

The Integration of Time-Space Prism and Psychological Mechanism on The Use of Public Transport

Mark Kariuki¹, Dimas Bayu Endrayana Dharmowijoyo^{1,2*}, Liza Evianti Tanjung^{1,3}, Sakinah F. Shalihati⁴

¹Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS, Malaysia

²School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Indonesia

³Department of Civil Engineering, Universitas Muhammadiyah Sumatera Utara, Indonesia

⁴Department of Education of Geography, Universitas Muhammadiyah Purwokerto, Indonesia

Abstract. *A hierarchical structured equation model and a multi-dimensional 21-day household time-use and activity diary conducted in Bandung Metropolitan Area, Indonesia investigated the interaction among individuals' psychological mechanism, daily activity participation and built environment in selecting public transport as a mode choice. The preliminary analyses of the collected data indicated that different beliefs, support and attachment to motorised modes significantly relate with different groups of occupation, gender, age, income class, activity participation and activities. Therefore, an individuals' subjective characteristics and day-to-day time-space components significantly influence their selection of public transport as their preferred mode choice to participate in certain activities. The study results also show how built environment influences individuals' mandatory and discretionary activity participation in the selection of public transport as their preferred mode choice.*

Keywords: *Psychological mechanism, daily activity-travel participation, Bandung metropolitan area*

1. Introduction

Transportation involves movement of people and goods from one location to another with the aim of achieving a set objective. Individual movement is characterized by their need to satisfy a certain need. These needs can be split into two types of activities: mandatory and discretionary activities. Mandatory activities are activities that are difficult to be rescheduled. On the other hand, discretionary activities are activities that are easy to be scheduled or do individuals' free time such as grocery shopping and leisure travel (Dharmowijoyo, Susilo, Karlström, & Adiredja, 2015).

To facilitate this movement, individuals have been able to come up with different modes of transport such as road, rail and air. Each of these modes can either be relevant or irrelevant when other factors are considered.

These factors include cost, location, access, perceived behaviours, attitudes and external variables such as age, gender and income (Dijst, Farag, & Schwanen, 2008). For many years, humans have used these factors in selecting their preferred mode choice. It is important to note that the most used mode of transport used around the world is road-based mode which walking, driving or being in a bus, road is the worlds most used mode of transport. This is because people daily make frequent trips to and from different places most of them easily accessible by road.

According to Dharmowijoyo et al. (2015), the most common practice in transport demand analysis has been trip-based analysis. This analysis is solely built on transverse observation of a specific day over a certain duration usually its peak hours. In this scenario, the relationships between trip and activity has been disregarded as well as the different time- space constraints an individual

*Corresponding author. Email: dimas.bayu@utp.edu.my

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School of Business and Management-Institut Teknologi Bandung

encounter in their day to day decision making process (Hägerstrand, 1970). Hägerstrand, (1970) argued that individuals' daily mobility Capability constraints deal with the necessity of personal care; Coupling constraints require individuals to come together with people, at designated places, at specific times, for a specified duration to achieve a desired objective; Authority constraints, determine who has or does not have access to specific spaces (places) at specific time durations (Fox, 1995).

Nonetheless, studies have also shown their involvement in new ways of analysing transport demand. One of these new ways is the activity-based analysis. This type of analysis investigates travels and movement as a demand by which an individual's activities, time and location plays a major role in how they move around. According to Susilo and Axhausen, (2014), the variation in activity-travel patterns and constraints result into a dynamic pattern or a routine. These set of patterns evolve into habitual behaviour leading to perceived actions. A choice of taking a particular mode is influenced with how many activity locations that someone will visit, how many trip chains on a day, activity participation on mandatory activities such as working/studying, discretionary activities such as outdoor sports and other corresponding constraints (Dharmowijoyo et al., 2015; Hägerstrand, 1970). Moreover, built environment conditions also shape geographical constraints of individuals, that can influence people's mode choice. The distances between two different locations frequented by an individual influence their mode choice greatly. For shorter distances, individuals would rather walk while for longer distances, public transport or personal motorised modes will be preferred.

Access to public transport in built environments greatly influences an individual. Lack of it leads to a preference to personal motorized mode choice while good access to it makes it the preferred transport choice. Social psychology perspective also

including the reason of taking a mode is shaped by three types of constraints: capability, coupling and authority constraints. contributes in understanding why people takes the mode. A set of variables that influence people's mode choice is not only instrumental variables, but also non-instrumental variables, such as goal desire, attitude, perceived behavioural control, volition, social subjective norms, behavioural desire, and past behaviour (Dharmowijoyo, Susilo, & Karlström, 2018; Dharmowijoyo et al., 2015; Dijst et al., 2008; Nanggong & Rahmatia, 2019; Yaacob & Baroto, 2019).

These variables greatly influence the way people move around to do their discretionary and nondiscretionary activities. For example, a household that wishes to travel for a long-distance leisure activity without access to personal motorized means will consider using public transport as alternative means. The desire to achieve this will be combined with socio- demographics such as age, disable persons, income levels and more. If a crucial factor hinders this choice, an alternative mode of transport will be considered, or the leisure activity abandoned. This goes to show how all these different perspectives influence mode choice

2. Proposed Model

Proposed model is shown in Figure 1.

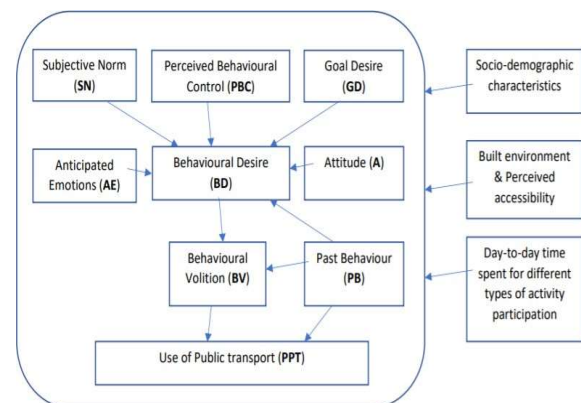


Figure 1.
The Proposed Model

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + \varepsilon$
 Y = Independent Variable; $\beta_0, \beta_1, \beta_2$ = Coefficients; X_1, X_2, X_3 = Explanatory variables; ε = Random error term

A. Activity Diary Classification

The daily activities done by individuals in the Bandung Metropolitan area were classified into seven (7) categories: 1. Mandatory in-home (MANDI) 2. Mandatory out-of-home (MANDO), 3. Leisure in-home (LEISI), 4. Leisure out-of-home (LEISO), 5. Maintenance in-home (MAINTI), 6. Maintenance out-of-home (MAINTO) 7. Travel (TRAVEL).

Mandatory activities are activities that are difficult to reschedule in relation to time and space such as working and going to school.

This means that these activities are priority and therefore affect an individual's capability to undertake their discretionary activities. Discretionary activities can fall under maintenance or leisure activities. If a discretionary activity involves satisfying personal and household physiological and biological needs, the activities would be classified as a maintenance activity. Leisure activities are classified as activities done within the individual's free time, in or out-of-home to satisfy their own physiological needs for example listening to music and watching tv/internet surfing. Leisure activities involve cultural needs as well such as social time and visiting family and friends. Recreational activities such as outdoor sports, volunteering, society clubs among others fall under out-of-home leisure activities (LEISO).

Table 1.
Activity Classification

Activity	Activity Criteria	Activity Classification
A	Sleeping	MANDI
B	Personal Care	MANDI
C	Eating and Drinking at house	MANDI
D	Relaxing activities e.g. watching tv	LEISI
E	Social and family activities	LEISI
F	Household activities	MAINTI
G	Babysitting activities	MAINTI
H	Indoor working activities e.g. work at office desk	MANDO
I	Driving vehicle to other places	TRAVEL
J	Outdoor working activities: operating machine or heavy vehicle at outdoor, outdoor inspection or outdoor engineering inspection and other related activities	MANDO
K	Sales activities from door to door, delivery something, purchasing activities	MAINTO
L	Indoor school activities	MANDO
M	Outdoor school activities: visiting zoo/museum/park, camping, and other related activities	LEISO
N	Eating and drinking outside home	MANDO
O	Shopping activities: -Grocery shopping -Shopping to the shopping centre/mall	MAINTO

Table 1. (Continue)
Activity Classification

Activity	Activity Criteria	Activity Classification
P	Organization/volunteer/political activities: boy scout, youth/political/religious meeting activities	LEISO
R	Sport activities	LEISO
S	Maintenance activities: going to hospital/health centre/medical doctor, visiting bank/post office	MAINTO
sT	Dropping/picking up children/other family members/friends/business partner and others	MANDO
U	Holiday	LEISO
V	Waiting for public transport	MANDO
W	Other out-of-home activities	LEISO
Z	Out-of-home sleeping	MANDO

B. Psychological variables

Psychological theory provides a structure on how subjective characteristics of the individual and other people influence individual behaviour. In this study, individual actions when performing certain behaviours were divided into actions influenced by previous information processes without contemplation. Actions taken after a contemplative process, whether premeditated or rational behaviours, refer to the individual's goal of participating in certain actions that appear after their intention or planning.

Intention is formed by an individual's attitude, beliefs, and/or the influence wielded by others on the individual as well as the extent of how easy or difficult it will be to perform specific behaviours. Perceived behavioural control encompasses both internal factors such as knowledge, skills and adequate planning and external factors such as the availability of resources. An individual may at first choose a rational mechanism for

performing certain actions. If this leads to a positive outcome, the individual will unconsciously repeat the same action, thereby turning it into a habit.

Subjective characteristics take in individual's planned behaviour, and habit. Actions preceded by the contemplative processes; whether premeditated or rational behaviours; refer to the goal of the individual taking part in certain behaviours that appear after intention or planning. Intention to perform a specific activity is formed by the individuals' motivation. When the individual performs a specific activity, he/she is being motivated to achieve that activity goal. This means to achieve a goal or a set of goals, motivation is a necessity aiding the decision-making. Therefore, behavioural desire is applied to represent motivation which in turn directly influences intention. The behavioural desire also includes attitude, subjective norms, perceived behaviour control (PBC) and anticipated emotions as precursors assumed to indirectly influence intention.

Table 2.
Psychological Variables

Category	Description	Possible Answers
Goal desires	1. My desire to do out-of- home activities within the forthcoming week is:	1=very weak,7=very strong
Attitude	1. I think, using public transportation (bus / public transportation) to do outdoor activities in the next few weeks is:	1=very unpleasant, 7=very pleasant 1=very unenjoyable, 7=very enjoyable
Subjective Norm	1. People who are important to me think I should make use of public transport to do out-of-home activities within the forthcoming weeks: 2. People who are important to me think I MUST make use of a public transport to do out-of-home activities within the forthcoming weeks:	1=strongly disagree, 7=strongly agree 1=strongly disagree, 7=strongly agree
Anticipated emotions	1. If I take public transport to do out-of-home activities within the forthcoming weeks, I will feel:	1=sad, 7=happy 1=dissatisfied, 7=satisfied 1=stressed, 7=relaxed 1=passive, 7=active 1=bored, 7=enthusiastic
Goal Perceived Feasibility	1. I think that using public transport to do out-of- home activities within the forthcoming weeks is:	1=very difficult, 7=very easy
Perceived Behavioural Control	1. For me, taking public transport to do out-of-home activities within the forthcoming weeks is: 2. My freedom in terms of using public transport to do out-of-home activities within the forthcoming weeks is:	1=very difficult, 7=very easy 1=very weak,7=very strong
Behavioural Desire	1. My DESIRE to take public transport to do out-of-home activities within the forthcoming weeks is: 2. I WANT to take a motorised Vehicle /public transport/ non-motorised transport to do out-of- home activities within the forthcoming weeks:	1=very weak, 7=very strong 1=very unlikely, 7=very likely
Volition	1. I will INVEST time in taking public transport to do out-of-home activities within the forthcoming weeks: 2. I INTEND to take public transport to do out-of-home activities on the weekdays within the forthcoming weeks:	1=very unlikely, 7=very likely 1=strongly disagree, 7=strongly agree
Past Behaviour	1. How often did you take public transport to do out-of-home activities during the previous year?	1=never, 7=everyday

3. Result and Discussion

A. Data Profile

From the survey conducted, the data

obtained was organized based on different variables related to time-use, household characteristics, perceived behaviour and built environment. The table below shows some of the variables to be considered.

Table 3.

Sample Profile

VARIABLES	PERCENTAGE/MEAN
<i>Socio-demographic characteristics at individual level</i>	
• Male/Female	52.5%/47.5%
• Worker	51.61 %
• Young adult (18 – 22 years old)	16.5 %
• Aged (23 - 45	54.3%
• Aged 45-55 years old	17.4 %
• Part of low income (< IDR 3 million/month) and medium income households (IDR 3-6 million/month).	90.3%/9.7%
<i>Household characteristics:</i>	
• Number of household members	4.47
• Number of dependent children per household	0.83
<i>Trips engagements and travel time spent on weekdays and weekends</i>	
• Number of trips	2.5
• Number of trip chains	1.14
• Percentage of using motorised mode	34.4
• Percentage of using public transport	5.1
• Percentage of using non-motorised mode	15.7
<i>Time spent for different activities on weekdays and weekends</i>	
• Time spent for in-home mandatory activities (minutes)	670.23
• Time spent for in-home leisure & maintenance activities (minutes)	242.3
• Time spent for working/school activities (minutes)	249.4
• Time spent for out-of- home social-recreational (minutes)	22.03
• Time spent for out-of- home other maintenance and sport (minutes)	28.23
<i>Built environment variables</i>	
• Km-length of road and railway per square-km within the respondents' residential location	36617.9/6036.5
• Density of industrial and trade centre or wholesale centre area per square-km within the respondents' residential location	0.023/0.011
• Density of government office and settlement area per square-km within the respondents' residential location	0.0146/30.22

B. Descriptive Analysis

Travel behaviour is different for everyone at different times of the day and location. Using the time space prism, the interaction between

needs and constraints can be analysed. These needs are influenced by socio-demographics, the level of development or infrastructure in an area to support transportation and the socio-environmental background.

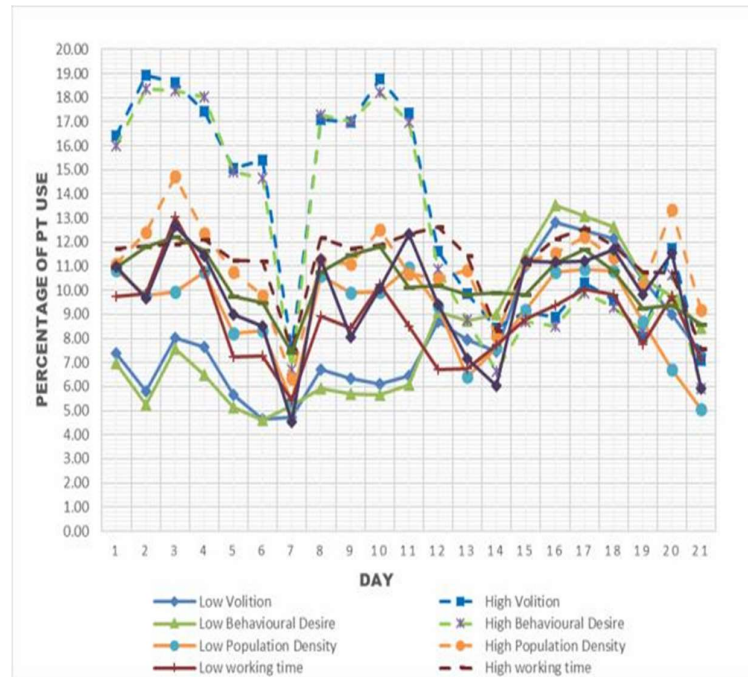


Figure 2.

Day-to-Day Daily Activity, Built Environment, Behavioural Desire and Volition Against Percentage of Public Transport Use

Figure 1 below shows the day- to-day daily activity, built and environment, behavioural desire and volition against percentage of public transport use. From the graph above, individuals with a low working time used public transport less compared to those who had a high working time. Moreover, the lower volition and behavioural desire an individual had in using transport, the lower their

percentage of public transport use. The higher commitment and intention (high volition) corresponds with high percentage of use public transport. Locations with high population density showed a higher percentage in the use of public transport among individuals living in these areas compared to low population density areas.

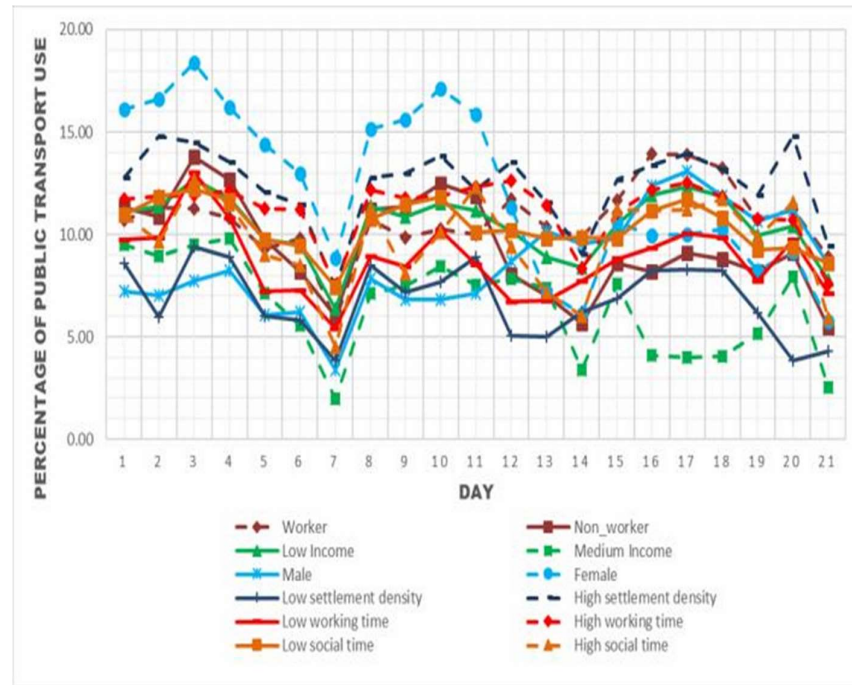


Figure 3.

Day-to-Day Individual Activity, Socio-Demographic and Built Environment Against Percentage of Public Transport Use

Figure 2 shows the day-to-day individual activity, socio-demographic and built environment against percentage of public transport use. From the graph, individuals with higher income used public transport less compared to individuals who earned lesser. Furthermore, the percentage of public transport use by males was significantly lower than females. From the graph, it was also noted that there was a decrease in public transport use on day 7, 14 and 21(all Sunday). Settlement density affected the percentage of public transport use. Individuals living in high settlement density areas use public transport more. Subsequently, individuals with low social time used public transport more than their counterparts, however the difference was minor. Social time and working time are represented by out-of-home leisure and out-of-home mandatory activities respectively.

C. Modal Estimation Results

From the table below, the results show how the different psychological variables namely past behaviour, behavioural desire and behavioural volition affect the use of public transport among different demographics and their geographical location.

Individuals who had previously used motorise mode of transport had low intention and motivation to use public transport in performing the out-door mandatory, maintenance and leisure activities. Similarly, individuals using non-motorised means had low motivation to use public transport. This is because of them being able to do most of their out-of- home activities without travelling a great distance that requires the use of motorised or public transport mode.

Table 4

Estimation Results (only significant variables showed on the table with p -value < 0.1)

VARIABLES	Past Behaviour		Behavioural Desire		Behavioural Volition		Percentage of public transport use	
	Co-eff	T-stat	Co-eff	T-stat	Co-eff	T-stat	Co-eff	T-stat
<i>Intercept</i>	2.855	9.06	-3.785	-6.206	0.143	0.096	-31.849	-1.885
Socio-demographic characteristics								
• <i>Male/Female</i>								
• <i>Worker</i>			0.112	4.097			2.037	1.759
• <i>Student</i>	0.266	5.362	0.122	2.933				
• <i>Non-worker</i>	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
• <i>Young adult (Aged 18-22 years old)</i>							5.737	2.431
• <i>Aged 23-45</i>							5.234	1.927
• <i>Aged 46-55 years old.</i>	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
• <i>56 years old ++</i>								
• <i>Part of low income (< IDR 3 million/ month)</i>	-0.206	-2.768					2.641	1.926
• <i>Medium income households (IDR 3-6 million/ month).</i>								
	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Household characteristics:								
• <i>Number of household members</i>	-0.068	-4.414	0.038	3.248	-0.056	-2.339		
• <i>Number of dependent children per household</i>	-0.083	-3.024						
Trips engagements and travel time spent on weekdays and weekends								
• <i>Number of trips</i>								
• <i>Number of trip chains</i>	-0.054	-2.477					-1.204	-2.810
	0.088	1.972					9.698	12.096
• <i>Percentage of using motorised mode</i>	-0.001	-1.870					-0.319	-45.910
• <i>Percentage of using public transport</i>								
• <i>Percentage of using non-motorised mode</i>							-0.280	-45.117
Time spent for different activities on weekdays and weekends								
• <i>Time spent for in-home mandatory activities (MANDI)</i>								
• <i>Time spent for out-of-home mandatory activities (MANDO)</i>								

Table 4. (Continue)

Estimation Results (only significant variables showed on the table with p -value < 0.1)

VARIABLES	Past Behaviour		Behavioural Desire		Behavioural Volition		Percentage of public transport use	
	Co-eff	T-stat	Co-eff	T-stat	Co-eff	T-stat	Co-eff	T-stat
• Time spent for in-home maintenance activities (MAINTI)							0.046	17.684
• Time spent for out-of-home maintenance activities (MAINTO)			0.000312	2.482				
• Time spent for in-home leisure activities (LEISI)							0.087	23.851
• Time spent for out-of-home leisure activities (LEISO)			0.000201	1.852			0.00877	2.960
							0.046	12.164
Built environment variables								
• Km-length of road per square-km within the respondents' residential location								
• Railway per square-km within the respondents' residential location								
• Density of plantation area/ km ² within the respondents' residential location	1.237	3.803					-39.510	-2.328
• Population density/km ² within the respondents' residential location	0.000024	5.217	-1.677	-7.554				
• Density of trade centre or wholesale centre area per square-km within the respondents' residential location	8.838	3.895	-0.000008	-2.220	4.169	2.419		
• Density of settlement area per square-km within the respondents' residential location	-0.00219	-3.909			-0.00104	-2.610	-0.031	-1.930
Psychological Variables								
Perceived travel time to CBD (minutes)	0.0199	10.614	-0.007	-2.862			-0.205	-1.905
Endogenous variable of past behaviour			0.634	5.616			16.616	2.121
Endogenous variable of behavioural desire					0.682	1.687		
Endogenous variable of behavioural volition							-28.613	-2.154

Time spent for different activities varies between individuals. In performing their out-of-home mandatory activities, many individuals used public transport as their preferred means despite their planning, intention or motivation. Workers had the intention to use public transport and despite their low volition, they eventually would use public transport. Non-workers had a high intention and motivation to use public transport in performing their out-door maintenance and leisure activities. This is because they have no time constraint in getting to perform their activities in a day compared to students and workers.

As predicted, behavioural volition was influenced more by situational variables rather than behavioural desire. Planning and motivation play a role but are not close to actual behaviour when compared to behavioural volition. Therefore, logically situational variables eventually affect the volition to carry out an activity. An individual who perceives public transport as having a shorter travel time, has a greater intention in using it to perform their activity. An individual's location of residence influenced whether they would use public transport as a means. Individuals living in dense settlement areas had a higher commitment and motivation to use public transport as their preferred means. This is because they perceived a shorter travel time in. Less dense settlements are greatly dominated by higher income earners who may have access to private motorised mode hence low intention and motivation to use public transport.

In conclusion, the results show that percentage of using public transport was influenced by past behaviour. The frequency at which an individual used public transport before, will make them to use public transport again to perform the day to day activities. Someone who has high commitment and intention to use public transport might not use public transport or will use public transport less often.

4. Conclusion and Recommendation

Studies on travel demand have progressed since the 1970s. Other than trip-based analysis, studies began to include other factors such as the inclusion of socio-demographics. From this study, the relationship between psychological mechanisms and their interactions with time-space prism and activity-travel patterns can be investigated and its influence used in planning of urban areas, new cities and reliable public transport systems. Using a hierarchical Structural Equation Model (SEM), complex interactions between day-to-day time-space factors and psychological mechanisms can aid in understanding the way individuals and households select their preferred mode of transport.

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