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Factors Affecting Road Traffic Congestion In Delhi NCR And Its Solution

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Abstract:

The rapid growth of urban areas in the Delhi NCR (National Capital Region) has resulted in worsening road traffic congestion, creating significant environmental and economic challenges. This study investigates the factors influencing traffic congestion, including population growth, government policies, pride in vehicle ownership, and adherence to traffic rules. Through a dual-stage survey and analysis using Structural Equation Modeling (SEM), we explore the relationships between these variables. Our findings suggest that improving compliance with traffic regulations can substantially mitigate congestion, while population growth, government policies, and vehicle ownership do not have significant direct impacts. Recommendations are provided for policymakers to integrate infrastructure development with strict traffic management practices to ensure sustainable urban mobility.

I. INTRODUCTION

The Master Plan of Delhi (MPD) 2021 underscores the unprecedented growth of vehicles and traffic in Delhi between 1981 and 2011. During this period, the per capita trip rate surged from 0.72 to 0.87 in 2001 and further increased by 2011. The surge in private motor vehicle trips, coupled with a decline in bus trips, highlights the challenges faced by public transport in meeting the growing demand. Studies from regions like Bogota and Tianjin emphasize the importance of reliable public transport services in encouraging ridership. Furthermore, research indicates that connected automated vehicles could significantly reduce fuel consumption and emissions, offering a potential solution to congestion and environmental concerns.

In the Delhi NCR region, rapid urbanization has intensified the demand for mobility, exacerbating traffic congestion. With private cars, two-wheelers, buses, metro, and auto-rickshaws comprising the major modes of transport, the need for an improved transport and traffic system is evident. Policy interventions are crucial in addressing congestion, with studies suggesting that policy effectiveness correlates with acceptability. Pull policies, such as reducing transit access time, are deemed more effective and acceptable compared to push policies.

Research from various regions offers insights into the relationship between transportation development, environmental sustainability, and economic growth. In Hainan Province, China, transportation development has led to increased carbon emissions and air pollution, necessitating innovative solutions like speed-guided intelligent transportation systems. Consumer behaviour significantly influences the sustainability of transportation systems, with factors like convenience and environmental awareness driving the adoption of eco-friendly mobility options.

Efforts to optimize freight logistics and promote sustainable commuting practices are essential for reducing energy consumption and emissions. Multivariate time series analysis helps understand the interplay between traffic congestion and socio-economic factors, informing targeted interventions. Road pricing schemes and

integrated Bike-and-Ride services offer market-based approaches to mitigate congestion and promote active transportation.

Our study aims to evaluate the factors contributing to traffic congestion in the Delhi NCR region and assess their economic and environmental impacts. By proposing solutions aligned with India's context, such as promoting shared ridership and leveraging technology for efficient traffic management, we seek to address congestion while ensuring economic and environmental sustainability.
In conclusion, the synthesis of diverse research underscores the complex dynamics of urban transportation systems and their profound impacts on environmental quality, economic productivity, and quality of life. By drawing on a range of methodologies and analytical approaches, these studies provide valuable insights for policymakers, planners, and stakeholders striving to create sustainable and liveable urban environments.

II. REASON FOR THE STUDY:

1. Based on gap analysis of literature review, addition of variables that capture congestion mitigation policies such as Population growth, Govt policy, Infrastructure etc. need to be studied further.
2. We need to evaluate and analyse the factors leading to traffic congestions in Delhi NCR region, their economical (in terms of Fuel saving vs spend of ridership commute etc.) and environment impact (Emission by own vehicles vs shared ridership etc) and propose a solution for low congestions, with economical and environment friendly methods available in India.
3. The studies will offer valuable insights into various facets of transportation and critical issues and potential solutions in urban environments.
4. Each concept contributes to different aspects of transportation systems, traffic management, and their impacts on urban life
5. The cause and effect of Each concept and its outcome on the Environment performance will be evaluated.

III. DATA AND SOURCES OF DATA

To identify the causal relationship between Traffic congestion and the various factors which affect traffic congestion, data was collected from several secondary research through literature review. A total of 41 relevant literatures were studied and detailed analysis of the Theory used, Methodology followed, outcome and gap analysis was done. The details of the papers review are provided in the reference section of the report a) Pair-wise construct and hypothesis: Previous papers have used various measures to evaluate the impact on traffic congestion by various factors. b) Hypotheses supported by the literature

IV. THEORETICAL FRAMEWORK

Framework: Based on literature review following framework has been prepared based on below considered factors and effects:

Traffic congestion

- Population growth
- Govt. policy
- Pride of ownership
- Traffic rules adherence

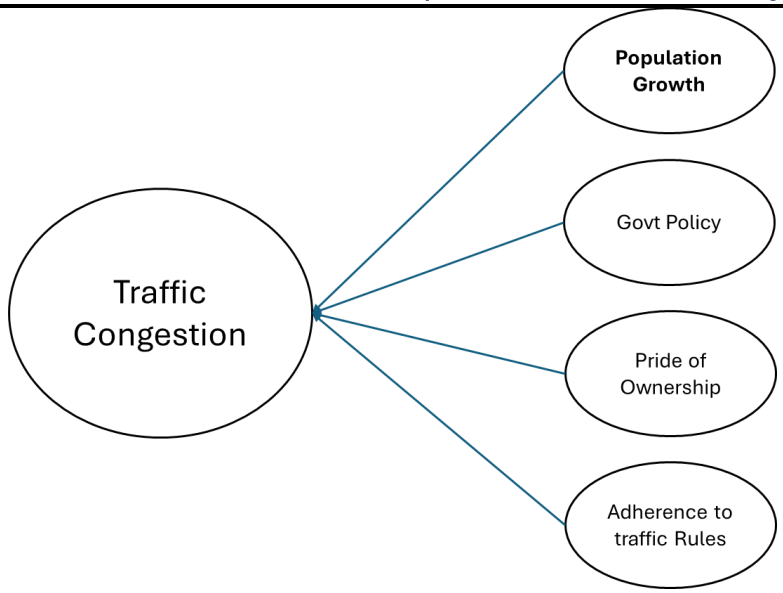


Figure 1: Conceptual Diagram

The conceptual framework hypothesis that below mentioned factors are responsible for traffic congestion:
H1: Population Growth – Areas experiencing rapid population growth are likely to face increased traffic congestion due to higher demand for transportation infrastructure and services
H2: Government Policy: Government policies regarding transportation planning, infrastructure development, and traffic management strategies play a significant role in mitigating or exacerbating traffic congestion
H3: Pride of Ownership of a Vehicle: Individuals' attachment and pride in owning vehicles may contribute to increased vehicle usage, leading to higher traffic congestion levels
H4: Adherence to Traffic Rules: Compliance with traffic regulations, such as speed limits, lane discipline, and traffic signal adherence, can impact traffic flow and congestion levels.

V. RESEARCH METHODOLOGY

Measure: For each of the construct there and 3-5 number of items. For each items, the scale type used is Likert scale or Ordinal scale. For each construct scale of 1-7 is used, describing 1 as Strongly Disagree & 7 as Strongly Agree. Thus, this will measure the discrete measure from 1 to 7.

A dual-stage survey questionnaire was designed to collect data from the Delhi NCR residents. First part of the survey questionnaire screened the respondents who owned cars and travelled in and around Delhi-NCR. This section captured respondents demographic information, such as Gender, Occupation, income, and age, as well as information related to commuting mode. Part two of the questionnaire was comprised of variables used in the study. All variables were adopted from past studies done in various literatures.

Construct	Items		Scale						
Traffic congestion	Population growth rate	TC1	1. Strongly Disagree	2	3	4	5	6	7. Strongly Agree
	Help in reducing traffic congestion	TC2							
	Slow moving vehicles (HMV, auto rikshaws, E-Rikshaws etc) don't adhere traffic rules and cause congestion	TC3							
	Non adherence to traffic rule will cause congestion	TC4							
Population growth	Urban planning adaptation	PG1							
	Government initiatives	PG2							
	Urban planning initiatives	PG3							
	Relationship between population density and traffic congestion	PG4							
Government policies	Benefit economically/financially	GP1							
	Save time on commuting	GP2							
	Encourage people to prefer public transport	GP3							
	Eliminate inconveniences associated with commute	GP4							
Pride of ownership	My car provides me status and prestige	PO1							
	Driving meets my self esteem or personal image	PO2							
	Importance of owing a car in Delhi NCR region	PO3							
	I think of giving up my route and share a ride	PO4							
	I prefer Cab over public transport for vacations	PO5							
Adherence to traffic rules	Read and understand traffic signs	TR1							
	Traffic law enforcement should be strict	TR2							
	Design of roads and intersections influence adherence to traffic rules	TR3							

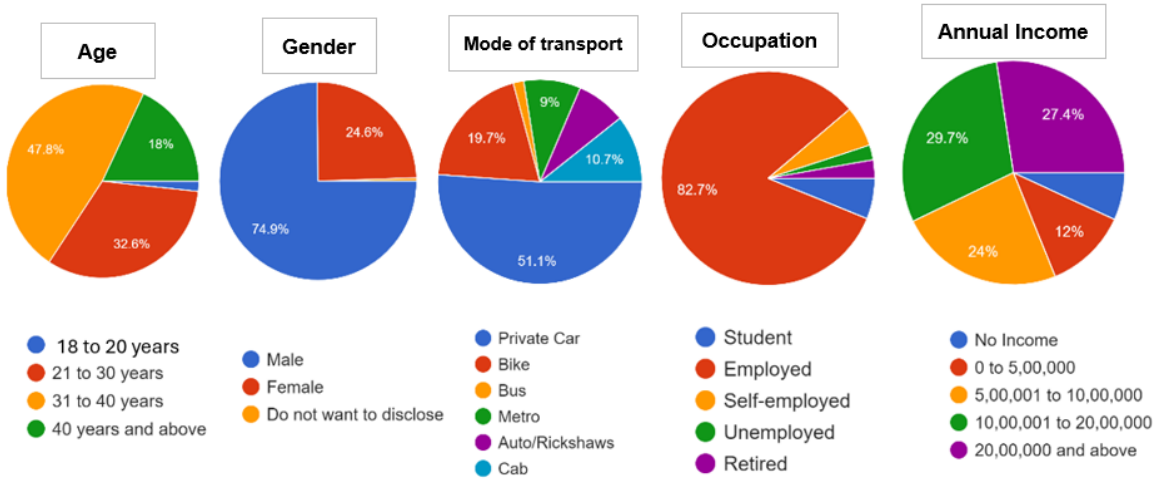
Figure 2: Sampling design, sampling method and sampling frame

Sampling design, sampling method, and sampling frame:

The survey method is used to collect the data related to the constructs. The analysis is conducted on samples collected across Delhi NCR metrics of urban traffic congestion and factors representing the structural, socio-economic, and behavioral aspects of urban areas. 206 usable responses were collected. The samples is spread across various Age, Gender, Occupation, Income groups and also across various modes of transport. A summary of the demographic data collection has been shown below.

As per literature review, a sample size of greater than 200 is good to conduct SEM analysis (Boomsma,1982).

Demographic data collected:



Demography summary table

Analysis: The constructs are divided to measure Traffic congestion (TC) as a dependent variable and Population growth (PG), Government policies (GP), Pride of ownership (of vehicles) (PO) & Adherence to traffic rules (TR) as independent variables.

i) Reliability measure: To test the constructs a reliability test is being followed using Cronbach's alpha is used. The reliability will measure the co-relation of the items of the construct with each other. Reliability of

each construct is measured using Cronbach Alpha. Hence it measures the inter item co-relations or the internal consistency. It measure the internal consistency of all the possible split halves for multi item scale. The measurement is done using Jamovi statistical software.

Criteria- $\alpha \geq 0.7$ → Good co-relation, $\alpha \geq 0.97$ → Highly co-related (Same Constructs)

S. No.	Constructs		Reliability test (Cronbach's α)
1	Traffic Congestion	TC	0.696
2	Population growth	PG	0.877
3	Govt policy	GP	0.888
4	Pride of ownership	PO	0.707
5	Adherence to traffic rules	TR	0.862

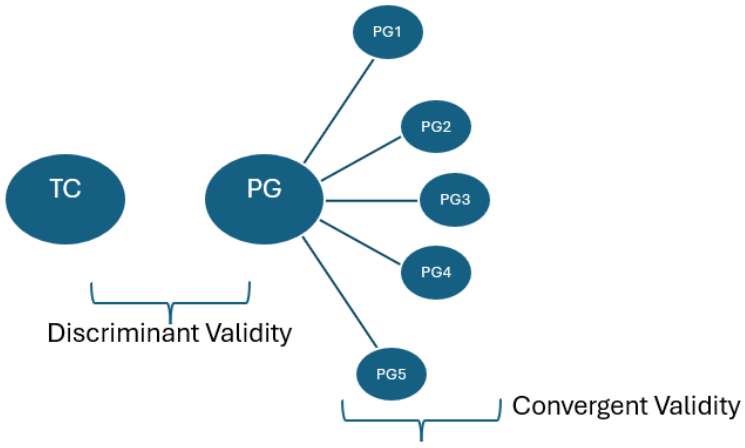
Reliability test- Cronbach's Alpha

All the items or questions of the each of the construct have good co-relation with each other with all alpha being greater than 0.7 and below 0.97.

ii) Validity measures (convergent and discriminant validity): Next the validity of the items is measured. The data is cleaned for blanks, Unengaged responses and multivariate Outliars.

Validity means the accuracy with which a measure is true to the construct being measured. To measure the validity Convergent validity and Discriminant validity is used. Convergent validity measures how the items are related to each other. Discriminant validity measures the uniqueness or distinctiveness of the measurement which means the corelation should not be very high to be not independent.

To measure the Convergent and Discriminant validity Jamovi software is used and Confirmatory factor analysis (CFA) is used. CFA is performed to test and verify the model constructed. Also, a path diagram is created. The maximum likelihood (MLE) method is used to estimate the validity coefficients.



Convergent Validity: To measure Convergent validity the following criteria is used.[Hair et al.,2014)

- CR (composite reliability)>0.7

$$CR = \frac{(\sum \lambda_i)^2}{((\sum \lambda_i)^2 + \sum \epsilon_i)}$$

- AVE (Average Variant Extracted) >0.5

- CR>AVE

SE>0.5
Avg >0.7

Average Variance Extracted

Composite Reliability

Factor Loadings										
Factor	Indicator	Stand. Estimate (B)	B^2	AVE	Criteria 1	residue=1-B^2	Sum(B)	Sum (Residuals)	CR	Criteria 2
TC	TC2	0.615	0.38			0.62				
	TC3	0.811	0.66			0.34				
	TC4	0.906	0.82	**0.62**	>0.5	0.18	2.33	1.14	**0.83**	>0.7
PG	PG2	0.844	0.71			0.29				
	PG3	0.811	0.66			0.34				
	PG4	0.92	0.85			0.15				
	PG5	0.641	0.41	**0.66**	>0.5	0.59	3.22	1.37	**0.88**	>0.7
GP	GP2	0.87	0.76			0.24				
	GP3	0.889	0.79			0.21				
	GP4	0.706	0.50			0.50				
	GP5	0.786	0.62	**0.67**	>0.5	0.38	3.25	1.64	**0.87**	>0.7
PO	PO1	0.834	0.70			0.30				
	PO2	0.878	0.77			0.23				
	PO3	0.765	0.59	**0.68**	>0.5	0.41	2.48	0.95	**0.87**	>0.7
TR	TR1	0.757	0.57			0.43				
	TR2	0.839	0.70			0.30				
	TR3	0.876	0.77	**0.68**	>0.5	0.23	2.47	0.96	**0.86**	>0.7

Convergent validity

Each construct AVE>0.5, CR>0.7. Hence each questionnaire score converge (are correlated) with Constructs. The accuracy of the measure is true to the construct being measured i.e. TC, PG, GP, PO & TR.

Discriminant Validity: To measure discriminant validity the following criteria is used. [Hair et al.,2014).

- MSV (Max shared variance)<AVE

Max Shared Variance

Factor Covariances							
		Stand. Estimate	Shared Variance (SV)		MSV	AVE	is AVE>MSV
TC	TC						
	PG	0.501	0.251	TC	0.61	0.62	TRUE
	GP	0.436	0.190	PG	0.251	0.66	TRUE
	PO	0.195	0.038	GP	0.190	0.67	TRUE
	TR	0.778	0.605	PO	0.058	0.68	TRUE
PG	PG			TR	0.605	0.68	TRUE
	GP	0.342	0.117				
	PO	0.133	0.018				
	TR	0.473	0.224				
GP	GP						
	PO	0.237	0.056				
	TR	0.344	0.118				
PO	PO						
	TR	0.24	0.058				
TR	TR						

Discriminant validity test

Each construct AVE>MSV, hence each questionnaire score diverge (are not completely independent) with Constructs.

iii) Test type : Model Fit : Additionally a indices set is calculated to check the model's Goodness-of-fit. To check the model fit following indices are referred.

Fit indexes	Acceptable level
X2/df	<2
CFI (Comparative Fit Index)	≥0.9
TLI (Tucker-Lewis Index)	≥0.9
SRMR	≤0.05
RMSEA (Root mean square error of Estimation)	≤0.08
CR	>0.7
HTMT	<0.85-0.9

Test for Exact Fit				
χ^2	df	p		Criteria
177	89	<.001	1.99	<2

Normed Chi-sqare/df is less than 2 which is accetable as per criteria and hence the model has good fit.

	Fit Measures					
					RMSEA 90% CI	
	CFI	TLI	SRMR	RMSEA	Lower	Upper
	0.952	0.935	0.0497	0.0717	0.0561	0.087
Criteria	>0.9	>0.9	<0.05	<0.08		

The Comparative fit index (CFI) & Tucker Lewis index (TLI) of the model is >0.9 and SRMR is<0.05 & Root mean square error of estimation is less than 0.08, thus the model has a very good fit to measure the related constructs.

Validity & HTMT Ratios

Convergent: The reliability indices check the convergentg validity of the constructs. W1 is same as Composite reliability. For Convergent validity CR (composite reliability)>0.7.

From the below table it is observed that the composite reliability of the constructs is >0.7. Each construct AVE>0.5, CR>0.7. Hence each questionnaire score converge (are correlated) with Constructs. The accuracy of the measure is true to the construct being measured i.e. TC, PG, GP, PO & TR.

Reliability indices	
Variable	**ω_1**
PG	0.845
GP	0.874
PO	0.849
TR	0.857
TC	0.776

Discriminant: To measure Discriminant validity the following criteria is used. [Hair et al.,2014).

Heterotrait-monotrait (HTMT) ratio of correlations					
	PG	**GP**	**PO**	**TR**	**TC**
PG	0.4619	0.336	0.1351	0.818	1
GP	1	0.303	0.0966	0.418	0.462
PO	0.3026	1	0.1642	0.333	0.336
TR	0.0966	0.164	1	0.175	0.135
TC	0.4175	0.333	0.1748	1	0.818

Model has goodness of Fit, since the HTMT (Hetero Trait Mono Trait) is less than 0.85.

VI. RESULTS AND DISCUSSION

Results: Regression analysis Structural Equation Modeling (SEM) analysis: As per the literature review done many of the studies have used Regression analysis i.e. SEM to study the relevant factors. In the current study we have used SEM to study the causal relationship between Traffic congestiona and various factors like Population growth, Govt policies, Pride of ownership & Adherence ti traffic rules. SEM is a very famous analysis technique and used widely by reseachers.

The aim of the study is to find the realtionship betwwen Dependent variables (endogenous) and Independent variables (Exogenous). SEM study is a statistical study whoch includes regression, factor and path analysis. The study involved to test the valisity using Confirmatory factor anaysis(CFA) & Exploratory factor analysis(EFA).

In SEM a regression coefficient is used to check the strength of the variables. It is used to depict if the Independent variable changes, what is the impact on the dependent variable.

The SEM analysis is performed using Jamovi Statustical software. The methods used are to check the parameter estimates – P value & Beta (β). The probability level (P-value) is estimated.

From the below table of SEM analysis it can be obseved that the pvalue for TC & TR is less than 0.05, which means they are significant at 99%, 95% ad 90% confidence interval. This indicates that Traffic rules impact positively the traffic congestion. For rest of the coefficients i.e. TC & PG, TC & GP, TC & PO the pvalue is greater that 0.05. Thus, there is no significant impact of Population growth, Govt Policy, Pride of vehicle ownership with Traffic congestion. This means these are unrelated.

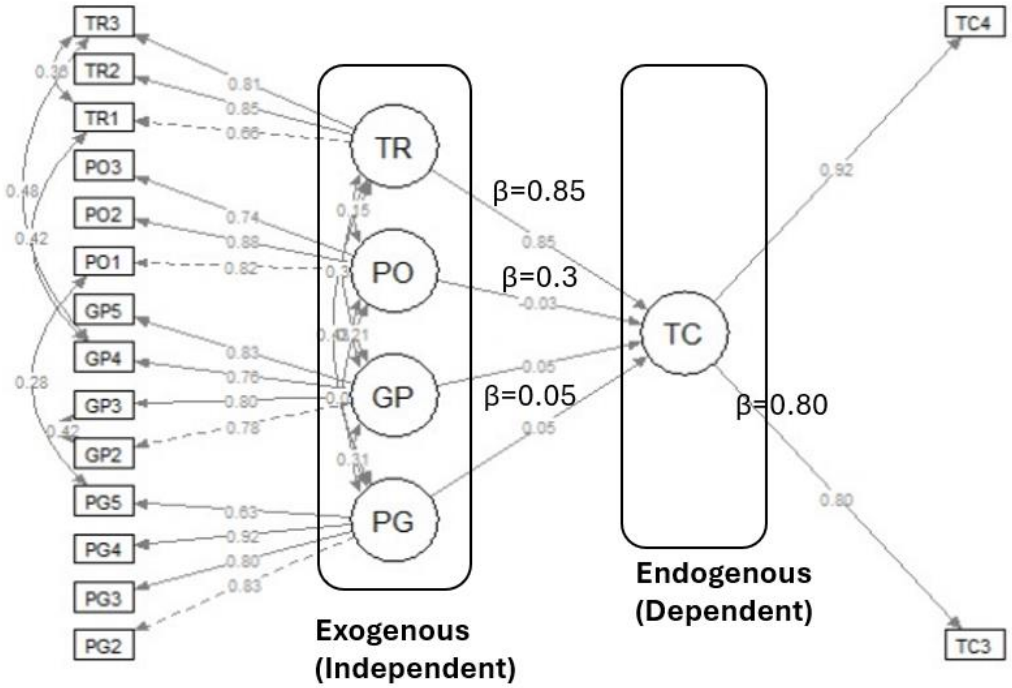
Parameters estimates								
		95% Confidence Intervals			β 95% Confidence Intervals			
Dep	Pred	Lower	Upper	β	Lower	Upper	z	p
TC	PG	-0.1097	0.252	0.0488	-0.0764	0.174	0.771	0.44
TC	GP	-0.097	0.23	0.0502	-0.0721	0.1724	0.799	0.424
TC	PO	-0.1835	0.109	-0.0287	-0.14	0.0826	-0.503	0.615
TC	TR	0.8862	2.027	0.8481	0.7493	0.9469	5.006	<.001

Parameters estimates								
		99% Confidence			β 99% Confidence			
Dep	Pred	Lower	Upper	β	Lower	Upper	z	p
TC	PG	-0.166	0.309	0.0488	-0.116	0.213	0.771	0.44
TC	GP	-0.148	0.282	0.0502	-0.11	0.211	0.799	0.424
TC	PO	-0.229	0.154	-0.0287	-0.175	0.118	-0.503	0.615
TC	TR	0.707	2.206	0.8481	0.718	0.978	5.006	<.001

Parameters estimates								
		90% Confidence			β 90% Confidence			
Dep	Pred	Lower	Upper	β	Lower	Upper	z	p
TC	PG	-0.0806	0.2229	0.0488	-0.0562	0.1539	0.771	0.44
TC	GP	-0.0707	0.2041	0.0502	-0.0524	0.1528	0.799	0.424
TC	PO	-0.16	0.0851	-0.0287	-0.1221	0.0647	-0.503	0.615
TC	TR	0.9779	1.9349	0.8481	0.7652	0.931	5.006	<.001

SEM analysis: pValue

Path Diagram:



Relationship between Independent & Dependent variable: Beta is significant.

VII Discussion:

We can discuss the results based on the above outcomes by considering each independent variable and its impact on dependent variables.

1. Traffic congestion and Population growth: Traffic congestion is not significantly related to population growth. Hence as per the study results Traffic congestion is not affected by population growth. This implies that beyond the factor of population growth, there are other factors which affect traffic congestion. These factors could be economic growth, population size, density, income level.
2. Traffic congestion and Government policies: Traffic congestion is not significantly related to Government policies. Hence as per the study results Traffic congestion is not affected by Govt policies. The Government policies are not implemented properly and hence does not lead to improved traffic conditions. For example, the odd even scheme in Delhi NCR was introduced to reduce pollution and also vehicular traffic. This was a good success, but people acceptability of such policies are quite difficult and there is less trust on any policy implementation by Government. Thus it cand be said that the Government policies are not considered significantly affecting the Traffic congestion.
3. Traffic congestion and Pride of ownership: Traffic congestion is not significantly related to Pride of ownership. Hence as per the study results Traffic congestion is not affected by Pride of ownership. Any owner's personal vehicle is considered as his/her pride. Particularly in a Metro city like Delhi NCR it is very frequent for commuters to travel by personal vehicle. The car fulfills not only the transportation needs, but also holds important symbolic meaning for the owners and users. In particular, owning and using a car can be a symbol of an individual's social status or personal image ('Owners pride'). Pride of ownership is not impacting Traffic congestion much and people are aware of the environmental impact due to vehicle emission and hence are willing to give up private vehicle travel to use public transport. The people are willing to travel by metro in Dehi NCR region where connectivity of metro is very good particularly in Delhi , Gurugram and Noida.
4. Traffic congestion and Adherence to traffic rules: Traffic congestion is significantly related to Adherence to traffic rules. Hence as per the study results Traffic congestion is strongly affected by traffic rules. Non-Adherence / Adherence to Traffic rules enhances/reduces the traffic congestion. A proper imposition of traffic rules and ensuring the same is followed by public is required. This will not only reduce congestion but also reduce road accidents. Both traffic congestion and road accidents are a burden to our society, and therefore it is very important for transport policy makers and Governments to ensure proper policy making and compliance to reduce their impact. An ideal scenario would be that traffic congestion and accidents are reduced simultaneously, this may not be possible since it has been speculated that increased traffic congestion may be beneficial in terms of road safety. This will significantly reduce Traffic congestion in Delhi NCR. It is therefore necessary to design policies and measures which are multidisciplinary in nature which will make it possible to keep traffic congestion under control, since it is not reasonable to think of eliminating it altogether. A lack of driving discipline reduces the capacity of the road network to a fraction of its potential.

VIII. Conclusion and implication:

The correlation between population growth and increasing traffic congestion has been established from above. More population growth leads to Increased traffic congestion due to which there is higher demand for transportation. With increase in urban population, the demand for transportation also increases, which leads to congestion on roads. Also, with surge in population not only amplifies the need for transportation but also create a migration trend towards urban areas, further intensifying the vehicular presence on roads, where, urban infrastructure struggles to cope with the increasing vehicular load, leading to increase in commute time.

Further, it is being observed that effective government policies are important in mitigating the impacts of population growth on traffic congestion. One key approach involves prioritizing infrastructure development and enhancing public transportation systems. Others include, incentivizing public transport usage, authorities can alleviate the strain on roads by reducing the number of private vehicles in circulation. Such initiatives not only ease traffic congestion but also promote sustainable urban mobility, fostering a more efficient and environmentally friendly transportation landscape.

Also, adherence to traffic rules is important for derisking road congestion and improving safety. Increased awareness and compliance with traffic regulations plays a major role in promoting orderly traffic flow. Further, Strict enforcement of rules serves as a deterrent against reckless driving, which again contribute to safer road conditions. Proper road infrastructure development, including well-marked lanes and clear signage, facilitates smoother traffic movement. Ensuring adherence to speed limits and lane discipline helps prevent accidents and maintain efficient traffic flow. Overall, prioritizing adherence to traffic rules is essential for creating safer and more organized road environments for all commuters.

From an industrial perspective, recent research underscores the substantial impact of population growth on traffic congestion. With increasing populations, there is a proportional rise in the demand for transportation services, particularly pronounced in urban areas where more individuals settle. This influx leads to a surge in the number of vehicles on the roads, exacerbating congestion challenges. To address this, government policies should prioritize proper infrastructure development and bolster public transport systems. Encouraging public transit usage can help alleviate congestion by reducing the reliance on private vehicles. Additionally, promoting awareness and compliance with traffic regulations is essential. Strict enforcement of rules, coupled with infrastructure improvements ensuring speed limits and lane discipline, plays a crucial role in enhancing traffic flow and safety. Collaborative efforts involving governmental bodies, industry stakeholders, and the public are vital to formulating effective strategies that mitigate congestion while accommodating population growth in urban environments.
Through an academic lens, recent research elucidates the significant impact of population growth on traffic congestion dynamics. As populations burgeon, the concomitant escalation in transportation demand, particularly discernible in urban settings, precipitates heightened traffic congestion. This phenomenon is compounded by the migration of individuals to urban areas, leading to an upsurge in the vehicular population on roadways.

In addressing this complex issue, governmental policies are pivotal. Prioritizing proper infrastructure development and the enhancement of public transportation systems emerge as imperative strategies. By incentivizing the utilization of public transit, authorities can mitigate congestion by diminishing reliance on private vehicles.
Moreover, fostering awareness and compliance with traffic regulations is paramount. Effective enforcement mechanisms, coupled with infrastructural enhancements ensuring speed limit adherence and lane discipline, play instrumental roles in ameliorating traffic flow and safety standards.
Collaborative endeavors involving academia, governmental agencies, and stakeholders are indispensable for formulating comprehensive strategies that navigate the intricacies of congestion mitigation amidst population growth trends in urban environments.
Future scope:
This study has certain limitations which can be in the scope of future research. First, sampling was convenient and representative in nature, which restricts the generalized findings to the entire population of Delhi. Future research with random sampling of a larger representative sample may generalize the results. A further study by considering the economic impact of traffic congestion can be done.

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