ANALYSIS OF FACTORS AFFECTING SCHOOL CHILDREN TRAVEL MODE CHOICE IN DAR ES SALAAM

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ABSTRACT

This paper examines the relationship between mode of travel to school and the range of factors that might affect children's choice of transport mode. The study reported upon in the paper uses data from school travel survey conducted in 2011 to analyse the factors affecting mode choice for primary and secondary school children. The data is modelled using a multinomial logit approach to explain the school mode choice for school children. Key factors are identified in terms of their influence on the choice of travel mode among school children. The paper concludes with a discussion on the policy implications of the results by indicating that community schools serving nearby residential areas as well as improved local conditions have the potential to attract non-motorised trips.

1. INTRODUCTION

As transport becomes more important to our society, more problems are being generated as a result. Transport, especially in cities, causes a number of problems such as environmental problems and negative impacts on human health due to emissions of noise or vibrations, and road crashes. Walking and cycling modes cause virtually no noise or air pollution and are ideal means of getting around cities and to/from schools. On the contrary, studies conducted in South Africa, the United Kingdom, the US, and other developed countries show that schools are attracting more trips, most of these trips being taken with private car, causing congestion and children having less physical activities.

In connection to this, walking and cycling to school have become a concern for public health and transportation planners and policy makers around the world during recent years (Marchetti et al, 2007). Much attention is being paid to the analysis of factors affecting travel mode choice behaviour of children for the trip to and from school (Beck et al, 2008). There have been a number of studies which explore the potential conditions on which children's school travel behaviour depends upon. These studies have shown that children's travel behaviour to school is a complicated socio-economic activity which is affected by many factors that impact the choice of mode, some of these factors include travel cost, family income, gender, travel time (which is an indirect reflection of distance), home-school proximity, neighbourhood built environment characteristics, and parental or guardians perceptions of neighbourhood safety and trip characteristics.

The literature shows evidence of the application of multinomial logit models to examine the relationship between mode of travel to school and a range of factors that might affect mode choice, as well as various policies that have a potential to increase walking and cycling rates (McDonald, 2008; Müller et al., 2008; Ewing et al., 2004). However, most of the studies are carried out in developed countries cities with very little information available about the policy implications of the relationship between mode of travel to school and factors that might affect school travel mode choice in developing countries cities and sub-Saharan African cities in particular.

Discrete choice models are widely used in transportation, economic, marketing, and other fields when individuals have to select an option from a finite set of mutually exclusive alternatives (Mohammadian et al., 2003). They are developed on the basis of Random Utility Theory, whereby a choice with the greatest utility has the highest probability of being chosen (Ortuzar and Willumsen, 2001). Logit models are by far the most widely applied discrete choice models due to the fact that the formula for the choice probabilities takes a closed form and is readily interpretable. However, the multinomial logit model suffers from several well-known limitations. The most severe is the IIA property, which states that a change in the attributes of one alternative changes the probabilities of the other alternatives in proportion. While the IIA property is realistic in some choice situations, this substitution pattern may not be realistic in others. Secondly, the coefficients of all attributes are assumed to be the same for all respondents in a choice set experiment, whereas in reality there may be substantial taste variation among individuals placed on each attributes of the alternatives (Train, 2002).

In this paper, factors affecting mode choice was modelled using a multinomial logit approach to explain the school travel mode choice. The paper attempts to analyse the factors affecting mode choice for primary and secondary school children with a discussion on the policy implications of the results. It has five sections. The following section outlines the factors influencing school travel mode choice. The third section develops school travel mode choice model for Dar es Salaam. The fourth section describes the data that was used in the study, whereas the fifth section presents model results and discussion. The sixth section concludes the paper by giving a summary of key findings and their policy implications.

2   FACTORS THAT INFLUENCE SCHOOL TRAVEL MODE CHOICE

There has been considerable amount of research aimed at studying children's school travel mode choice behaviour and as a result a number of factors affect school travel mode choice have been identified. Travel time, and therefore distance has been found to be a significant determinant factor of the school travel mode choice in the US (McDonald, 2008). Many school children are not willing to walk long distances and therefore are much more sensitive to walk travel time than car travel time. Ewing et al. (2004) report a similar result in analysis of data from Gainesville, Florida. They found that school children with shorter walk and bike times to and from school are more likely to walk and bike. They further found that students from households with more vehicles per capita and higher incomes are less likely to walk to school than to take a car, school bus or bicycle. Evenson et al. (2003) reporting about the Georgia survey in the US observed that girls are less likely to walk than boys.

Other studies have analysed the influence of the built environment and urban form on school travel mode choice. Generally, the results are somehow mixed; the built environment appears to exert a small, but significant effect on walking to school (McDonald, 2008). Srinivasan and Rogers (2005) found location to be one of the factors influencing travel mode choice. Braza et al. (2004), in the analysis of data from elementary schools in California, found that walking and biking rates were associated with neighbourhood density (positively) and school size (negatively). In their study, Pearson correlation results showed junctions densities to be significantly and strongly correlated with walking and biking but not in multiple regression models with other variables. Similarly, it has been found that urban form variables have a relatively less impact on mode choice compared to other variables like socio-economic attributes, distance, and vehicular traffic conditions (McMillan, 2006). On the other hand, Boarnet et al. (2005), in the evaluation of California Safe Routes to Schools, found sidewalk improvement, crossing improvements and traffic control enhancements increased walking and cycling among

school children. Likewise, Ewing et al. (2004) found street sidewalk coverage to have the most significance influence on walking. However, they also found that none of the other urban form variables that proved important in earlier study, such neighbourhood population density and street tree coverage, proved significant.

Furthermore, other factors influencing travel behaviour in children include traffic safety and parental perception about traffic danger and the risk of abduction or harassment (McDonald, 2008). Ridgewell et al. (2009) noted that perceived stranger danger or danger of assault and danger from increase in traffic as the most significant factors influencing the choice of car instead of bicycles for school trips. Transport mode safety plays a significant role in mode choice since many parents believe that driving children to school is safer than having them use non-motorized transport (Rhoulac, 2005).

3 METHODOLOGY AND MODEL FORMULATION
3.1 Modelling Methodology
3.1.3 Multinomial Logit Model (MNL) Development
This study uses a multinomial logit model to explain mode choice behaviour for the trip to school. BIOGEME software was used to estimate the desired coefficients of parameters of the model.

3.1.4 Limitations of the Study
The limitations of this study can be summarized as follows:
- The study has been limited to developing multinomial logit model only. Nested logit models and more complex models could be developed to better describe the choice behaviour.
- Limitations associated with dataset are that the survey did not collect information regarding presence of intersections, condition of walkways. These variables have important effects on non-motorised transport mode choice behaviour.

3.2 Model formulation
This study uses a multinomial logit model to understand transport mode choice for school trips. The underlying assumption of the model structure assumes that children and their parents, as a family decision unit q, choose the child's travel mode, i, to maximize household utility since parents' wishes may determine mode choice for children. The applied random utility choice model assumes that the probability that alternative i is chosen by decision maker q is given as follows:

$$P_{iq} = \frac{\exp(U_{iq})}{\sum_{j \in A} \exp(U_{jq})}$$
1

where
P_{iq} is the probability of choosing mode *i* for a school trip,
U_{iq} is the utility of *i* for individual *q,*
U_{jq} is the utility of mode *j* in the choice set for individual *q,*
A is the set of all available travelling modes

The MNL model assumes that travellers have utilities for different transport modes and that they choose the mode providing the highest utility (Ben-Akiva and Lerman, 1985). The utility associated with a transport mode consists of two components: -a deterministic part reflects the influence of observed factors such as socio-demographic, mobility limitations, personality and lifestyle and a random part represents all unobserved impacts. The best fit equation is evaluated by comparing log-likelihood ratio value and Rho-square among

different other possible forms. As a result, the functions derived for each mode are different from each other in the attribute selection and their interaction.

3.2.1 Model specification

School children in Dar es Salaam face a choice between car, walking, cycling, public transport (Daladala) and taking a school bus for travel to school. The representative utility of each mode for each child, U_{nj}, is a function of different attributes including neighbourhood characteristics. Thus, the representative utility of multinomial logit model takes the following form.

$$U_{nj} = ASC_j * one + \beta\_ T_{nj} * X_{1j} + \gamma\_ C_{nj} * X_{2j} + \delta\_ HH_{nj} \qquad (2)$$

U_{nj}	represents the observed utility to child n of mode j;
ASC_j	is an alternative specific constant for mode j;
T_{nj} & C_{nj}	is the trip attributes to be estimated required for child *n* when choosing mode j;
X_{1j} & X_{2j}	represents characteristics such as age and gender of child *n* when choosing mode j
HH_{ni}	represents household characteristics such as income, car availability and employment for child *n* when choosing mode j
β , γ, and δ	are coefficients of the respective variables.

3.2.2 Choice sets

The most important stage in discrete choice modelling is determination of the right choice set for each individual. Modal accessibility among students has been assessed to identify alternatives that are available for children to choose from and beyond the reach of the children. Available transportation alternatives for making school trips form a universal choice set. It is understood that not all alternatives in the universal choice set are accessible to all children. Therefore, it was necessary to determine subsets of the universal choice set for every child. A single subset contains alternatives that are assumed to be accessible to all children. In this case, five alternatives were considered in the model formulation. These were car, school bus, public transport (daladala), bicycle and walk. In Dar es Salaam city; very few schools use school bus services to transport children to/from school while many schools trips (55%) use public transit (daladala) (Bwire and Chacha, 2011). In this study, it was assumed that at least one of these alternative modes (choice set above) will be available for children to choose from. Thus, the universal choice set *A* included car, school bus, bicycle, walk, and public transport (daladala) as shown in Figure 1.
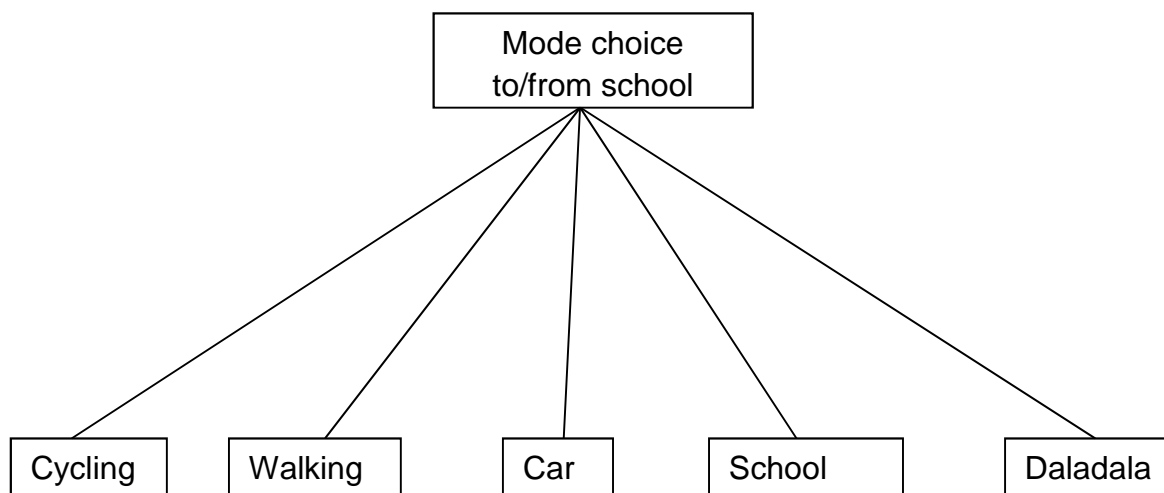
Figure 1: Mode choice used for children travel

The set of availability variables (CAR_AV, SCHOOL_BUS_AV, BIKE_AV, WALK_AV, and DALADALA_AV) were used to specify which alternatives are feasible for each individual. The following rules were used in mode formulation.
1.   Parent without a driver's license cannot use car to drive the child to/from school.
2.   Children in a household without a car cannot use car.
3.   Children in a household without a bicycle cannot use bicycle.

The remaining alternatives were assumed to be feasible to all children and the variables entering into the utility functions are shown in Table 1.

Table 1: Attributes for Model estimation

Variable Categories	Attribute	Variable
Trip Characteristics	Travel time	β_time (minutes for single trip include. in-vehicle and out-of-vehicle time):
	Safety	β_safety
	Distance	β_distance
Socio-economic characteristics:	Gender	β_gender
	Household income	β_income
	Car availability	Availability of a private car in the Family; β_car
	Employment	β_employment (parent employment status)
Alternatives Specific Constant		ASC_bus
		ASC_car
		ASC_cycle
		ASC_daladala
		ASC_walk

3.2.3   Processing data in the Biogeme software
The estimation of the parameters of the utility equation was done using Biogeme. All the choice set data was processed in the software for each choice combination separately. The model results were evaluated based on two sets of criteria:
• Model coefficients with their associated "t" ratios and p-value. These values indicate the significance of an individual parameter associated with an attribute. Using 95% confidence interval, p-value should be less than 0.055 and t-test should be greater than 1.96
• Model summary statistics showing a number of observations including Rho-square which gives an indication of overall goodness of fit whose value varies between 0 (no fit) and 1 (perfect fit) or good fit models.

3.2.4   Utility equation derivation
Five models were developed based on described attributes shown in Table 1 as follows

Utilities]
        (3)
// Id Name   Avail linear-in-parameter expression (beta1*x1 + beta2*x2 + ...)

1. WALK = one ASC_walk * one + β _distance * distance + β _safety * safety + β _age * age
2. CYCLE = one ASC_cycle * one + β _age * age + β _time * time   + β _gender * gender + β _safety * safety
3. DALADALA = one ASC_daladala * one + β _distance * distance + _safety * safety + β _employmt * empy
4. SCHOOL_BUS = one ASC_bus * one + β _time * time + β _income * income + β _employmt * empy
5. CAR = one ASC_car * one + β _income * income + β _car * car_avail + β _employmt * empy + β _age * age

4   DATA

This study used travel survey data that were collected in 2011. The survey was completed by school children either at home with the help of parents/guardians or in class, depending on teacher preference. Notes and instruction regarding the purpose of the research and the meaning of questions were provided. The dataset collected includes information on travel mode, travel time, distance to school and household size.

The dataset that were used for development of multinomial logit model (MNL) were at the level of the descriptive and aggregate data. Employment densities is an example of aggregate data used in this research and the descriptive data included information about a particular individual's characteristics for a given trip like person's income of the family, age of the children, car available for private use, distance, safety, household size and travel time. The dataset were subdivided into two groups; 80% of the data were used for model estimation and the remaining 20% for validating the model developed since there were no other similar dataset available for model validation. The total number of cases was 2060, a case represents a single alternative's data records among the choice set of a single student. Thus, a student may have 3 to 5 cases.

The sample size used were 1,511 children from ten primary and secondary school, whom 54.4% walked most of/all the way, 7.1% cycled, 32.5% used public bus transport (daladala), 1.4% used school bus, 2.7% travelled with parent driver on way to work, 0.5% with parent driver specifically for school trip and 0.9% used motorcycle. The age of children ranged from 6 to 24 years, where majority of children (79.7%) were between the age of 11-15 years, 13.5% were 16-20 years old followed by 6.6% ranging from 5-10 years old and very few 0.1% (two children) were between 21-24 years old. The travel data shows that, 24.7% of children walk at a distance of less than 1 kilometer, 8.8% walk at a distance of 1-2 kilometers and 5.5% at a distance of 2-3 kilometers as shown in Table 2.

Table 2: Distance and mode use to travel

	Walked most of/all the way	Cycled	Daladala	School bus	Parent driver on way to work	Parent driver specifically for school trip	Motor cycle	Others	Total
Less than 500 m	7.9	0.7	3.0	0.0	0.3	0.1	0.3	0.0	**12.4**
0.5-1 km	16.8	1.4	1.6	0.2	0.5	0.0	0.1	0.1	**20.6**
1.1- 2 km	8.8	1.7	3.5	0.3	0.3	0.3	0.1	0.1	**15.1**
2.1-3.0 km	5.5	1.6	3.4	0.1	0.3	0.0	0.0	0.1	**11.0**
3.1-4.0 km	3.2	0.7	4.3	0.3	0.2	0.0	0.0	0.1	**8.8**
4.1-5.0 km	4.7	0.3	5.3	0.1	0.3	0.0	0.2	0.1	**11.0**
Over 5 km	7.5	0.8	11.4	0.4	0.9	0.1	0.2	0.0	**21.2**
Total	**54.4**	**7.1**	**32.5**	**1.4**	**2.7**	**0.5**	**0.9**	**0.5**	**100.0**

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Note: Item non-responses were 32.5% (n=1020)

5   MODEL RESULTS AND DISCUSSION

5.1   Results

The mode choice model provides a more detailed understanding of the descriptive statistics given in the aforementioned section. Alternative specific constant for car transport was normalized to zero, all parameters are significant at a 95% level of confidence, t-statistics and p-values of all variables were used. The model estimation results are presented in Table 3.

The estimated parameters for ASCWALK and ASCdaladala are both significant and have the expected signs. The log likelihood increased from the initial value -349.248 to the final value -162.154 (without latent variables). The results show the statistical significance of two alternative specific constants (ASCdaladala and ASCWALK). The estimated value of alternative specific constant of walking and public transport (daladala) have positive signs indicating that a child has an priory preference for walking and public transport (daladala) over car transport modes. ASCWALK is larger than ASCdaladala, which shows that children have a greater preference for walking mode over the public transport. The estimated values given in Table 3 shows that the probability values for estimated coefficients of ASCWALK and ASCdaladala to be equal to zero are very low (p-value = 0.00). The alternative specific constants for bicycle alternative has a positive sign of estimated value indicating that, with all the rest remaining constant, there is a positive preference for this alternatives with respect to car. However, its value is statistically insignificant at 5% level and the probability that estimated parameter of ASCcycle will be equal to zero is 0.34 (p-value = 0.34). The ASCbus has a negative sign indicating a negative preference of children travel by school bus with respect to car transport but is statistically insignificant at 5% level. Car was taken as a base reference mode; therefore it has no Alternate Specific Constant's (ASCcar) value.

TABLE 3: Model Estimation Results

Variable Category	Variable	Value	Std err	t-test	p-value
Alternative Specific constant	School Bus	-5.86	24.3	-0.24	0.81
	Car	0	fixed		
	Cycle	3.09	3.21	0.96	0.34
	Daladala	4.45	1.76	2.52	0.01
	Walk	5.00	1.77	2.83	0
Trip Characteristics	β_time	-0.0409	0.0511	0.80	0.42
	β_safety	0.173	0.317	0.54	0.59
	$\beta\_distance$	-0.570	0.321	-1.77	0.08
Individual Characteristics	Age	0.0793	0.112	0.71	0.48
	Gender (1=male, 2=female): β_gender	-2.35	2.47	-0.95	0.34
Household Characteristics	Family net month income; β_income	-9.63E-06	1.93E-06	0.50	0.62
	Availability of a private car in the Family; β_car	0.341	0.387	0.88	0.38
	Employment; $\beta\_employment$	0.144	0.0838	1.72	0.08
Summary statistics					
Null log-likelihood:		-349.248			
Cte log-likelihood:		-167.260			
Init log-likelihood:		-349.248			
Final log-likelihood:		-162.154			
Likelihood ratio test:		374.189			
Rho-square:		0.536			
Adjusted rho-square:		0.504			
N		1209			

Note: the results were calculated from 80% of the dataset

Coefficient of travel time, β_time, is statistically insignificant with a negative sign of estimated value, implying that the utility of the mode (mode with time as attribute) decreases as the mode become slower. This, in turn, will reduce a choice probability of the corresponding mode. Thus, the value of -0.0409 indicates the negative effect of a minute of travel time when children use mode to school. It also indicates that travel durations affect the utilities of the respective modes in a negative way. Moreover, its low value shows that travel time is less important in the choice of cycling than in the choice of school bus.

The estimated parameters for safety and availability of car for private use (β_safety and β_Car) have positive influence indicating that children can use car if car is available in the family for private use and can use daladala, cycle and walk when it is safe to use these mode. Gender and age of the students was statistically found to be insignificantly associated with school mode choice.

The negative sign of parameter $\beta\_distance$ shows that the longer the distance to/from school, the lower the utility of a mode. It affects the choice of soft modes (walking and cycling) to school in a negative way. This is consistent with the fact that children do not want to choose walking and cycling modes when they need to travel long distance.

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5.2   Goodness of fit

5.2.1   The Rho-square (ρ^2)

In this study the Rho-square (ρ2) value is 0.536 and adjusted Rho-square (ρ2) is 0.504 which is greater than 0.4 indicating that the discrete choice model developed fit the data well.

5.2.2   Log likelihood LL(θ)

The log likelihood LL(θ), log-likelihood at convergence, shows a good convergence in the model analysis presented in Table 3. This is performed by comparing the log likelihood function evaluated at both the estimated parameters and at zero for all parameters (which is usually equivalent to having no model at all).

5.2.3 Model Validation

Validation is done by using data of same variables on which the model was developed. Since there are no data on same variable from an independent study (data on the modelling of factors that affect school travel mode choice in Dar es Salaam) to check the accuracy of the model prediction, the primary data collected was grouped into two sets, one set, the training set 80% of data which was used to build the model given in Table 3 and another set 20% of data, the test set data that was used to validate developed model as shown in Table 4. As it can be noted from Tables 3 and 4, the rho-square and adjusted rho-square values of the model developed using 80% of data vs the model developed using 20% of data show that the model developed in Table 3 is valid and can be opted for application.

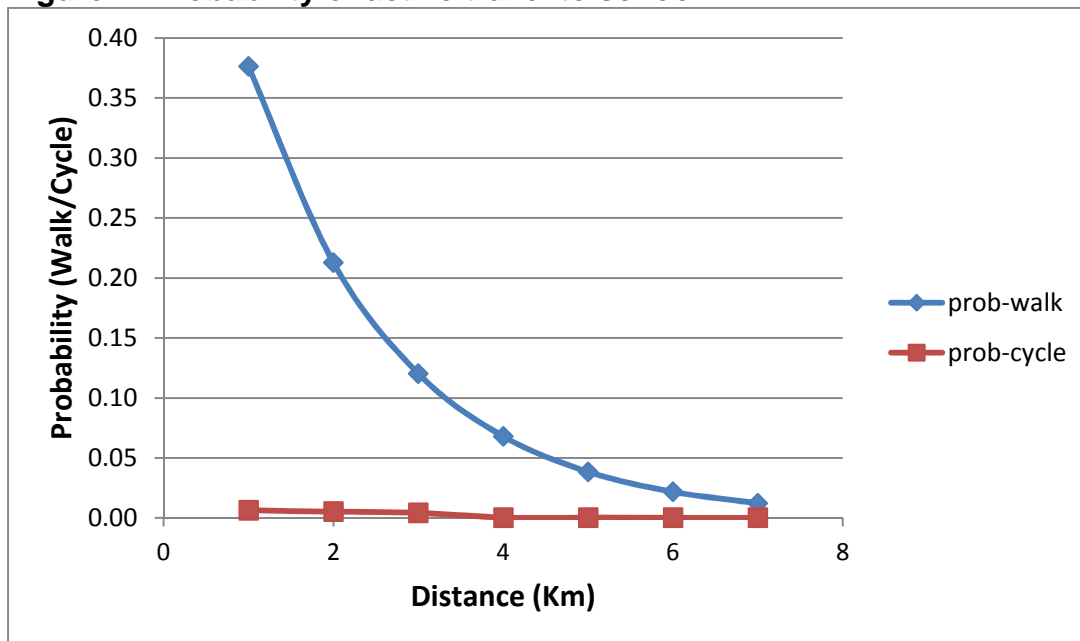**TABLE 4: Model Estimation Results**

Variable Category	Variable	Value	Std err	t-test	p-value
Alternative Specific constant	School Bus	-7.30	15.4	-0.47	0.64
	Car	0	fixed		
	Cycle	1.47	2.90	0.51	0.61
	Daladala	2.97	0.715	4.15	0
	Walk	3.54	0.715	4.95	0
Trip Characteristics	β_time	-0.0281	0.0184	-1.53	0.13
	β_safety	0.203	0.165	1.23	0.22
	β_distance	-0.02554	0.151	-0.17	0.87
Individual Characteristics	Age	0.0682	0.106	-0.64	0.52
	Gender (1=male, 2=female): β_gender	-2.39	1.75	-1.37	0.17
Household Characteristics	Family net month income; β_income	1.54E-06	6.58E-07	2.34	0.02
	Availability of a private car in the Family; β_car	0.0742	0.228	0.32	0.75
	Employment; β_employment	0.0686	0.0784	-0.87	0.38
Summary statistics					
Null log-likelihood:		-479.612			
Cte log-likelihood:		-243.718			
Init log-likelihood:		-479.612			
Final log-likelihood:		-237.367			
Likelihood ratio test:		484.491			
Rho-square:		0.505			
Adjusted rho-square:		0.482			
N		302			

Note: the results were calculated from 20% of the dataset

5.3   Distance Impacts on Walking and Cycling Mode Share

To better illustrate how the distance from home to school affects the share of school trips by walking and cycling, Figure 2 shows the probability of walking or cycling to school for trips of different distances from home. It is assumed that all other factors including safety are improved. It can be seen that at a distance of 1 kilometer to school, the probability of children to walk to school increases to 39%, a further increase in walking distance reduces the probability to walk dramatically. The figure also shows that cycling mode share decreases with increase in travel distances. It can be said that walk mode share could be increased if most students lived within 1.5 km of their school.

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8-11 July 2013
Pretoria, South Africa
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Figure 2: Probability of active travel to school

6   CONCLUSIONS

In this study, the dataset for school children's travel behaviour have been analysed with an attempt to reveal the effect of various factors on travel mode choice. The specific objectives of the study were to develop a model that captures the actual school travel mode choice behaviour and provide an understanding of the factors that influence school travel mode choice.

The model results show that distance to school has the strongest effect on the decision to walk or cycle to/from school. The likelihood of walking to school decreases as household income, distances to school (or travel time to school) and the availability of car for private use increases. The results of the analysis conclude that students with lower income are more likely to walk or bike and girls are less likely to prefer biking to travelling by other modes than boys. In addition to the socioeconomic information of the respondents, perceptions of children safety have significant impact on school travel mode choice as well.

The likelihood of using school bus increases with household income when parent/guardians are full employed and cycling or walking to school increases with parental perceptions of neighbourhood safety and security of children while cycling to/from. The likelihood of using public transport (daladala) to school is more influenced by increases in distance of travelling to school and travel time, when parent/guardians are employed and can pay for public transport to school and children perceive daladala to be a safe mode of transport.

The implication of these findings is that planners and policymakers wishing to increase walking and cycling among children need to consider options that address distance constraints. Additionally, findings from the study give land use planners and transport professionals a better understanding of the various factors that affect children's choices of school travel mode. The results suggest that all school travel attributes should be considered during school location, however, the distance and travel safety attributes should be considered a priority.

The study has also shown that there is a positive preference of cycling to school as compared to car use. Since children can cycle to school the implications of land use and transportation decisions for areas around new and existing school locations should be considered with a view to improve road sidewalk cycle ways so as to enhance safety. It

can also be argued that in order to increase the number of school children who can use walking and cycling modes to school, long term strategies must use distance to school as a criterion in school location. In this case, efforts should be made to establish and improve both publicly and privately owned schools in every ward so as to reduce distances to schools. The result of the study can also be applicable for urban transportation planning to other areas with the same characteristics of the study area.

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