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INTEGRATED APPROACH FOR INCREASING PUBLIC TRANSPORT SHARE IN MEDIUM-SIZE CITIES

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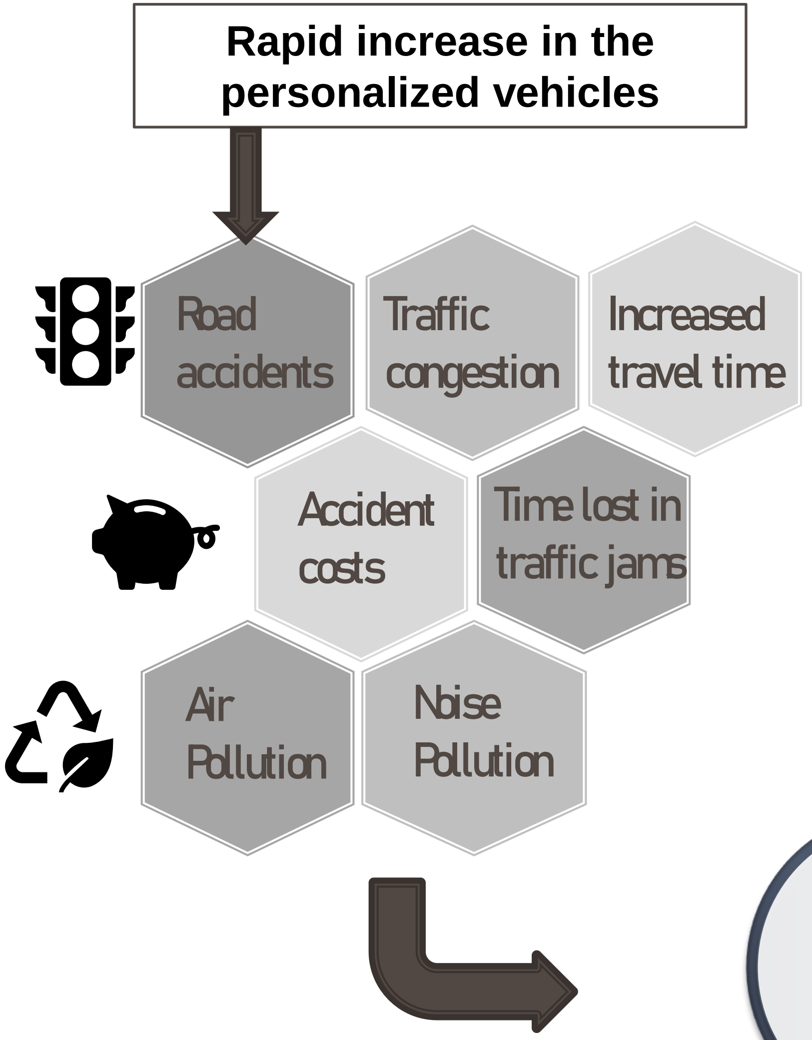
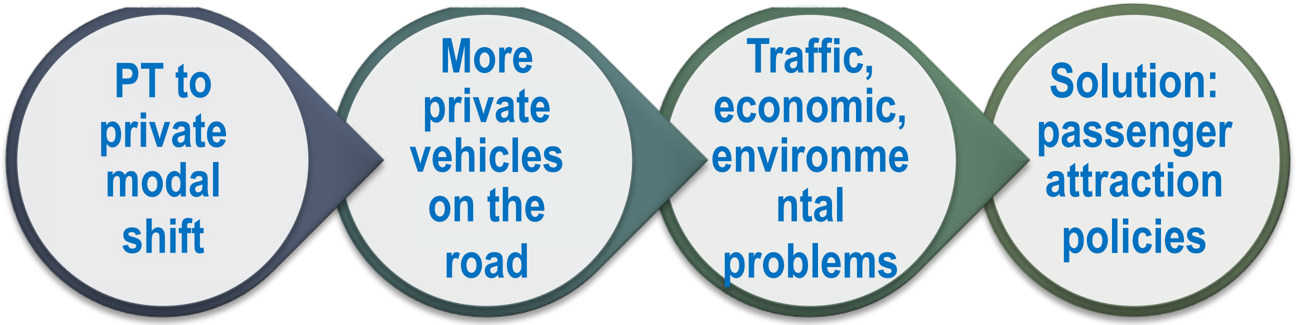
Introduction



- India's urban population is expanding on average at a rate of about 3% annually.
- An enormous surge in the private vehicle population is a matter of major concern in the existing traffic scenario on the urban road network in India
- Many nations have so far taken steps to reduce the use of private vehicles in favour of public transportation.
- Policy interventions are an effective way to influence the decision-making of the public and to discourage the use of private vehicle users by encouraging greater utilization of public transport



Literature review

No	Author	Summary /Findings
1	Abou-Zeid et al. (2012)	Examined the effect of a temporal change in the mode of travel to work on travel happiness and mode switching. Studies are also conducted on the modelling and policy significance of various well-being metrics.
2	Santos et al. (2013)	Observed that promotional measures such as lower public transport charges and increased bus frequency would likely increase public transport patronage.
3	Ashalatha et al. (2013)	Used an MNL model to study commuter’s mode choice decisions in Thiruvananthapuram city. According to the study, most commuters shifted from public transit to private vehicles owing to increased journey duration and cost.
4	Atasoy et al. (2013)	Developed a latent variable enriched mode choice model that considered environmental concerns as well as passengers’ overall attitude towards public transportation.
5	Seetharaman et al. (2009)	Compared mode choice modelling using logit & fuzzy logic techniques in the city of Ludhiana.
6	Padma et al. (2024)	Developed a structural equation modelling (SEM) system, owing to its essential strength in handling idle and unproductive connections.
7	Devika et al. (2020)	Developed mode choice models to detect the variables affecting the adoption of public and private modes on the basis of the Theory of Planned Behaviour (TPB).

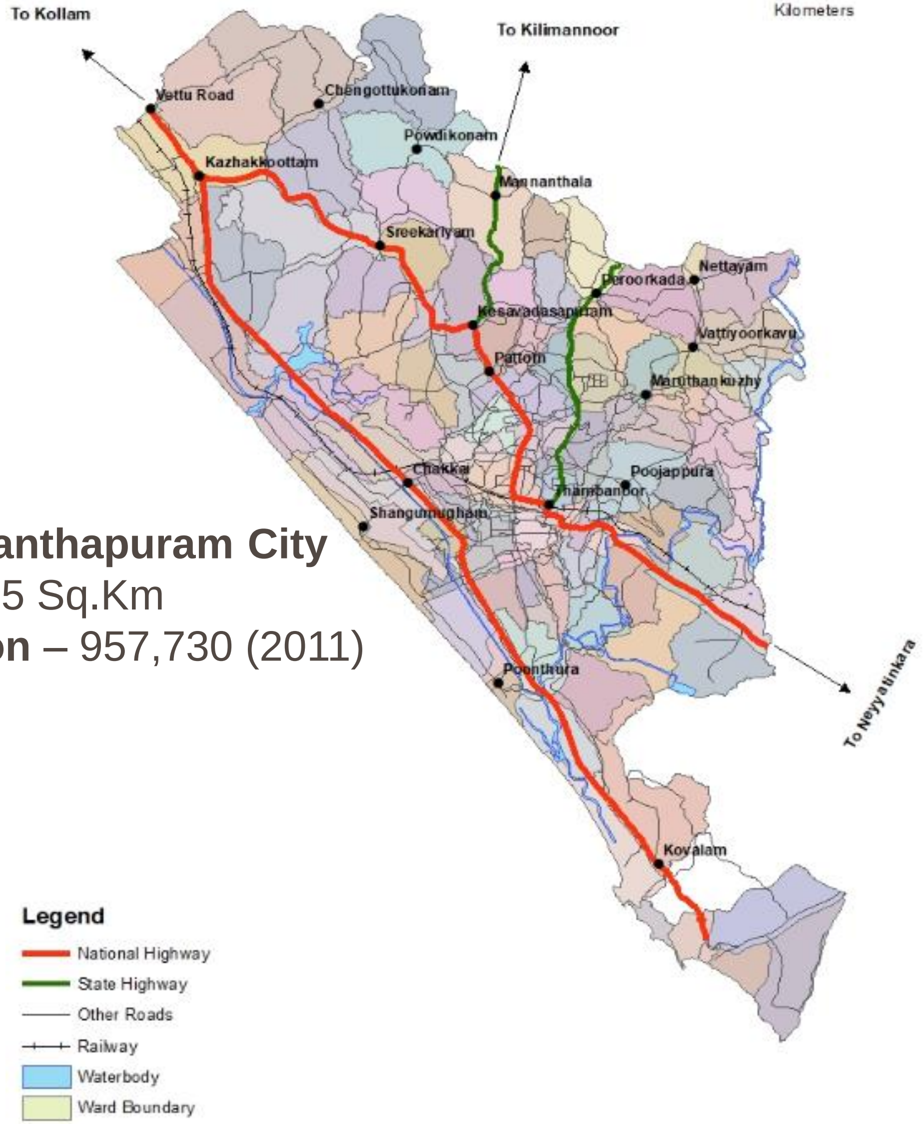
Objectives

i) To develop conventional and latent variable integrated mode choice models influencing the mode selection behaviour of commuters performing work trips.
ii) To identify major variables affecting the modal shift by developing a Structural Equation model.
iii) To estimate the modal shift from personalised to public transport modes by modelling of proposed policies using Fuzzy logic technique.

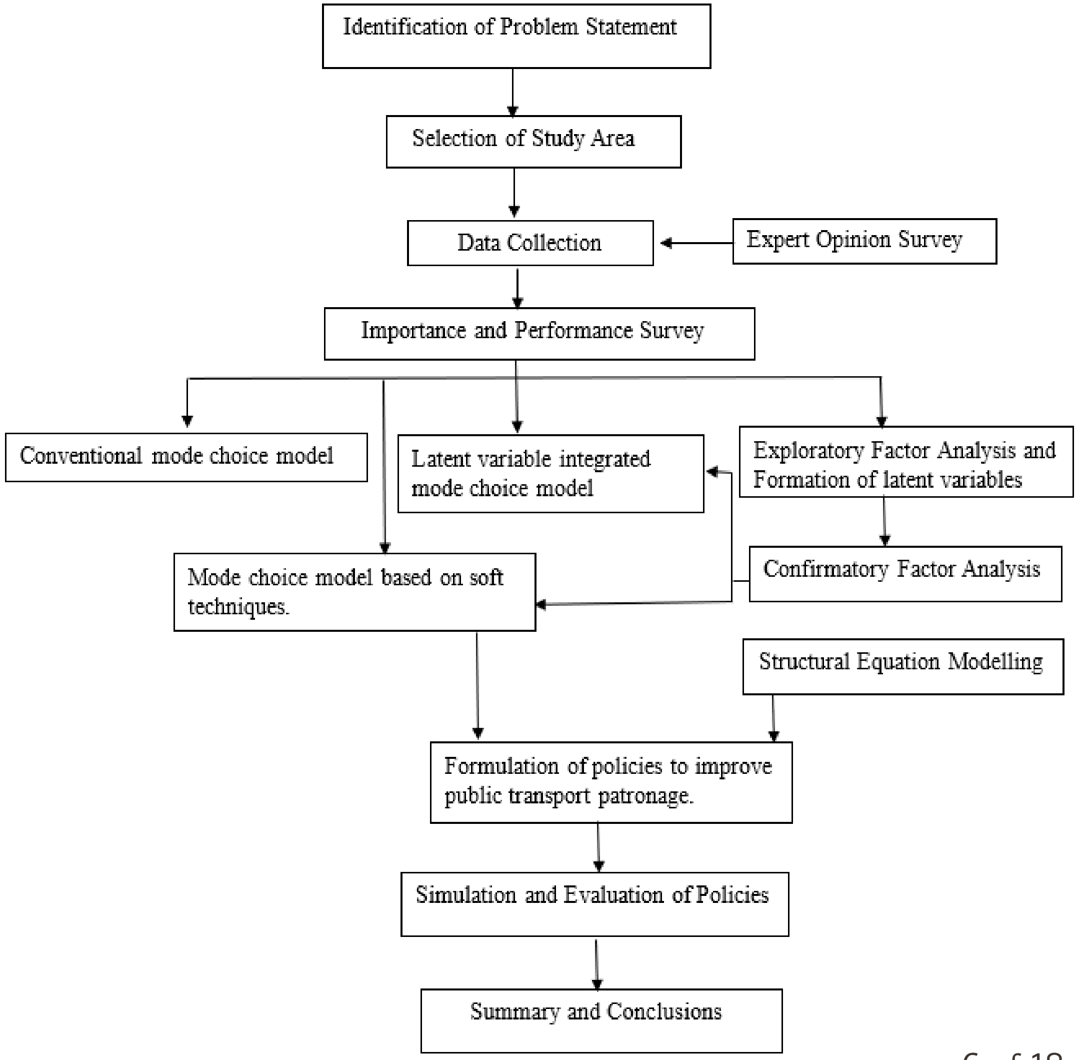
Scope of the study

The scope of the study is limited to the employees working within the precincts of Thiruvananthapuram city.

Study Area & methodology



Thiruvananthapuram City
Area – 215 Sq.Km
Population – 957,730 (2011)



Descriptive Statistics

Questionnaire survey was conducted among employees working in Thiruvananthapuram city

Attributes	Sample Statistics
Gender	54% males and 46% females
Age	18-30 (26%), 31-40 (30%), **41-50 (27%),** 51-60 (14%), 61-65 (3%)
Married status	Unmarried (22%), Married (78%)
Education	SSLC (15%), Plus two(14%), Diploma (17%), Degree (26%), PG (20%), Professional (8%)
Income Level	Rs 0-10000(14%), Rs 10000-20000 (30%), **Rs 20000-50000 (43%),** Rs 50000-100000 (12%), >Rs 100000 (1%)
Household Size	1 (2%) ,2 (9%) ,3 (24%) ,**4 (37%)** ,>=5 (28%)
Vehicle Ownership	Nil (18%) , Only car (15%) , Only two-wheeler (32%) , **Car and two-wheeler (35%)**
Driving License for 2-wheelers	Yes (66%) , No (34%)
Driving License for cars	Yes (44%) , No (56%)
Distance to workplace	0-5 km (31%) , 5-10 km (23%) , **10-30 km (33%)** ,30-50 km (9%) , >50 km (4%)
Access distance	**<=300m (48%),** 300-500 m (28%) , 500-1000 m (16%) , >1000 m (8%)
Egress distance	**0-100 m (43%),** 100-200 m (28%), 200-500 m (16%), >500 m (13%)
Mode of travel	**Bus (35%)** , Car (9%) , Auto (4%) , **Two Wheeler (46%)**, Walk (6%)

Conventional Mode choice model

Mode choice models were developed using the travel profile data collected from employees performing work trips.
Conventional Mode choice models were developed using **NLOGIT** software

Utility Equations

U(BUS) = -1.098 - 0.771*TTPERTD - 0.018*TC
U(CAR) = - 0.771*TTPERTD - 0.018*TC – 0.595 *HHSIZE - 1.163 *GENDER + 0.278 *INCOME
U(AUTO) = - 0.771*TTPERTD - 0.018*TC – 0.694*VEHOWN - 0.425 *TD
U(TW) = - 0.771*TTPERTD - 0.018*TC –1.433 *GENDER + 0.312*EDU - 0.056*TD

U(BUS)	-	Utility value of Bus
U(CAR)	-	Utility value of Car
U(AUTO)	-	Utility value of Auto
U(TW)	-	Utility value of Two-wheeler
HHSIZE	-	Household Size
VEHOWN	-	Vehicle Ownership
GENDER	-	Gender of the user
INCOME	-	Monthly Income
EDU	-	Education of the user
PTAVAIL	-	Public Transport Availability
TD	-	Travel Distance
TC	-	Travel cost
TTPERKM	-	Travel time per Travel Distance

Exploratory Factor Analysis (EFA)

Data reduction technique EFA is used to group **20 indicator statements** into a small number of factors without any loss of information

Sl. No.	Indicator Variables	Reliability	Comfort	Safety & Security	Convenience
IS06	Bus services take less travel time	**0.880**	0.108	-0.026	-0.024
IS07	Bus services offer less vehicle time inside the bus	**0.868**	0.120	-0.010	0.033
IS05	Bus services are reliable	**0.752**	0.160	0.079	0.166
IS04	Bus services are very punctual and helps to arrive at destinations on time	**0.746**	0.154	0.067	0.213
IS08	Waiting time to get into bus is reasonable	**0.733**	0.032	-0.003	0.237
IS20	Travel in public buses are comfortable in all weather conditions	0.080	**0.857**	-0.002	0.080
IS18	Public buses offer calm and non-noisy travel	0.248	**0.854**	0.034	0.069
IS16	Cleanliness of public buses is very good	0.116	**0.848**	0.176	0.023
IS15	Public buses offer peaceful travel without harassments and insults	-0.001	0.067	**0.866**	0.066
IS14	Public bus is a safe mode of travel	-0.005	0.020	**0.841**	0.086
IS19	Public bus crew behaves properly	0.064	0.090	**0.763**	0.013
IS09	Frequency of bus services is good	0.213	0.149	0.001	**0.832**
IS03	Walking to bus stop is easy	0.168	0.000	0.153	**0.832**

KMO value – 0.792, **Latent factors** - Reliability, Comfort, Safety & Security and Convenience

Confirmatory Factor analysis was also done to confirm the identified latent variables using AMOS software.

Latent integrated mode choice model

Latent variable integrated mode choice models were developed using NLOGIT software

Utility Equations

U(BUS) = - 3.883 - 3.337*TTPERTD - 0.011*TC

U(CAR) = - 3.337*TTPERTD - 0.011*TC – 0.225*CON – 1.237*GENDER
- 0.243*SS + 0.375*INCOME - 0.331*HHSIZE + 0.258*EDU

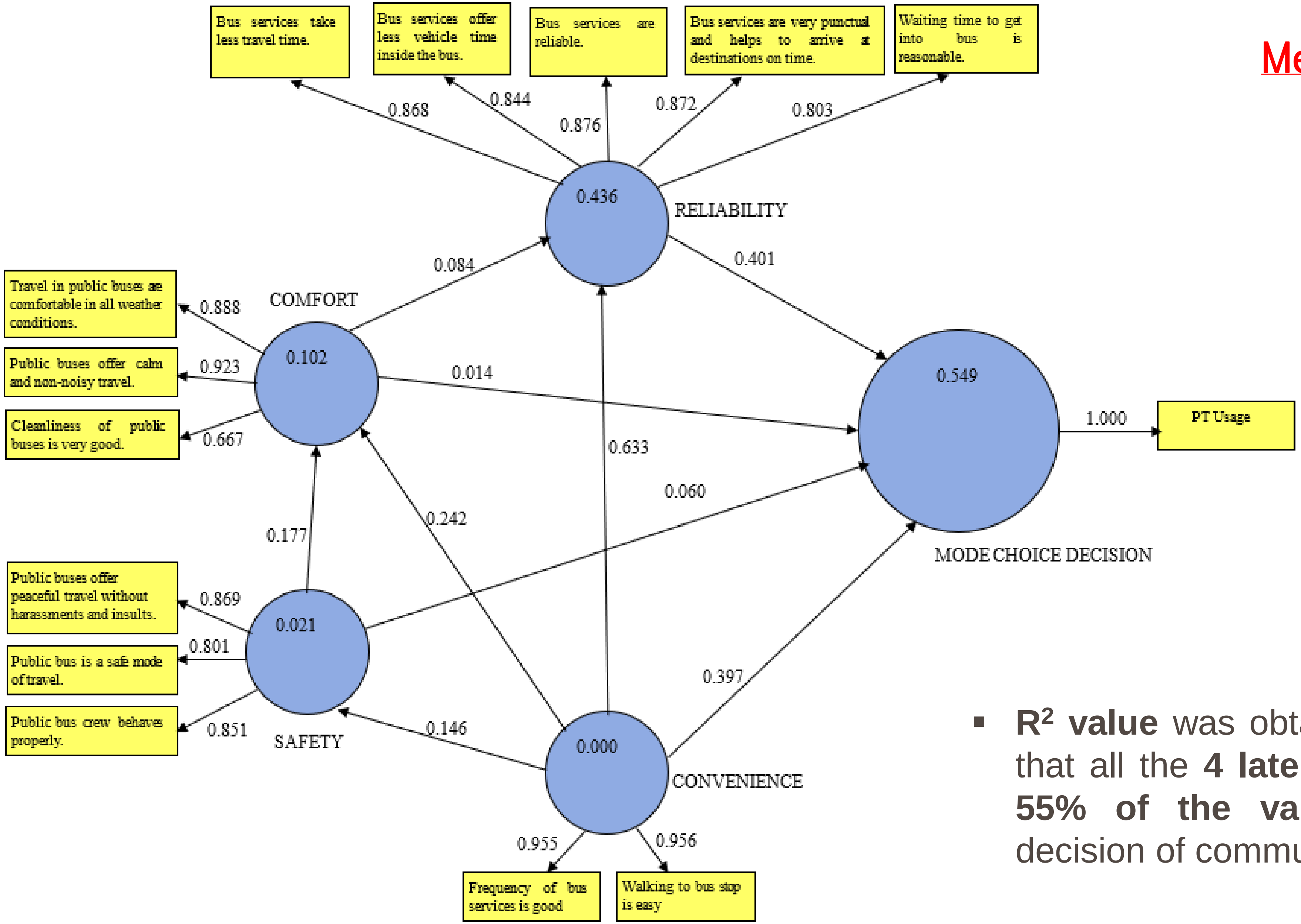
U(AUTO) = - 3.337*TTPERTD - 0.011*TC - 0.310*CON – 0.906*VEHOWN - 1.573*MS

U(TW) = - 3.337*TTPERTD - 0.011*TC - 1.872*GENDER + 0.216*COM
- 0.069 *TD + 0.246*EDU - 0.168*REL - 0.193*AGE

Likelihood ratio index (ρ2)		Percentage correctly predicted (Calibration)		Percentage correctly predicted (Validation)	
Conventional	Integrated	Conventional	Integrated	Conventional	Integrated
0.26	0.31	68.8%	73%	65.7%	70.2%

- Improved pseudo R^2 value for Model with latent variables shows that it can explain more than conventional model without latent variables.

Structural Equation Model

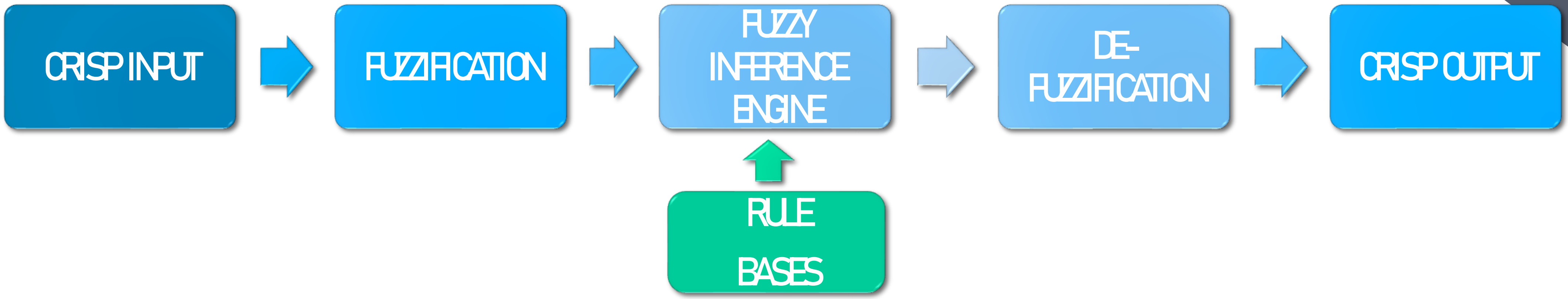


Measurement Model results

Sl. No.	Model fit indices	Values
1	Chi-Square/df	4.97
2	GFI	0.97
3	AGFI	0.95
4	CFI	0.97
5	RMSEA	0.054

- **R^2 value** was obtained as **0.55**, which indicates that all the **4 latent constructs are explaining 55% of the variance** in the mode choice decision of commuters

MODE-CHOICE MODEL USING FUZZY LOGIC



Post-Lockdown Calibrated Model (70% data)

		Observed					Total Estimated
		WALK	TW	AUTO	CAR	BUS	
Estimated	WALK	0	0	1	0	0	1
	TW	1	189	4	17	16	227
	AUTO	1	0	0	0	0	1
	CAR	2	8	1	36	7	54
	BUS	5	1	2	0	35	43
Total Observed		9	198	8	53	58	326
Prediction Accuracy		((0+189+0+36+35)/326) *100 = 79.75%					

Post-Lockdown Validated Model (30% data)

		Observed					Total Estimated
		WALK	TW	AUTO	CAR	BUS	
Estimated	WALK	145	1	1	46	28	221
	TW	4	12	0	8	10	34
	AUTO	8	0	10	3	2	23
	CAR	37	2	1	281	22	343
	BUS	1	0	0	12	83	96
Total Observed		195	15	12	350	145	717
Prediction Accuracy		[(145+12+10+281+83)/717] *100 = 74%					

Sensitivity Analysis

- The developed Fuzzy logic model was used to estimate the **mode shift from private to public transport** mode by varying **latent variables from 10% to 25%.**

Variation in Latent Attributes	Mode Shift from Private to Public Transport			
	Convenience	Safety	Comfort	Reliability
10%	4.3%	0.9%	0.2%	3.4%
15%	5.9%	1.3%	0.3%	4.9%
20%	7.3%	1.7%	0.5%	6.4%
25%	8.7%	2.1%	0.7%	7.9%

- Mode shift from **private to public transport** estimated from the sensitivity analysis varied from **0.7% to 8.7%.**
- There was **no major shift** observed from private to public transport vehicles with respect to **comfort (0.7%) and safety (2.1%).**

Estimated mode shift of selected policies

Selected Transport Policies	Associated Latent Variable	Variable to be Quantified	Quantified Variation (%)	Estimated Mode Shift from Private to Public Transport Mode (%)
Real time bus information using smart phone app (P1)	Reliability	Waiting time	17	5.5
Priority for buses at traffic signals (P2)	Reliability	Dwell time	10.5	3.6
Improving public transport coverage and supply (P3)	Convenience	Access Distance	19	7.0
Operating limited stop buses services (P4)	Convenience	Travel time	17	6.5

It was also found that the highest mode split share of public transport was seen after the implementation of **improving public transport coverage and supply (P3)** (42%) as against the existing public transport share of 35%.

Conclusions

- Conventional MNL model developed identifies travel time and travel cost as generic variable for employees working in Thiruvananthapuram city.
- EFA identified major latent factors such as convenience, comfort, safety, and reliability for working employees. According to the model fit statistics, the confirmatory factor analysis results showed a good fit.
- Latent variable integrated MNL models were developed for car, Two-wheeler, bus and auto rickshaw separately and proved to be more accurate when compared to conventional mode choice models.
- From the path coefficients of the SEM, it was evident that reliability (0.40) and convenience (0.39) had significant positive direct effects on mode choice decisions, which suggests that policies targeting underlying factors such as convenience and reliability can be implemented to improve public transport patronage.
- Mode choice models developed using fuzzy logic were estimated to have an accuracy of 71% in calibration and 74% in validation, which suggests fuzzy logic model predicts mode choice more accurately than traditional models.

Conclusions

- The fuzzy logic model developed was used to estimate the mode shift related to each selected policy by varying the related latent factor up to 25%. The maximum mode shift obtained from the sensitivity analysis is 8.7%.

- The policy of improving public transport coverage and supply related to convenience was found to produce the highest mode shift to public transport (7.0%), followed by the policy of operating limited stop buses related to convenience (6.5%) and the policy of real-time information using a smart phone app related to reliability (5.5%).

Contributions of the study

- The study has shed light on the complex dynamics that govern mode choice decision of working population in Thiruvananthapuram city.

- The extent of the influence of latent variables identified from the Structural Equation model help the transport planners to develop policies related to the most significant latent variables.

- The developed fuzzy logic model in this study has proven to be an effective approach for testing transport policies and helping the government study changes in mode shift before adopting policies.

- The study provides actionable insights for enhancing public transport patronage, which is essential for sustainable development in countries like India.

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