seen that, among the motorised mode groups, this ratio is highest for bus mode. For traversing a km of distance bus travellers had to spent on average 6.37 minutes while that for two-wheelers is 5.30 minutes. This difference is found to be statistically significant. Overall, among the motorised groups, two-wheler chain had highest work duration, overall chain duration, and less travel time (per km) while public transport users had lower work duration and higher per kilometer travel time. This may be one reason behind the depleting shares for public transport and increasing shares of motorised two wheelers. A case study from China showed that the utility of bus for accessing a simple chain was very low compared to that using a motorcycle (Yun et al., 2011). Further, the parameter estimates for travel time showed that a unit change in bus travel time had highest disutility compared to that for motorised two-wheelers (Yun et al., 2011). Also, as noted by Bhat (1997), work duration is found to be positively influencing private mode usage. Further, he also noted that higher the per stage time lower was the preference for a particular mode. These findings along with the results presented above can be attributed to depleting shares of public transport as well as increase in shares of two-wheelers. In addition, as noted in World Bank (2005) and in Pucher et al. (2004), lack of comfort and convenience of public transport, congestion etc are also contributing to a shift from public transport to personalised modes, especially, to two-wheelers.

Complex Chain Analysis

A complex chain portrays the movement of an individual from home location to work location and then back, with a number of intermediate stops visited for participating in activities other than work. In this study, the chains characterised by stop making on the way to work location, on the way from work location, and both on the way to and from the work location are clubbed together and viewed as complex trip-chains. However, data quality became an issue for clearly defining the trip-chains based on the screening and cleaning criteria. Due to the trip-based nature of analysis and modelling, home based trips were well addressed and other stages of the same complex movement were either unaddressed or poorly coded in the given database. Due to this, discrepancies were found in the case of duration of stages/chain (un coded or negative), destination (circuit was absent), stage/activity purpose (either absent or miscoded) and in modal continuity. To deal with these issues and to ensure a sufficient sample size for the analysis, we use the concept of "open trip-chain" for the analysis. Valiquette and Morency (2010) introduced the concept of an open trip-chain. According to them, such chains lack a starting as well as a closing trip and other associated attributes. They attribute reason for their existence either to an incomplete diary or to the truncation of observations. With this, they found that 4% of total chains in their database (2003 Montreal OD survey) were open chains. Here, we exploit the concept of open chains along with the screening and cleaning criteria mentioned before to identify complex trip-chains. Due to this, only limited attributes are identified and analysed in this section of the study.

Analysis of Travel Related Attributes

A sample of 312 complex chains (including all three category) are identified based on the above mentioned analysis strategy. Due to the lack of sufficient cases, all other activities other than work are grouped into activity type "other". Data quality restricted as to do the analysis only for attributes like work duration, ratio of stage duration/stage distance and number of stages. For all the samples used in the analysis, the normality assumption was verified by using Kolmogorov-Smirnov (K-S) test at 5% significance level. The null hypothesis (follows normal distribution) was accepted at 5% significance level in all the cases. The homogeneity of variance was checked by using Levene statistic. At 5% significance level, the test revealed that the variances of groups are different in all the cases. Due to this, Welch test for equality (robust test for equality of means) of means was conducted for all samples (5% significance level) for finding the adjusted F-ratio (Welch, 1938, 1947). At 5% significance level, we could see that null hypothesis (equality of means) was rejected in all the cases. Due to unequal sample size and heterogeneity in variance, Games-Howell post hoc procedure (Games and Howell, 1976) is used for identifying which among the group means are significantly different.

Figure 9 shows the modal split for the complex chains. It can be seen that the trend closely follows the modal split scenario observed in the case of simple chains.

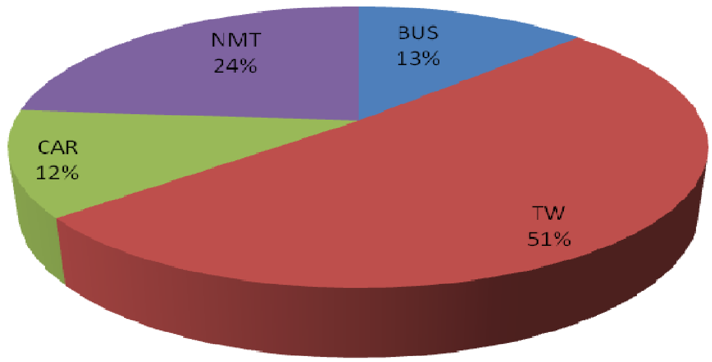

Figure 9: Modal Split for Complex Chains

Time Spent at Work Location

Analysis of average duration spend at work location is shown in figure 10. It can be concluded that the bus chains has the lowest duration among the groups. Other important aspect is that two wheeler chains and car chains have nearly same work duration. The analysis of variance shows that the group mean are different at 5% significance level [F (3, 13.67) = 29.15]. Further analysis using Games - Howell's test reveals that the mean values for bus and two wheeler chains are statically significant at 5% significance level.

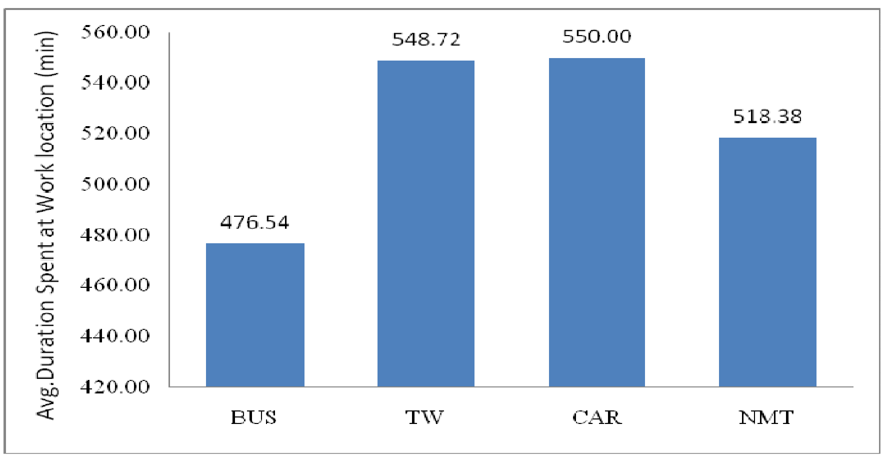

Figure 10: Average Duration Spent at work location

Ratio of Stage Duration to Stage Distance

Comparison of ratio betweeb stage duration to stage distance across different modes followed the same trend as that given in the case of simple chains. Figure 11 is the graphical representation of the comparison.

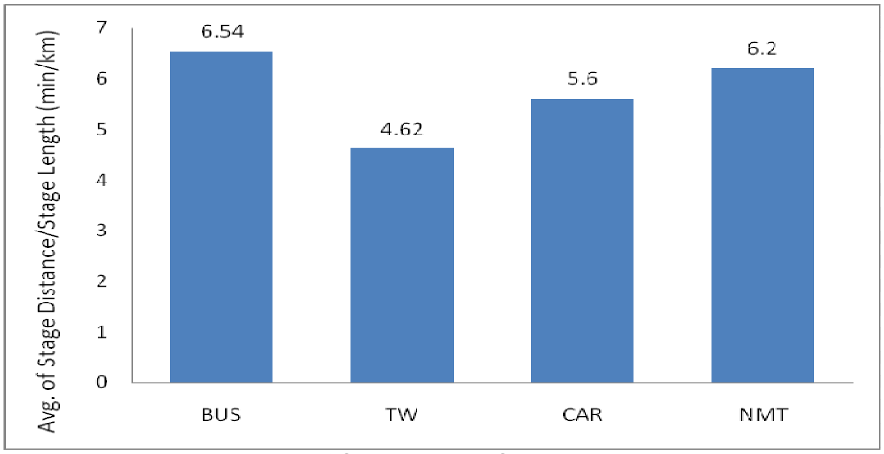

Figure 11 - Average Value of Stage Duration/Stage Distance for Various Modes

The means are found to be statistically significant at 5% significance level [F (3, 17.97) = 25.20]. Further, the multiple comparison test reveals that the the difference between bus group means and two-wheeler group means are significant (5% level).

Total Number of Stages

Total number of stages per chain is another attribute compared in this study. Figure 12 shows a comparison between average number of chains present in the complex chains with different modes. Please note that the stage movements to anchor locations are not included in the anslysis.

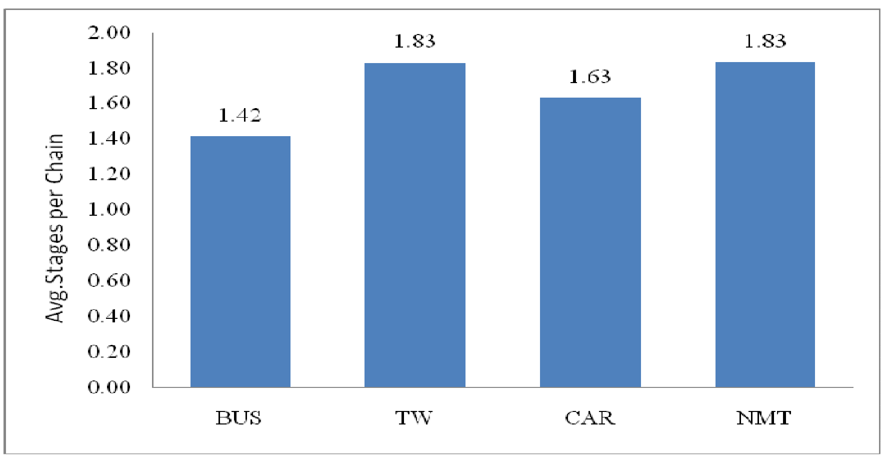

Figure 12 – Average Number of Stages by mode

As can be seen from the figure, among the complex chains, public transport chains has lowest number of of stages. This is found to be statistically significant from other modes at 5% significance level [F (3, 32.17) = 8.15].

Discussion

Analysis of complex chains was the focus of the previous section. Data limitations prevented us from undertaking a comprehensive analysis. Only few attributes, such as, average work duration, ratio between stage durtaion and stage distance, and number of stages in a chain are compared across different groups. It was seen that average work duration was less for all mode groups when compred with that of simple chains. Further, it can be seen that bus chains has lowest work duration among the groups. It is found to be statistically significant from other groups. The analysis of ratio between stage duration to stage distance revealed that bus chains had the highest per kilometer travel duration. Among the motorised mode groups, two-wheelers had the lowest per kilometer travel duration. Further analysis of number of stages per chain among various mode groups shows that, bus chains has lowest number of stages. This value is found to be significantly different from other mode groups. These findings are relevant from a policy testing perspective. As discussed in Yun et al. (2011), all else being equal, the utlity of motorised two wheeler for a complex chain was much higher than that gained by using a bus. Moreover, they identified that a unit change in travel time by bus had higher disutility for using them in a chain when compared that with two-wheelers. As noted by Bhat (1997), the higher the ratio of duration to distance the less attractive the mode would be. He also found that duration at work positively influenced usage of private mode. He also noted that work duration and ratio between stage duration to distance negatively influenced the stop making behaviour during commute. Here we can see that two-wheeler chains has higher duration at work location and lower stage suration per kilometer travelled. Relating to the above mentioned case studies, we can say that work duration, commute duration and need to visit stops under constraints might be influencing increased two-wheeler usage.

SUMMARY AND CONCLUSION

In this paper, an attempt is made to epxplore the mode choice behaviour of individuals from a trip-chaining perspective. Studies from various cities have shown that trip-chaining is a predominanat factor affecting the mode choice decision of individuals. It has been reported that individuals rely on flexible (private) modes to engage in complex trip-chain patterns. Reserchers also suggested that public transport is a barrier to undertake complex traip chaining patterns. Some contrasting results to these findings are also reported in the literature. Hence, there is a need to understand the mode choice behviour of individuals from a trip-chaining perspective. Such an analysis is important from Indian cities perspective as they have been witnessing depleting shares of public transport and increasing shares of private modes, especially, two-wheelers.

In this study, the trip-chaining behvaiour of different mode groups are compared. Due to poor data quality, only few attributes are identified and compred in this study. The overall analysis is undertaken for simple and complex chains. For simple chains, the two-wheeler groups had higher work duration as well as lower duration per km travelled. As can be seen from previous studies, these factors contributes to private mode usage. In case of complex chains, we found that the work duration is lower for all mode groups compared to that of simple chains. Further, it was seen that two-wheeler groups had highest work duration among the groups. Duration per stage was found to be higher in the case of bus users. Also, the number of stages in the case of complex chains were lower for public transport users. It is reported that such factors have a direct bearing mode choice decisions under complex travel behaviour. Overall, this study, despite the limited dimension due to data inadequacy, provided some hint on the reasons behind the increased use of two-wheelers and a decreasing trend in public transport.

Apart from infrastructure related issues, behaviour related activity-travel related factors are also affecting public transport dependency. Thinking from a trip-chaining persepctive, activity clustering around the terminals would be an option to make public attractive for use in non-work activities. Transit oriented development and mixed land use practices can also be considered as viable options for improving transit dependency. Since public transport is depended for longer chains, improvemnts in the form for light rail transit system, rail rapid transit system etc can also be considerd along with the above mentioned points. Such cases should also consider the integration between various public transport modes. In order to deal with access/egress issues, integrating public transport with paratransit modes (especially Autorikshaw (motorised three-wheeler)) is a viable option. This will also eliminte issues faced by pratransit mode operators in term of riderdhip.

The next step of study is to verify the findings from a behavioural stand point. Models have to be devloped with the inclusion of the attributes identified above, individual as well as household related attributes, and activity participation features to understand the reason behind trip-chaining and in turn the mode choice behaviour of individuals. Highly refined good quality data is a precursor for such study. These aspects can be considered for further expansion of this study.

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