# A Study on Travel Mode Choice for Work Commuting in Dhaka City Using Structural Equation Modeling


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# INTRODUCTION

The four step travel model is a framework for determining transportation forecasts:

- Trip Generation
- Trip Distribution
- Mode Choice
- Trip Assignment

## Mode choice

Mode choice is usually an application of users' decision making process of choosing different modes for particular types of trips. The choice of mode is one of the most important classic models in transportation planning

Understanding mode choice is essential for addressing policy challenges like transit revenue, traffic congestion, and route planning. It informs strategies to optimize urban mobility, allocate space effectively, and improve traveler options, making it a cornerstone of transport planning and policy (Horowitz et al., 1986; Ortúzar & Willumsen, 2001).

# Problem Identification

The proportion of the road to the built-up area is hardly 7% compared with 25% recommended for a good city planning

- Increasing transports cause congestion
- Environmental problems-Air Pollution
- Traffic jam
- Lengthier travel time
- Reduce traffic speed (World Bank study shows that Dhaka’s average traffic speed has dropped from 21 km/h to 7 km/h)
- Work time loss.( Traffic jam eats up 3.2 million work hours per day)

# Objectives of the Study

The specific objectives of this research:

i. To identify the relationships among the major attributes that affect mode choice and trip chaining by structural equation modeling.

ii. To study the mode choice behavior and its contributing factor in Dhaka city.

# LITERATURE REVIEW

This chapter gives a brief overview of the travel behavior, trip chain and its factor that influence choice of travel mode, few common mode choice models.

## Travel behavior

Travel behavior represents the spaces and ways that people get around: how far they travel, where they go, by which modes, at which times, which whom, for what purposes. Socioeconomic factors — race, income, and gender — shape travel patterns and travel needs.

Human activities are not concentrated at one place, and there is a need to travel from one place to another place for their livelihoods. Demand for travel is a requirement. Except for certain recreational purposes, people do not ask for travel for their own account. Instead, they demand such daily activities as work, shopping and education; and travel allow them to achieve these activities (Meyer & Miller, 2001).

# Trip chain

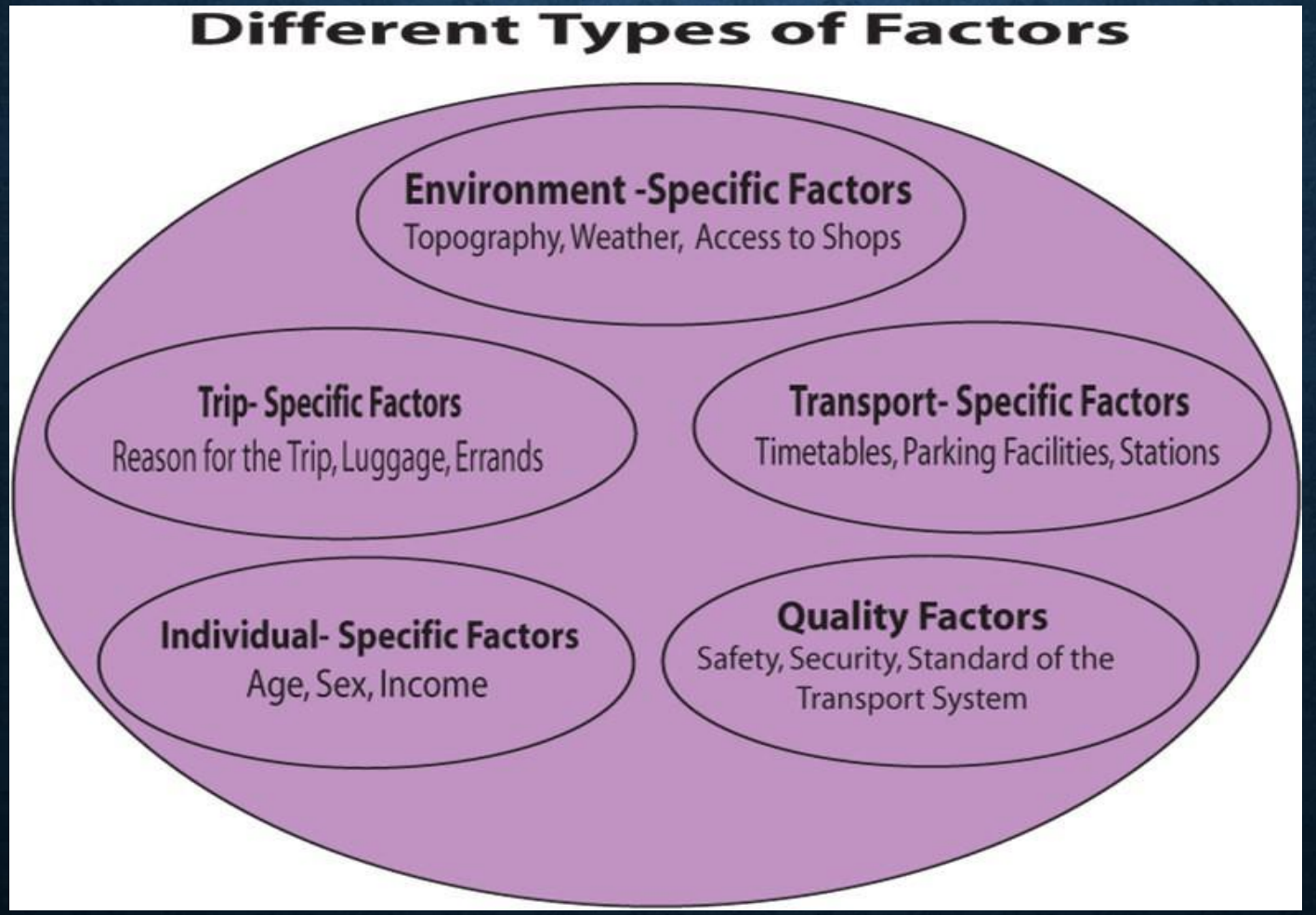
Trip chain may be defined as a sequence of trips that starts at home, involves visit one or more other places, and ends at home (Timmermans et al. 2003; Ye et al. 2007; Primerano et al. 2008). Lee et al. (2007) suggests that a trip chain comprises at least two out-of-home activities that are connected by travel after leaving home until returning home in a single 24-h day.

Trip chain may be classified into two categories:

- Simple chains: One stopover (e.g., home → shop → home).
- Complex chains: Multiple stops (e.g., home → work → shop → home).

Helps in forecasting travel demand, planning infrastructure, and designing policies.

# Factors that Influence Choice of Travel Mode



# Mode Choice Model

Discrete Choice Modeling

Random Utility Model (RUM)

Multinomial Probit Model

Multinomial Logit Model

Nested Logit Model

Structural Equation Modeling

## Structural Equation Modeling

1. Measurement Model
2. Structural Model

# Model Equation

**For exogenous latent variables:**

$$X=\Lambda x\ \eta +\delta$$

X: Vector of observed variables

η : Vector of exogenous latent variables.

δ: Measurement error for X.

Λx: Factor loading matrix (shows relationships between Xand ξ).

**For endogenous latent variables:**

$$Y=\Lambda y\eta+\epsilon$$

Y: Vector of observed variables.

η: Vector of endogenous latent variables.

Λy: Factor loading matrix (shows relationships between Y and η).

ϵ: Measurement error for Y.

# METHODOLOGY

The study used a two-step approach: data collection via a questionnaire survey and Structural Equation (SE) modeling. The survey, conducted at 14 locations in Dhaka in December 2022 (9:00 am–4:00 pm), gathered 1,000 responses on socio-economic details, trip chains, and trip characteristics. SE models were developed in STATA using trial and error, with parameter estimation at a 95% confidence level (t-value: 1.96). Structural Equation Modeling (SEM) requires large sample sizes, typically over 200. Its flexibility allows for analyzing complex relationships among various data types, though general guidelines are hard to establish. Suggested rules of thumb include minimum sample sizes of 100–200 (Boomsma) or 5–10 observations per parameter (Bentler and Chou). Factors like variable communality and sample size can influence model accuracy and fit. With 978 respondents, this study's sample size is deemed sufficient.

We Used secondary data for this study

# Field Survey Locations and Schedule

| Sl. No. | Date | Time | Location of Survey |
|---|---|---|---|
| 01. | 15/12/2022 | 10.00 am | Beside Orchard point, Anwar Khan Modern Medical College and Mirpur Road |
| 02. | 21/12/2022 | 12.00 pm | Beside Nilkhet Signal |
| 03. | 21/12/2022 | 11.00 am | Jigatola Bus Stand |
| 04. | 22/12/2022 | 12.30 pm | Beside keari plaza Dhanmondi-15 |
| 05. | 22/12/2022 | 10.30 am | Beside Panthapath Signal |
| 06. | 23/12/2022 | 12.30 pm | Beside Wasa Bhaban |
| 07. | 23/12/2022 | 2.00 pm | Beside Ananda Cinema Hall |
| 08. | 24/12/2022 | 10.15 am | Kalabagan Bus Stand |
| 09. | 24/12/2022 | 12.00 pm | Shukrabad/ Dhanmondi 32 number |
| 10. | 25/12/2022 | 9.30 am | Beside Mohammadpur Bus Stand |
| 11. | 25/12/2022 | 11.45 am | Beside Shyamoli Cinema Hall |
| 12. | 26/12/2022 | 9.30 am | Beside Sonargaon Hotel |
| 13. | 26/12/2022 | 11.10 am | Beside Asad gate Signal |
| 14. | 27/12/2022 | 10.00 am | Beside Gulshan 2 Circle |

# Questionnaire

**The questionnaire consisted of five parts:**

Demographic Information: Questions about respondents' sex, age, occupation, education, marital status, family details, and vehicle availability.
Work Characteristics: Questions on family income, daily working hours, and parking availability at the workplace.
Trip Characteristics: Questions on waiting time, travel time, trip distance, and modal changes.
Trip Chains: Divided into two categories—working days and non-working days.
Quality of Service: Questions on travel mode, comfort level, and monthly travel expenses.

The respondents, aged 20 to 60 years, were Dhaka city residents with experience using various transport modes. This age range was selected for their routine commuting behavior and consistent primary mode of travel. Questionnaires were completed on-site, and the data analysis is presented in Chapter Four. These data were used to develop and identify the best-fitting models.

# Data analysis

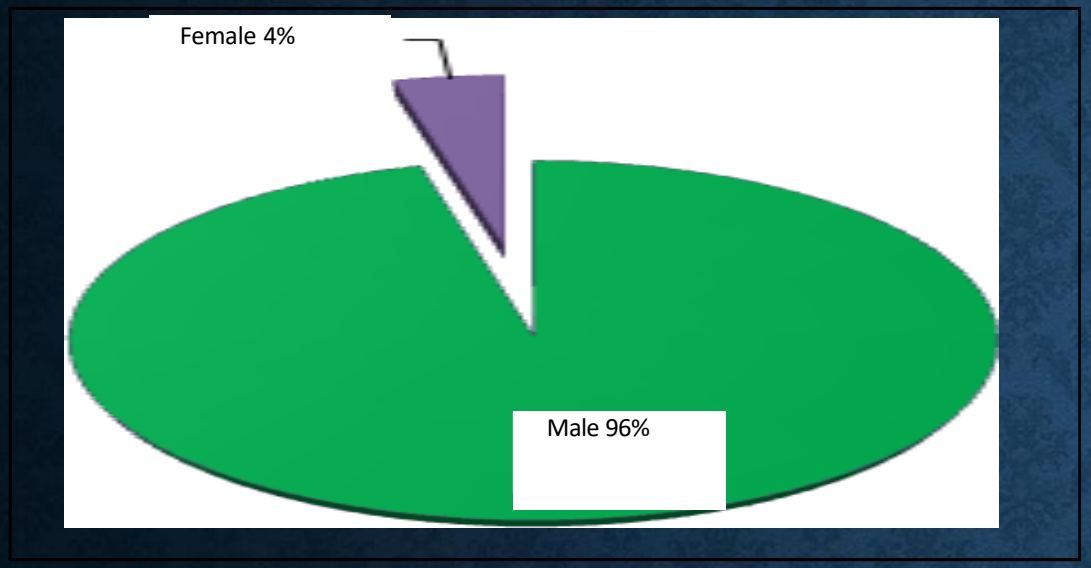
The study interviewed 1,000 trip makers across 14 locations in Dhaka, with 978 valid responses analyzed. Initial data analysis was conducted in Excel, followed by developing models to explore the relationship between mode choice and trip chaining for work trips. The goal was to identify influential variables and determine the optimal model representing the actual scenario.

Modeling was done using STATA 13, which applies the Maximum Likelihood (ML) estimation method. Multiple models were developed to assess goodness of fit using measures like SRMR, RMSEA, TLI, and CFI. RMSEA values $\leq 0.05$ indicate very good fit, while $\leq 0.08$ is reasonable. SRMR values $<0.10$ and CFI values close to 1.0 also signify good fit. The best-fitting model was identified as the most

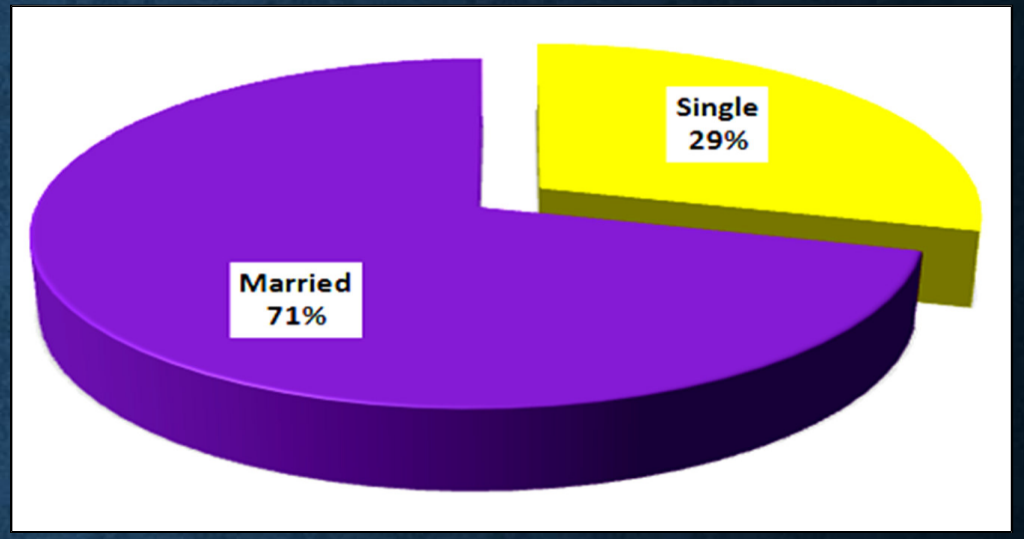
# General information of respondents

| Features | Statistics |
|---|---|
| Gender | Male (96%), Female (4%) |
| Marital status | Married (71%), Single (29%) |
| Age | 20~30 Years old (30%), 31~40 Years old (43%), Above 40 years old (27%), |
| Educational qualification | Doctorate (1%), Graduate (63%), Elementary (27%),Below elementary ((7%), no education (2%) |
| Number of household children | None (35%), One (32%), Two (28%), Three (4%), Above three (1%) |
| Number of household adults | One (8%), Two (42%), Three (25%), Above three (26%) |
| Number of family members | One (6%), Two (6%), Three (24%), Four (30%), Five or more (34%) |
| Occupation | Service holder (73%), Business (23%), Other (4%) |
| Working hour per day | 3~5 (0%), 5~7 (5%), 7~9 (55%), above 9 (40%) |
| Monthly family income | 5000~10000Tk. (1%),10000~20000Tk. (20%), 20000~40000 Tk. (43%), >400000 Tk. (36%) |
| Number of house hold motorized vehicle | None (69%), One (26%), Two (5%) |
| Monthly household travel cost | <500 Tk (9%), 500~2000 Tk. (19%), 3000~5000 Tk. (38%), 6000~10000 Tk. (23%), > 10000 Tk. (11%) |

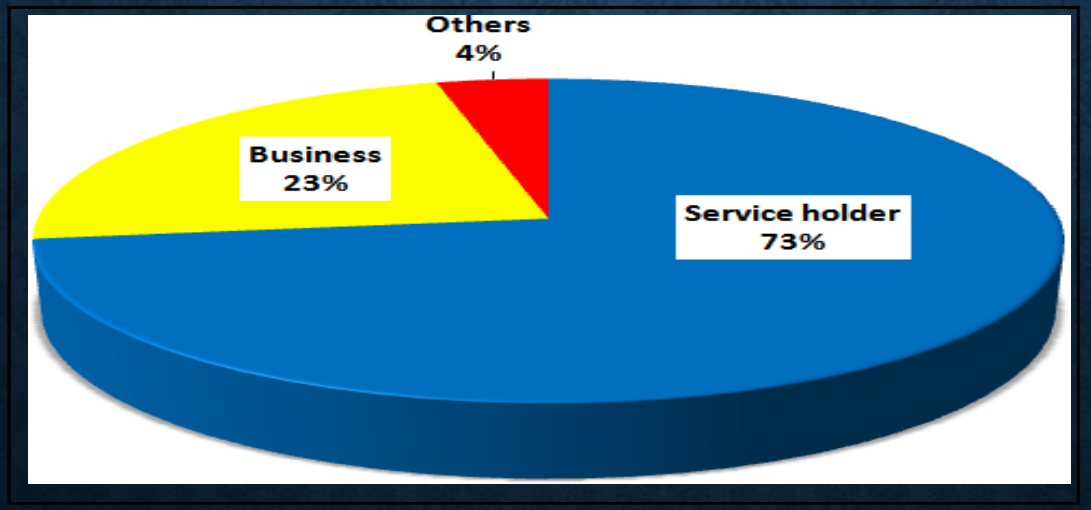
# Demographic



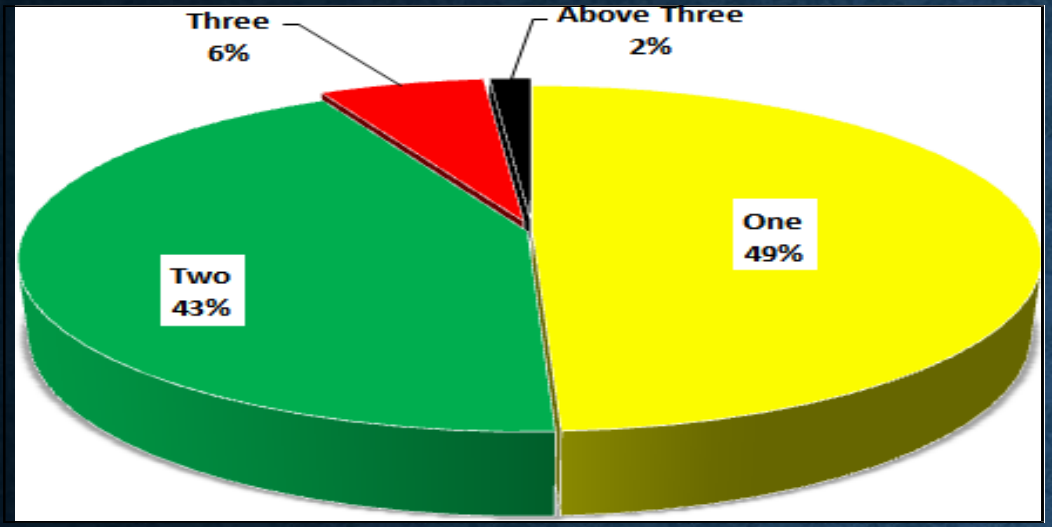

Gender status of respondents



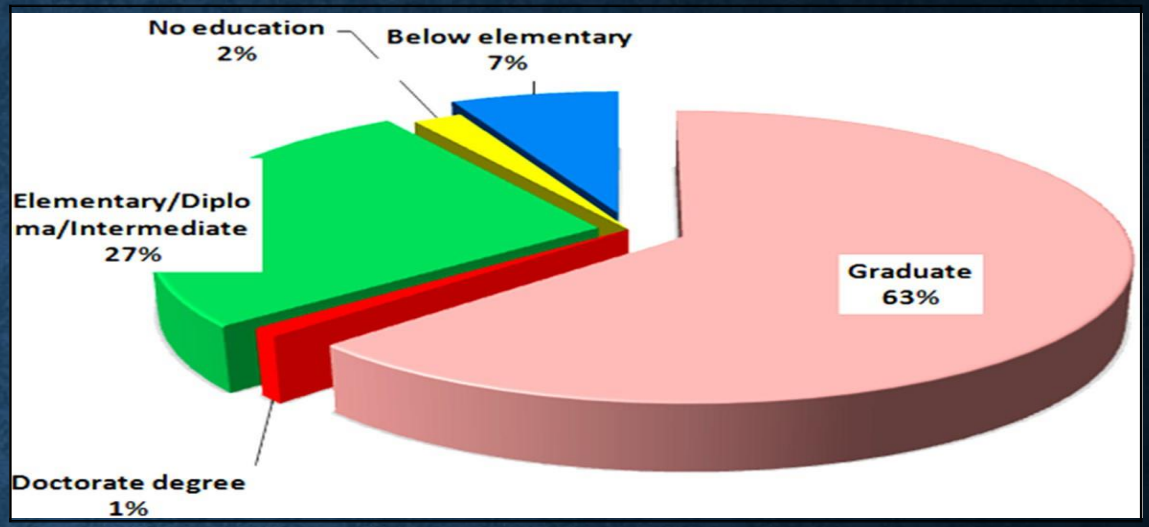

Marital status of respondents



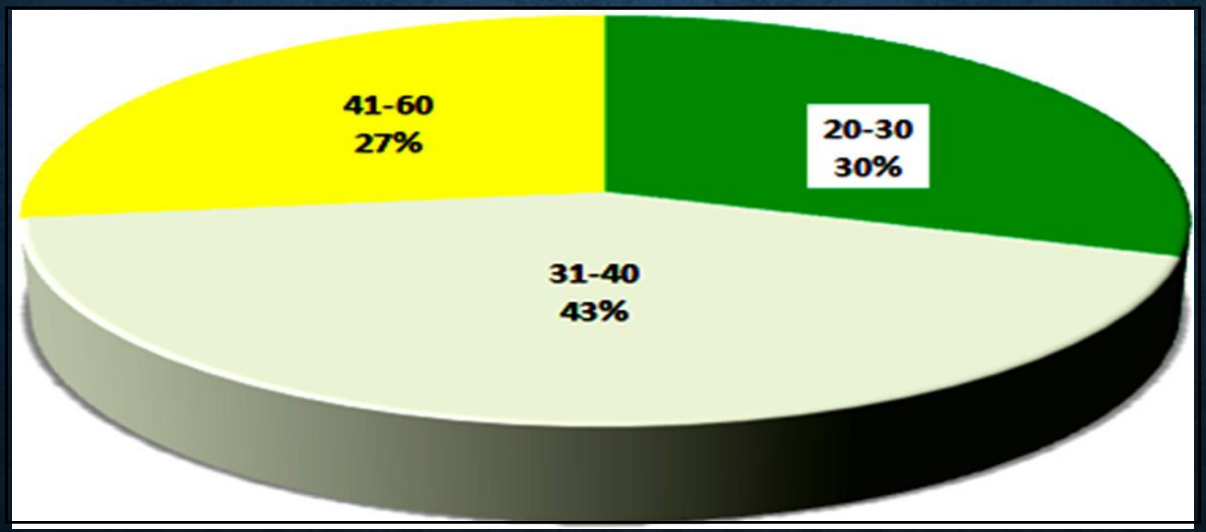

Occupation of the respondents



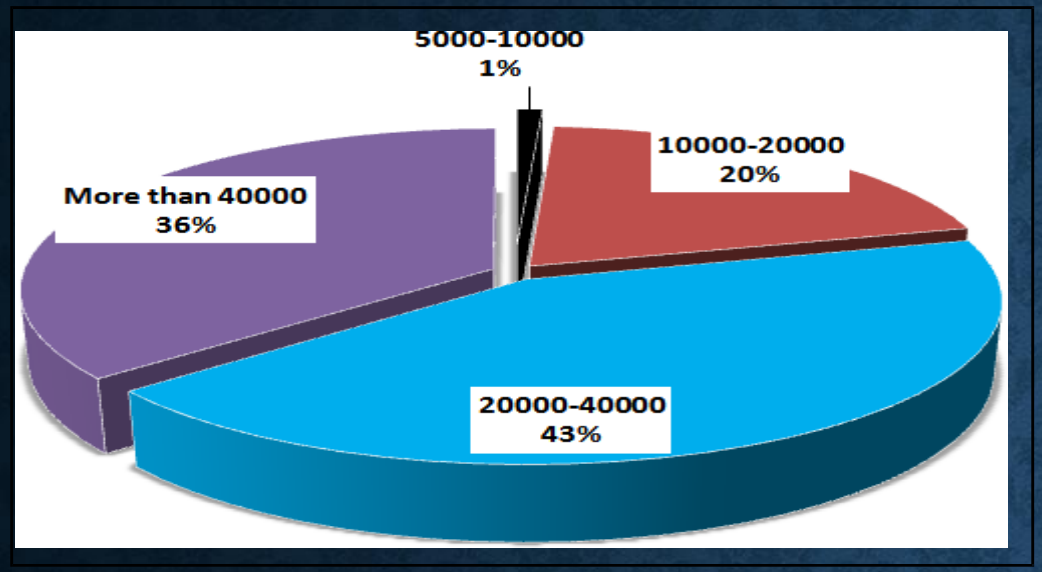

Number of household children



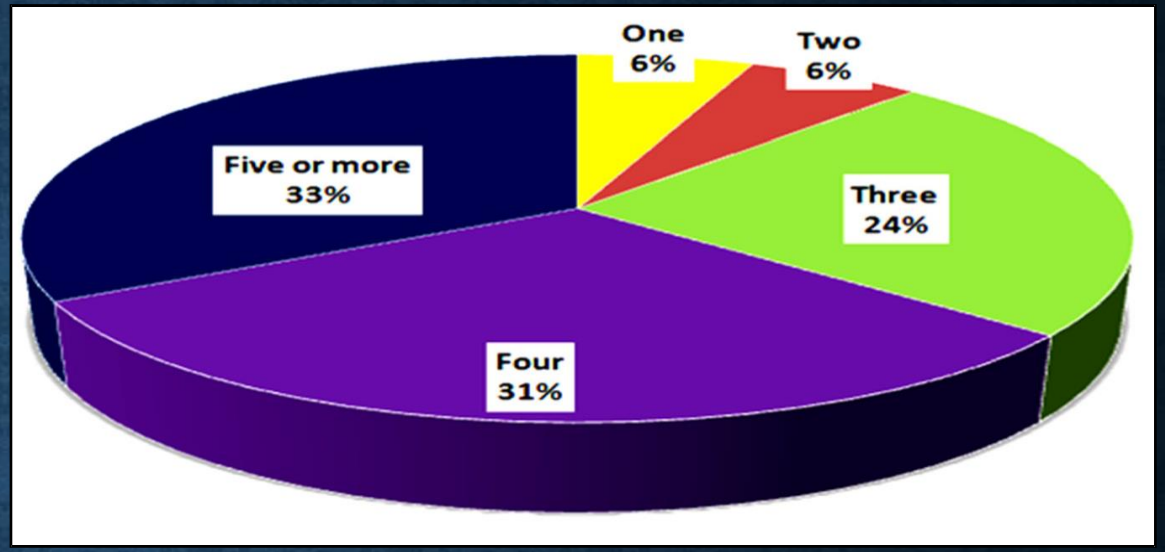

Educational qualification of respondents



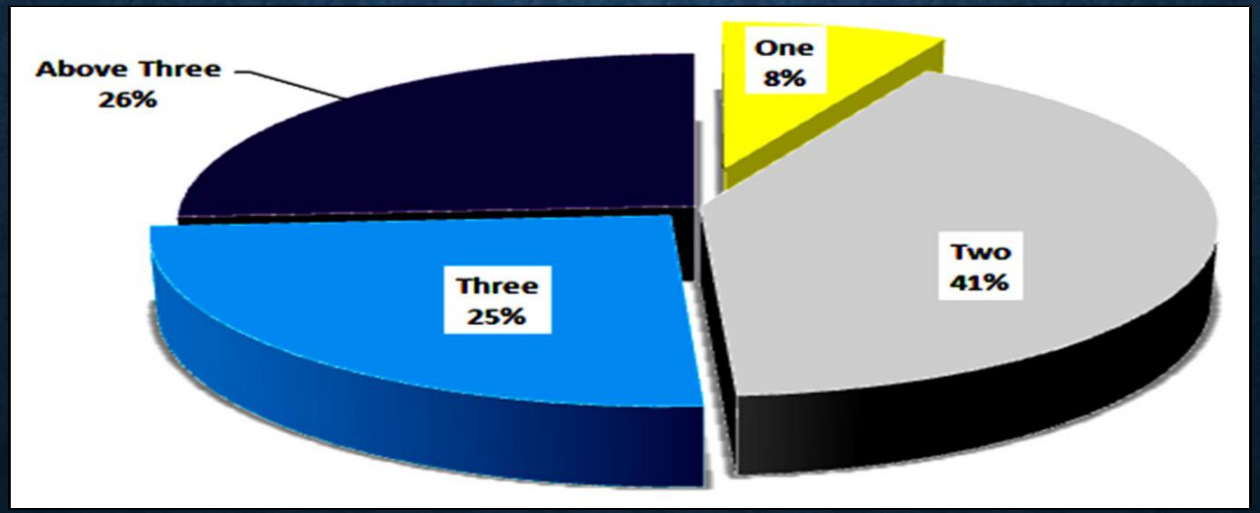

Age of respondents



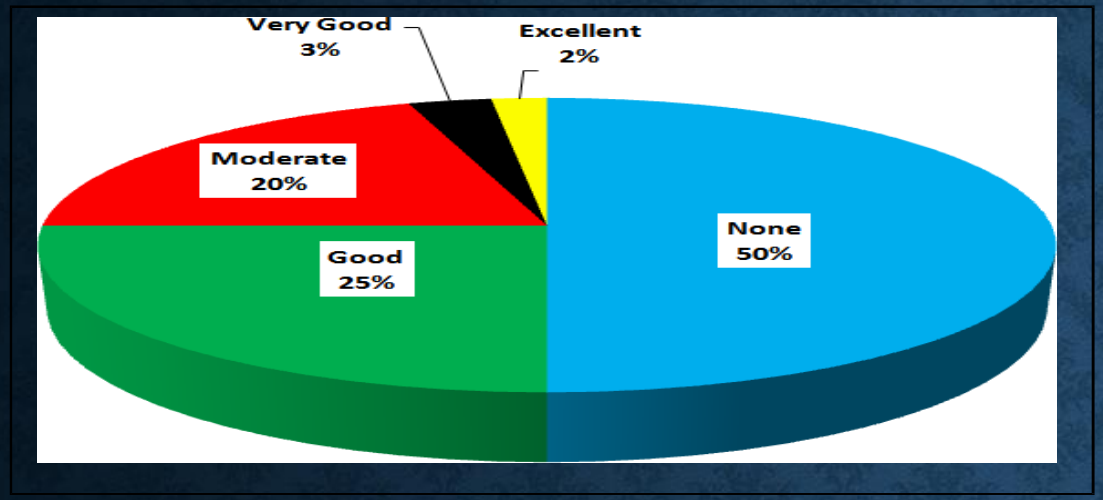

Monthly family income of respondents



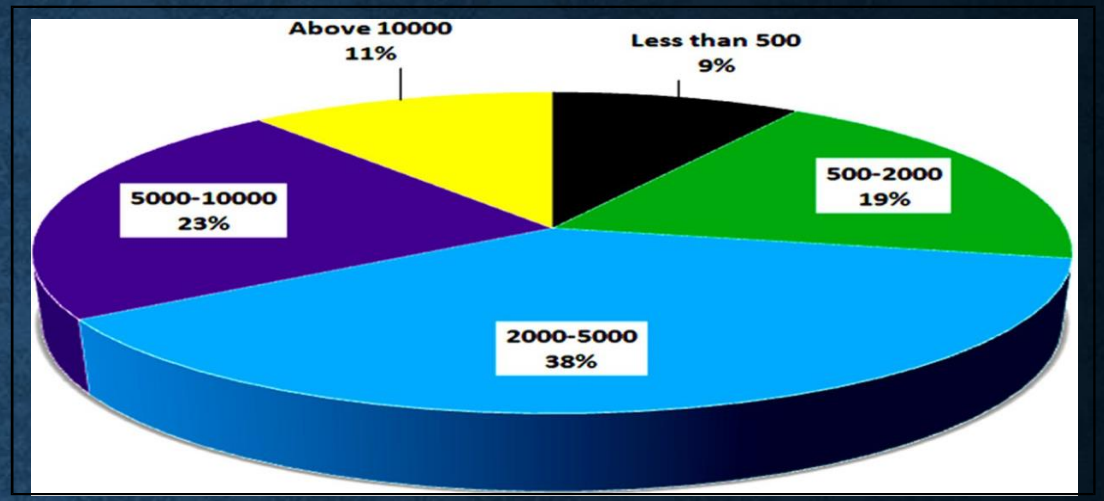

Number of family member



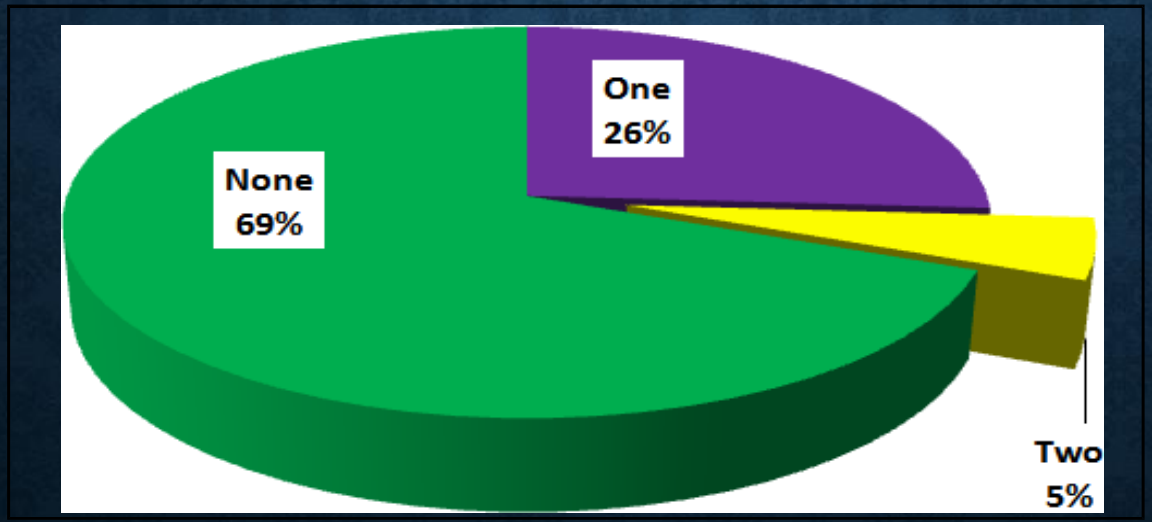

Number of household adults



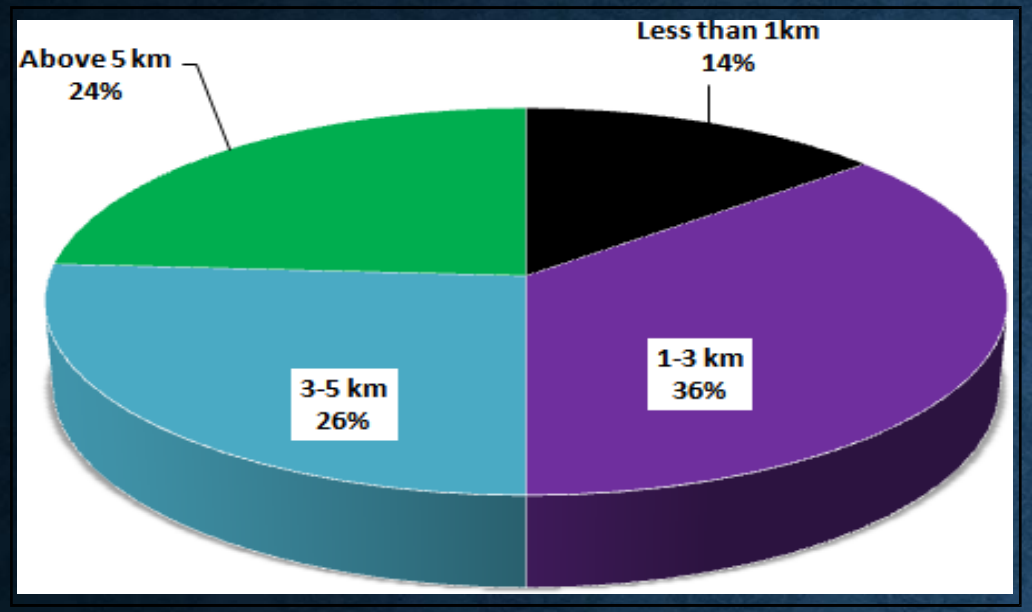

Parking availability at work place



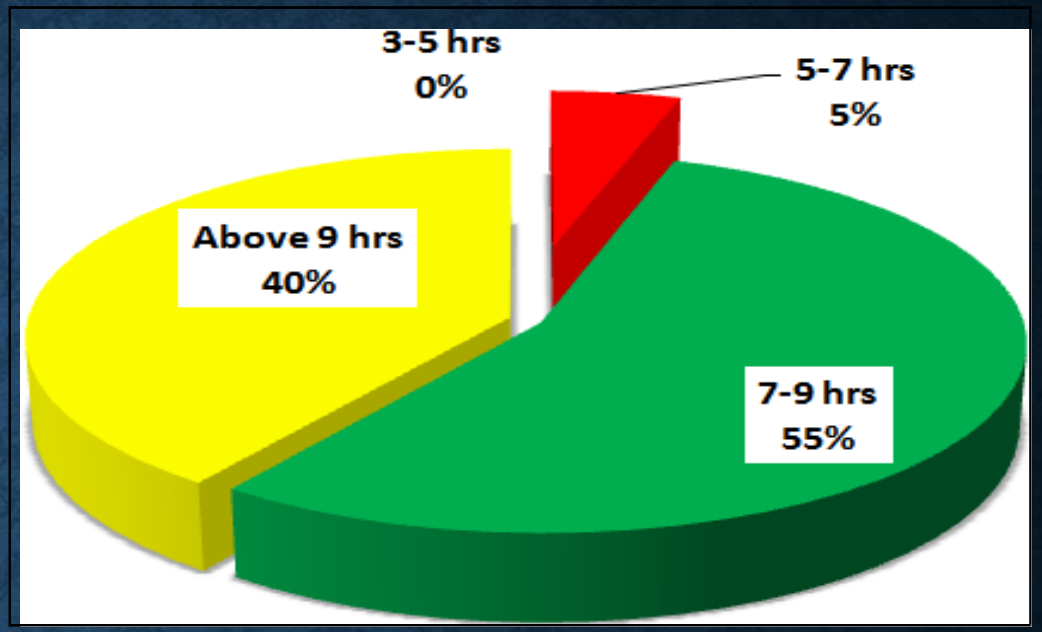

Monthly household travel expenditure



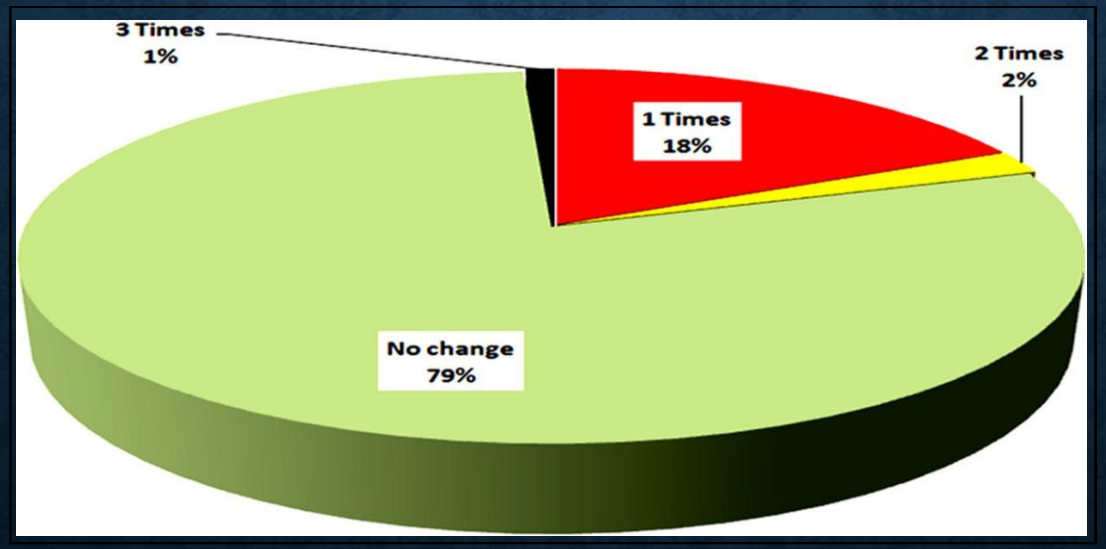

Number of household motorized vehicle




Home to work trip distance of respondents



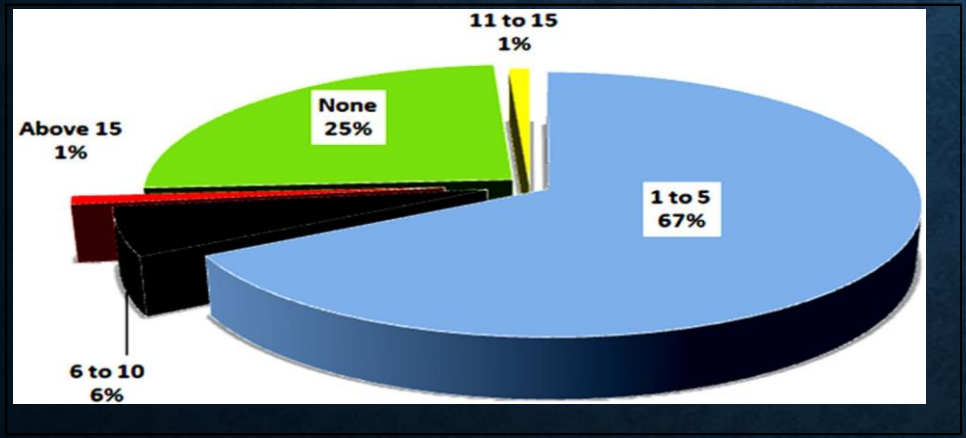

Working hour per day



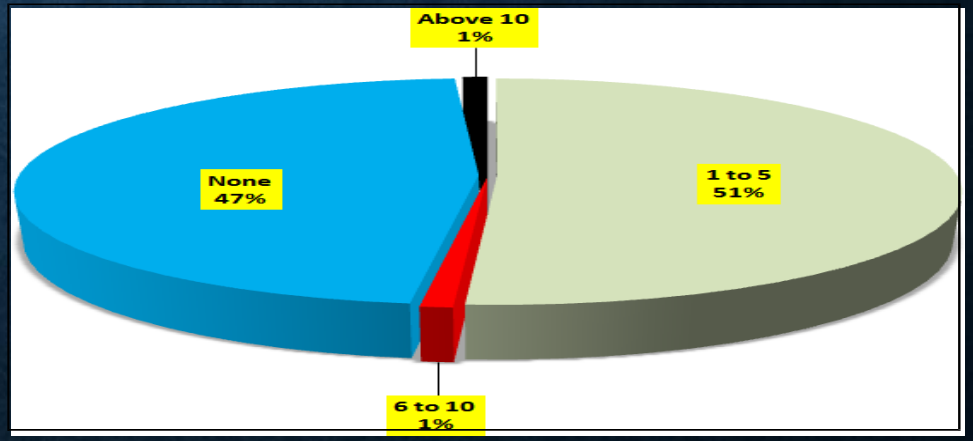

Percentage of changing mode

# Trip chain in work related days

| Trip Chain | Number of trip chain made by respondents | | | | |
|---|---|---|---|---|---|
| | 1 to 5 days | 6 to 10 days | 11 to 15 days | Above 15 days | Percentage |
| 1. h-w-(-w-)-h | 20 | 30 | 41 | 829 | 50% |
| 2. h-nw-w-(-w-)-nw-h | 158 | 56 | 19 | 32 | 14% |
| 3. h-w(-w-)-nw-h | 204 | 168 | 86 | 28 | 26% |
| 4. h-w-(-w-)nw-nw-h | 27 | 3 | 6 | | 2% |
| 5. h-w(-w-)-nw-nw-(-nw-)-h | 11 | 1 | 1 | | 1% |
| 6. h-nw-w(-w-)-h | 15 | 3 | | 18 | 2% |
| 7. h-nw-(-nw-)-w(-w-)-h | | 1 | 1 | | 0 |
| 8. Others (multiple non-work stops from home to work journey and from work to home journey not covered in trip chain pattern 1-7) | 32 | 16 | 5 | 30 | 5% |




h-nw-h trip chain within a month

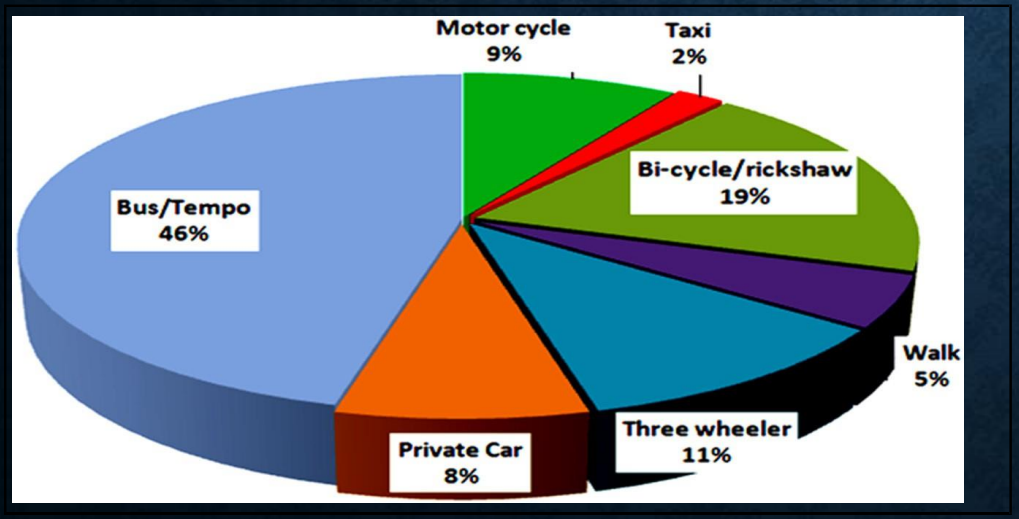


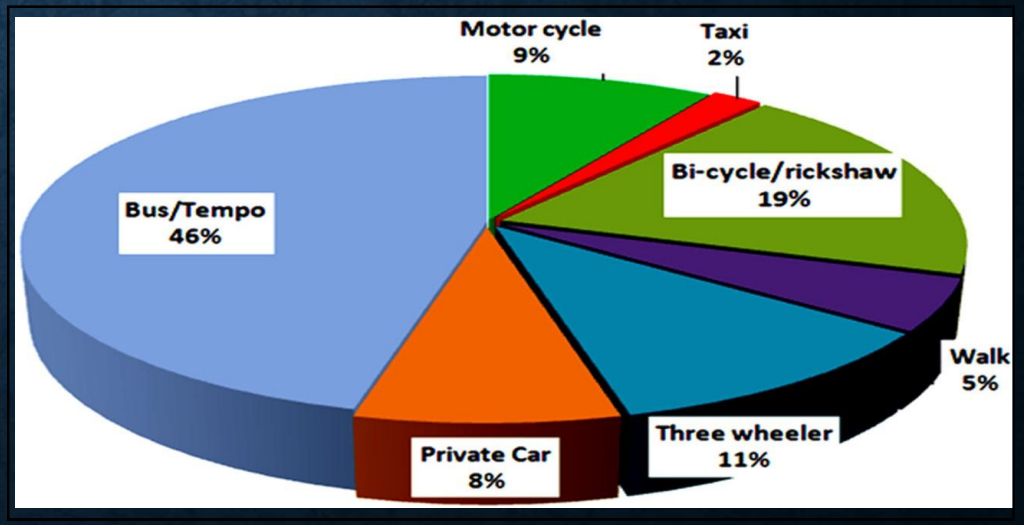

h-nw-(-nw)-h trip chain within a month

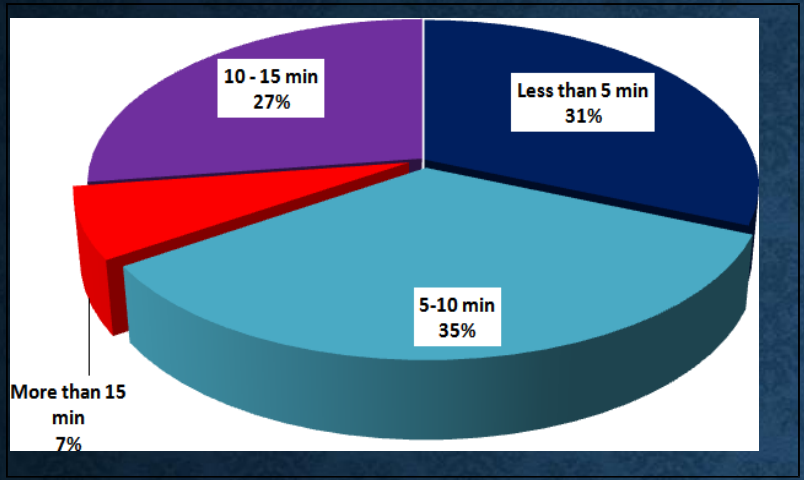
# Mode of Travel within a month

| Mode of Travel | How many times within a month you use | | | | |
|---|---|---|---|---|---|
| | 1 to 5 days | 6 to 10 days | 11 to 15 days | Above 15 days | Percentage |
| **Bus/Tempo** | 29 | 17 | 23 | 607 | **46%** |
| **Three wheeler** | 76 | 33 | 20 | 32 | **11%** |
| **Private car** | 3 | 2 | 3 | 114 | **8%** |
| **Taxi** | 26 | 5 | 1 | 3 | **2%** |
| **Motor cycle** | 4 | 2 | 8 | 121 | **9%** |
| **Bi-cycle/Rickshaw** | 115 | 63 | 24 | 85 | **19%** |
| **Walk** | **18** | **9** | **4** | **40** | **5%** |

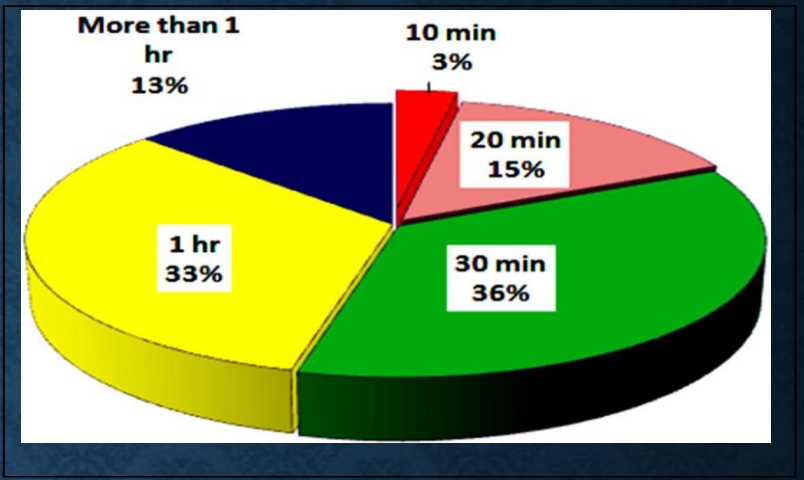
## Mode of Travel use in a month



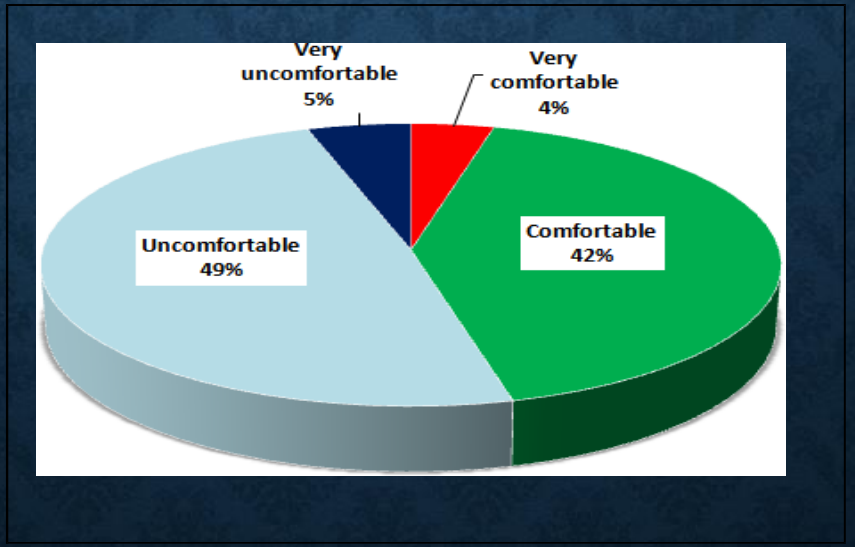






Waiting time of respondents




In vehicle travel time of respondents




Comfort level of respondents

# MODELING AND RESULT ANALYSIS

## Attributes and their input in the models

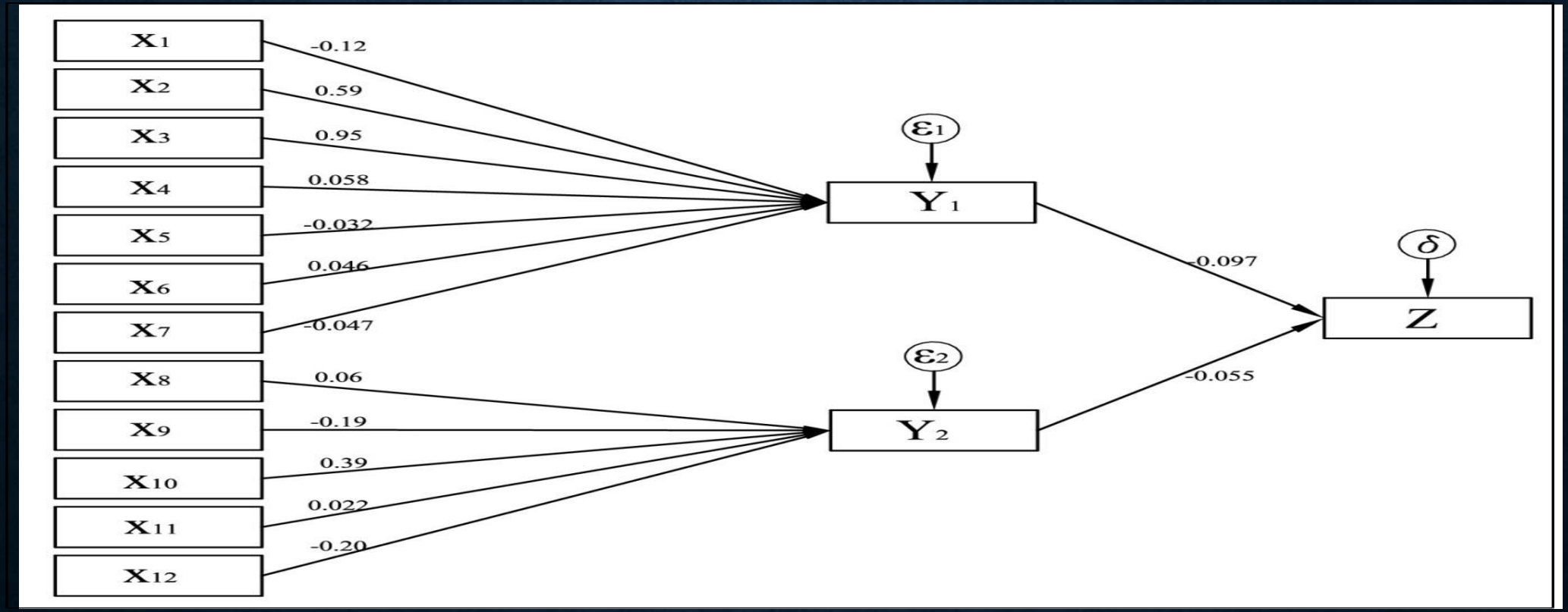
| Item no | Description | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Type | Notation | Type | Notation | Type | Notation | Type | **Notation** |
| **1** | Parking availability | Ex. | X1 | Ex. | X1 | En. | y 1 | En. | **y1** |
| **2** | Trip distance | Ex. | X2 | Ex. | X2 | En. | y 2 | En. | **y 2** |
| **3** | Change of mode | P. | Z | P. | Z | En. | y 3 | En. | **y 3** |
| **4** | Simple home to work-work to home trip | Ex. | X4 | Ex. | X3 | En. | y 4 | En. | **y 4** |
| **5** | One non-work from home to work and one non-work stop from work to home trip | Ex. | X5 | Ex. | X4 | En. | y 5 | En. | **y 5** |
| **6** | No non-work from home to work but one non-work stop from work to home trip | Ex. | X6 | Ex. | X5 | Ex. | y 6 | En. | **y 6** |
| **7** | No non-work from home to work but more than two non- work stop from work to home trip | Ex. | X7 | Ex. | X6 | En. | y15 | En. | **y 13** |
| **8** | Travel by bus/tempo | Ex. | X10 | Ex. | X7 | En. | y 14 | En. | **y 7** |
| **9** | Travel by bicycle/rickshaw | Ex. | X8 | Ex. | X10 | En. | y 10 | En. | **y 10** |
| **10** | Travel by private car | Ex. | X12 | Ex. | X8 | En. | y 13 | En. | **y 8** |
| **11** | Travel by taxi | Ex. | X11 | N/A | N/A | En. | y 12 | N/A | **N/A** |
| **12** | Travel by motor cycle | Ex. | X9 | Ex. | X9 | En. | y11 | En. | **y 9** |
| **13** | Waiting time at the station | En. | Y2 | En. | Y1 | En. | y 9 | En. | **y 11** |
| **14** | Time taken to reach the destination | En. | Y1 | En. | Y2 | En. | y 8 | En. | **y 12** |
| **15** | Comfort level of the mode | Ex. | X3 | En. | Y3 | En. | y 7 | En. | **y 14** |
| **16** | Trip Characteristics | N/A | N/A | N/A | N/A | Lt. | η1 | N/A | **N/A** |
| **17** | Trip chain of work related days | N/A | N/A | N/A | N/A | Lt. | η2 | N/A | **N/A** |
| **18** | Trip chain of non-work related days | N/A | N/A | N/A | N/A | Lt. | η3 | N/A | **N/A** |
| **19** | Trip behavior | N/A | N/A | Lt. | η | N/A | N/A | Lt. | **η1** |
| **20** | **Trip chain** | **N/A** | **N/A** | **N/A** | **N/A** | **N/A** | **N/A** | **Lt.** | **η2** |

Ex. = Exogenous variables; En. = Endogenous variables; Lt. =Latent variables; N/A= Not applied in this model; P. = Overall Perceived variable

**Development of Model 1 (M1):**

Model 1 (M1) examines two key variables: **Time Taken to Reach Destination ($Y_1$)** and **Waiting Time ($Y_2$)**. Despite expectations, "Time Taken to Reach Destination" negatively impacts mode choice (-0.097), likely due to Dhaka's traffic congestion, where cost is prioritized over time. Other factors like "Parking availability" and "Waiting time" also negatively influence mode choice, while variables such as "Trip distance" and "Comfort level" positively impact it.

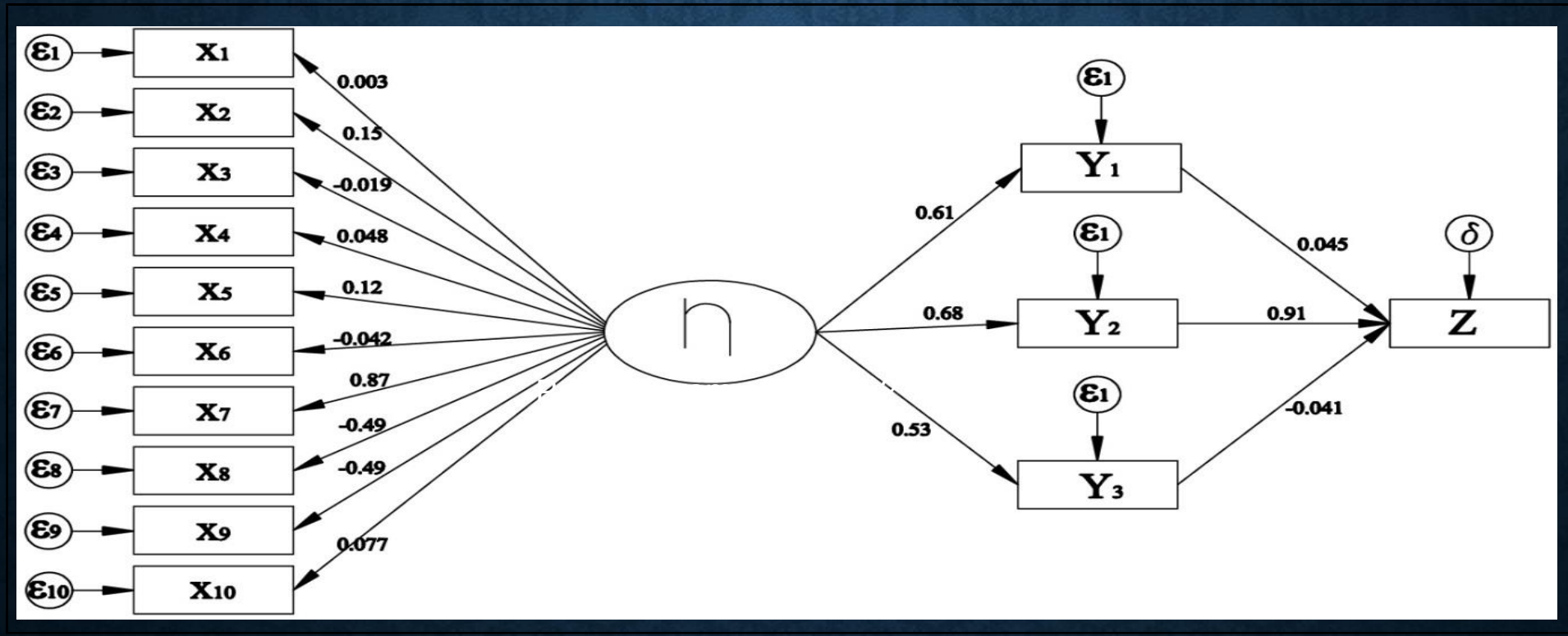
However, M1 has poor fit indices (CFI: 0.817, RMSEA: 0.066, SRMR: 0.051), showing it inadequately explains mode choice.




**Path diagram of model 1**

# Development of Model 2 (M2)

Model 2 (M2) introduces **Trip Behavior (η)** as a latent variable, improving mode choice analysis. **Waiting Time** and **Time to Reach Destination** positively influence mode change, while **Comfort Level** negatively affects it, which is unexpected. Other factors like **Parking Availability** and **Trip Distance** positively impact trip behavior, while **Private Car** and **Motorcycle** have a negative influence. M2 shows good fit indices (CFI = 1.00, RMSEA = 0.000, SRMR = 0.012), leading to the development of Model 3 (M3).




**Path diagram of model 2**

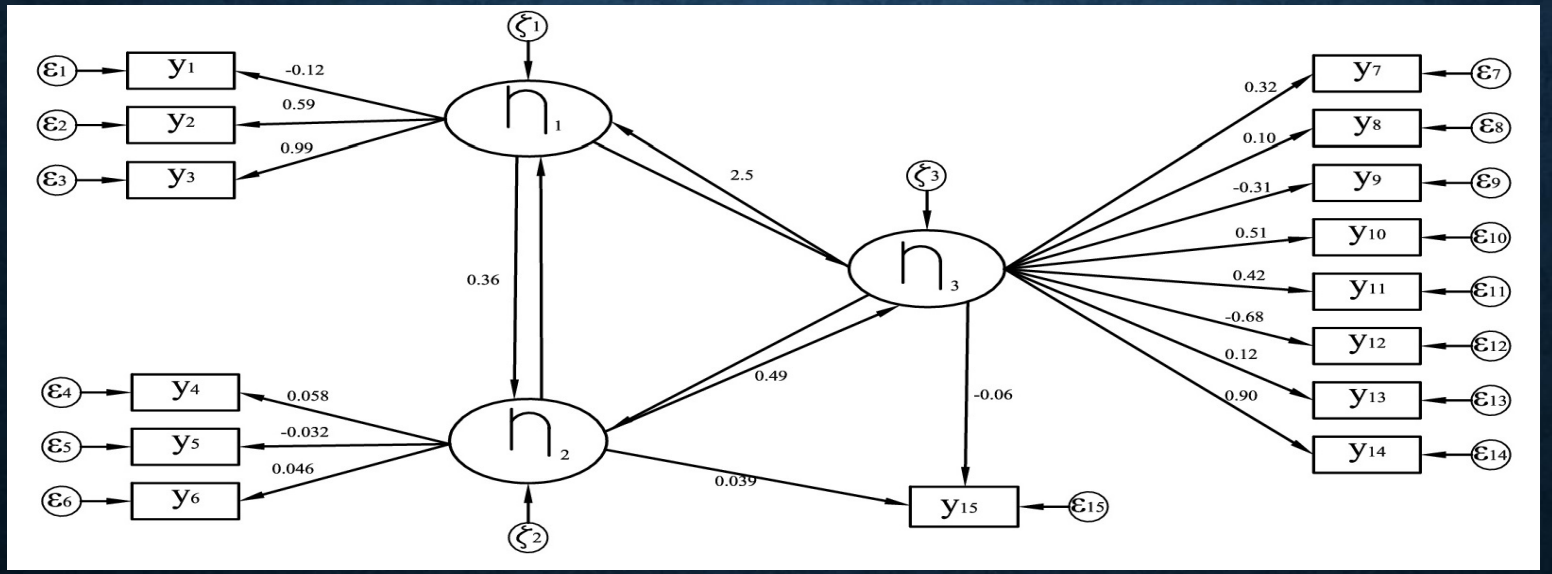
# Development of Model 3 (M3)

Model 3 introduces three latent variables: Trip Characteristics ($\eta_1$), Trip Chain of Work-Related Days ($\eta_2$), and Trip Chain of Non-Work-Related Days ($\eta_3$), with strong correlations between them.

Key Findings:

- $\eta_1$: Negatively impacts Parking Availability and positively influences Trip Distance and Mode Change.
- $\eta_2$: Positively affects certain trip patterns, but negatively impacts others.
- $\eta_3$: Positively impacts Comfort Level, but unexpectedly negatively affects Waiting Time.

M3 shows strong fit indices (CFI = 1.00, RMSEA = 0.000, SRMR = 0.000), indicating a good model.




Path diagram of model 3

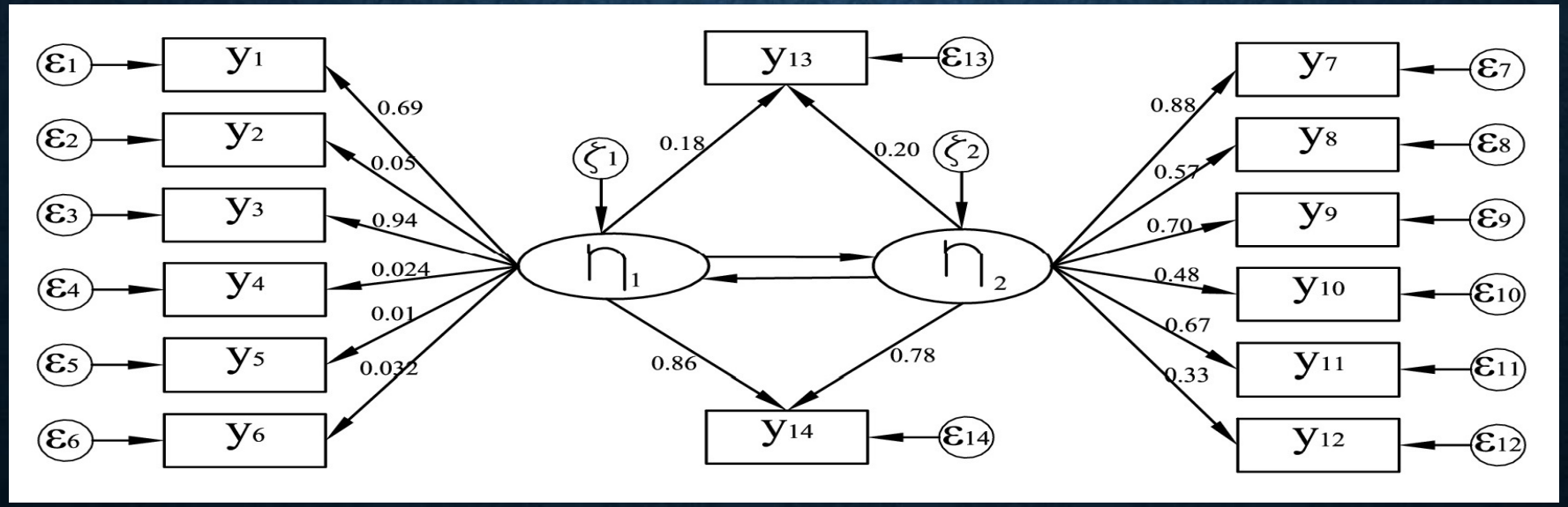
# Development of Model 4 (M4):

Model 4: introduces two latent variables: **Trip Behavior ($\eta_1$)** and **Trip Chain ($\eta_2$)**, which significantly influence each other. **Trip Behavior** is positively influenced by **Parking Availability**, **Trip Distance**, and **Mode Change**, while **Trip Chain** is influenced by trip related factors. The correlation between the two latent variables is strong (coefficient: 2.5).

**Model Fit:**

- **CFI**: 1.00
- **RMSEA**: 0.000
- **SRMR**: 0.000

Model 4 has perfect fit indices, making it the best model among the four.




Path diagram of model 4

# Estimated parameters for different models

| Observed Variables | Model 1 estimates | Model 2 estimates | Model 3 estimates | Model 4 estimates |
|---|---|---|---|---|
| Parking availability | -.12(0.00) | .0032(.650) | -.12(.169) | **.69(.745)** |
| Trip distance | .59(0.00) | .15(.001) | 0.59(.244) | **.05(0.00)** |
| Change of mode | .095(0.00) | .98(.224) | 0.99(.198) | **.94(.177)** |
| Simple home to work-work to home trip | .058(0.00) | -.019(.580) | 0.058(.130) | **.024(.096)** |
| One non-work from home to work and one non-work stop from work to home trip | -.032(.204) | .048(0.00) | -0.032(.136) | **.01(.0125)** |
| No non-work from home to work but one non-work stop from work to home trip | .046(.065) | .12(0.00) | .0.046(.194) | **.032(.003)** |
| No non-work from home to work but more than two non- work stop from work to home trip | -.047(.060) | -.042(0.00) | -0.06(0.00)<br>0.039(.306) | **.18(.004)**<br>**.20(0.00)** |
| Travel by bus/tempo | .39(0.00) | .87(0.00) | .9(0.00) | **.88(0.00)** |
| Travel by bicycle/rickshaw | .06(.030) | .077(0.00) | .51(0.00) | **.48(0.00)** |
| Travel by private car | -.2(0.00) | -.49(0.00) | .12(0.00) | **.57(0.00)** |
| Travel by taxi | .022(0.030) | | -.68(0.00) | |
| Travel by motor cycle | -.19(0.00) | -.49(0.00) | .42(0.00) | **.7(0.00)** |
| Waiting time at the station | -.055(.004) | .045(.192) | -.31(0.00) | **.67(0.00)** |
| Time taken to reach the destination | -.097(0.00) | .91(0.00) | .1(0.00) | **.33(0.00)** |
| Comfort level of the mode | .987(0.00) | -.041(0.00) | .32(.003) | **.86(0.00)**<br>**.78(0.00)** |
| **Latent Variables** | | | | |
| Trip Characteristics | - | - | .992 | - |
| Trip chain of work related days | - | - | .258 | - |
| Trip chain of non-work related days | - | - | .611 | - |
| Trip Behavior | - | .71 | - | **.0058** |
| Trip chain | - | - | - | **.068** |

Co-efficient of influencing variable are shown in Italic number.

## Fit indices to determine the goodness of fit of different model

| Fit Indices | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Absolute fit indices | | | | |
| Root mean square of error approximation (RMSEA) | 0.092 | 0.00 | 0.00 | 0.00 |
| Standardized root mean square residual (SRMR) | 0.040 | 0.012 | 0.00 | 0.00 |
| Incremental fit indices | | | | |
| Comparative fit index (CFI) | 0.823 | 1.00 | 1.00 | 1.00 |
| Tucker-Lewis index (TLI) | 0.725 | 0.758 | 0.824 | 0.95 |
| Parsimony fit indices | | | | |
| Akaike's information criterion (AIC) | 34468.13 | 35906.74 | 35783.13 | 35872.14 |

# CONCLUSION AND RECOMMENDATIONS

## General

This study used structural equation modeling (SEM) to analyze mode choice behavior in Dhaka, identifying key factors influencing travel modes and trip chaining. Among the models:

- **Model 1**:Discuss **Time Taken to Reach Destination** and **Waiting Time** .
- **Model 2:**Highlighted **Time to Reach Destination** and **Trip Distance** as key factors.
- **Model 3**: Introduced three latent variables, with **Travel by Bus/Tempo** as the most significant attribute.
- **Model 4**: Showed all variables positively influencing latent variables, with **Travel by Bus/Tempo**, **Comfort Level**, and **Waiting Time** being most critical.

Mode choice negatively correlates with **Waiting Time** and **Travel Time**, while simpler trip chains positively influence decisions. These insights help optimize transportation planning in developing countries.

# Summary

This study analyzed factors influencing travel mode choice for work trips in Dhaka, using data from 1,000 respondents. Key findings:

- **Demographics**: Most were male, service holders, aged 31–40, with 46% using buses or tempos and 69% lacking motorized vehicles.
- **Influential Factors**: Comfort level, waiting time, parking availability, income, and travel expenses significantly affect mode choice.
- **Model Insights**: The best SEM model identified two latent variables—trip chain and trip behavior—showing strong positive correlations and excellent fit indices.

The study highlights the need for better transport systems to improve user satisfaction.

# Limitations of the Study

i. A key limitation of this study is the small sample size, as only 1,000 respondents participated, which is relatively small compared to the total number of users.

ii. The survey data is taken from 14 locations of Dhaka city. This obviously does not represent equal proportion of socio-economic groups in the study area.

iii. Collected data may not represent users' actual choice of travel mode at pick hour in Dhaka city

iv. The survey was conducted in open areas or at road junctions, which may not accurately reflect the demographic profile of respondents across Dhaka city. Additionally, due to safety concerns, residents of Dhaka city are often reluctant to participate in household surveys.

# Recommendations for Future Study

Following are the few recommendations for future research study:

i. The most suitable model (model-4) could be valuable for future transportation planning in Dhaka City.

ii. A significant research opportunity with the mode choice model proposed in this study is to use it as a sub-model in the development of a travel demand model for the future.

iii. Route-specific and user-specific mode choice attributes can be further analyzed in detail using the same approach.

iv. Various statistical models can be developed in the future to gain a deeper understanding of mode choice behavior for work trips.


thank
you