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Research Paper on Performance Analysis and Recommendations of Traffic Congestion Strategies in Cities of Haryana

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Abstract: This experimental study uses national regulations and survey reports to identify short, medium, and long-term traffic congestion strategies in Haryana's cities.
The current study looked into a variety of successful road congestion mitigation techniques, ranging from expanded road capacity to the use of roadways, to see which ones were the most cost-effective. Using an examination of quantitative regression, interviews with transportation policy and decision makers, and alternate matrix criteria, I ranked each traffic congestion mitigation approach from least to most cost efficient based on three cost factors.
I discovered that ramp measuring was both the most cost-effective and the most difficult method. Meanwhile, I discovered that expanding transit capacity was the least cost-effective of the solutions I looked into.
Keywords: traffic congestion, quantitative regression analysis

I. INTRODUCTION

A. Introduction

At some point in our lives, most of us have encountered a congested situation roadway. The majority of passengers have encountered traffic during their morning and evening travels, which they are subjected to on a regular basis. Apart from the frustration and annoyance of slow moving traffic, crowded highways have a private cost in terms of time and fuel, as well as a social cost in terms of pollution and greenhouse gas emissions.

Haryana's road network, like that of other states, includes highways, national roads, state roads, and significant district roads. The National Highway Authority of India (NHAI) and the Public Works Department (PWD) are in charge of creating and maintaining the road network (B&R). The sub-region has six state highways (NH-9, 44, 48, 352, 709, and 919) and twelve state highways. Aside from these highways, the regional road network is strengthened by several key district routes and others.

Table 1.1 : Length of different types of roads inHaryana state

Hierarchy of Roads	Length (In Km.)
National Highways	1,566
State Highways	2,422
Major District Roads	1,471
Other District & Village Road	21,616
Total Length	27,075
HSAMB (Haryana State Agricultural Marketing Board Roads)	8,181

Source: PWD (B&R) Branch, Chandigarh, 2016

The private costs of congestion have risen at an exponential rate over the last few decades.

Since 1982, there have been over 5 times as many as the 101 billion in 2013. In light of these costs, politicians, planners, and other decision-makers have attempted to address traffic congestion in a variety of ways, ranging from increased road capacity and transit systems to promoting higher density with a focus on alternate (non-vehicular) travel modes to smart traffic systems like road metering and stoplight synchronization.

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Different mitigation measures have had varying degrees of success in mitigating traffic congestion, but many come at a high cost. The impact of various mitigation techniques on the traffic congestion problem should be seen in times when governments can do little to invest limited taxpayer resources on cost-cutting activities. In my master's thesis, I intend to clarify this subject by answering the following question: "What are the magnitudes of effects of various mitigation measures on traffic congestion?" The findings will help policymakers make better judgments on traffic congestion mitigation and will add to the increasing body of knowledge on the subject. The rest of this chapter will go into the costs of congestion, then address alternative mitigation measures before moving on to the next chapters of this research study.

B. Traffic Congestion & Cost

When calculating the cost of a problem, such as traffic congestion, it's crucial to distinguish between the costs of individuals and businesses against the costs of the entire society. Individual costs include time squandered due to slower than normal travel speeds or additional fuel burned by traffic idle, while society bears the expenses of higher air pollution and greenhouse gas (GHG) emissions as a result of congested roadways. Individual and corporate charges (private costs) must therefore be matched with societal costs (social costs) to pay the whole cost of traffic congestion. This indicates that the overall cost is equal to the sum of all private and social costs, as shown in the diagram below:

Total individual driving costs = personal driving costs + social driving costs not funded by the individual

C. Private Cost

When a road hits its full capacity, typical free-flow speeds are soon reduced to slower, loaded, restricted-flow rates. Every extra vehicle entering a congested road exacerbates this, and traffic flow can eventually be stopped. The private costs incurred as a result of the gridlock are staggering. According to Shrank et al., traffic congestion caused 4.8 trillion hours of delay and 1.9 trillion gallons of gasoline in 2010. (2011). According to Shrank et al., traffic congestion costs $101 billion when latency and fuel consumption are factored in. According to the authors, the average cost of traffic congestion in 2010 was $713 per commuter. In order to account for this sum, the national and local taxes paid in 2009 totaled 4160 dollars. 2012 (Tax Foundation). In other words, traffic congestion resulted in a 17 percent rise in passenger taxes in 2010.

At various levels, the table below compares the national road density of highways, highways and key states, NCR, Haryana sub-regions. The Haryana region has the highest road density.

The NCR is as follows (59.30 km/100 sq km); the NCR is as follows. Delhi has the highest density of 2.103 km/100 sq km, followed by Haryana, Rajasthan, and Uttar Pradesh. The Sub-wise Region's street density is also low.

Table 1.2 : Sub-Region Wise Road Density (Km. per100 Km2) in NCR

Sub-region		NCR		National Highway		State Highway		MDR	
	Area (Km2)	Total Length	Road Density	Length (Km)	Road Density	Length (Km)	Road Density	Length (Km)	Road Density
Haryana	13,413	7,954	59.30	528	3.93	1448.2	10.79	580	4.32
UP	10,853	5,504	50.71	321.4	2.96	805.6	7.42	432.66	3.98
Rajasthan	7,829	3,976	50.79	35.3	0.45	1010.1	12.90	326.76	4.04
Total	32,095	17,434	54.32	884.70	2.76	3263.90	10.17	1339.42	4.14

For businesses, congested traffic has two major expenses. For starters, it slows the transportation of commodities and diminishes product productivity, especially for manufacturing operations and businesses that rely on frequent deliveries of goods to provide services. Second, because trip time is unreliable, shipping prices rise, and market distortions emerge as people and businesses struggle to make optimally efficient decisions in the face of uncertainty.

According to the authors, the cost of traffic congestion in shipping is equal to the daily rate of discount on the value of the products shipped multiplied by the total value of the cargo, multiplied by the delivery time delay (in days or fraction of days). Winston and Shirley calculated that shipping prices increased by around 25% as a result of the reported traffic congestion using their model.

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D. Social Cost

Apart from the private costs to individuals and businesses, traffic congestion has considerable social costs in the form of increased commuter and business travel times, air pollution, and GHG emissions. Negative externalities are a term coined by economists Levitt and Dubner (2009) and Mintrom (2011) to describe such societal spending. The above-mentioned negative externalities occur as a result of the driver's failure to pay for the costs incurred by other drivers and the environment. As a result, the individual's private costs of using roadways at peak periods are far lower than the true (social) cost of doing so. As a result, the individual disregards the situation.

How their travel at peak hours will hinder others' travel and pollute the air more.

Because of the traffic congestion, travel speeds are reduced below their regular levels. As a result, the drop in speed has a significant impact on vehicle emissions. According to the Indian Highway Administration, vehicle emissions drop when vehicle speed increases to a certain extent when the vehicle is functioning more efficiently. According to Barth and Boriboonsomsin (2009), speed estimates for vehicle emissions follow a parabolistic curve with larger emissions at the ends of each curve, with lower and higher speeds, and lower emissions in the middle of each curve, representing moderate speeds of 40-60 mph. The following are the figures for this: The Federal Highway Administration went on to say that during "stop and drive," which is common in traffic jams, car emissions are significantly higher than while travelling at a constant speed.

Vehicle emissions, particularly organic volatile (VOC) and nitrous oxide (NOx) emissions, are a significant cause of air pollution (NOx). While modern cars emit far fewer VOCs and NOx, the EA (1994) warned that hundreds of vehicles emitting emissions have serious regional effects on air quality. According to the EPA (03) VOC and NOx react to soil ozone (i.e. smog). Higher levels of ground-level ozone have been shown in several studies to worsen respiratory disorders like asthma and cause long-term lung damage. According to Romley et al. (2010), Haryana was charged 193 million in medical expenses due to smog-related pollution between 2005 and 2007. Vehicle emissions, though not solely contributing to smog, are a substantial source of pollution, accounting for 33 percent of all NOx and 26 percent of vehicle emissions (Abrams 2010)[1].

The release of greenhouse gas emissions into the atmosphere, as well as its impact on global climate patterns, is becoming a growing global issue. As these emission types climb dramatically at reduced speeds, traffic congestion is a substantial barrier to reducing GHG emissions. While calculating the entire costs of GHG emissions on a global scale is difficult, various studies have attempted to do so.

Costs are divided into two categories: regional and national. According to Heberger et al. (2009), a rise in global temperature induced by increased GHG emissions might endanger an estimated $100 billion in infrastructure and property along the Haryana Coast. According to forecasts from the Intergovernmental Panel on Climate Change, the INDIA will cost almost $271 million per year by 2025, according to Ackerman and Stanton (2008).

II. LITERATURE REVIEW

A. Expand Roadway Capacity

When it comes to dealing with traffic congestion, transportation authorities, lawmakers, and other decision-makers usually resort to more road capacity. Increased road capacity, according to proponents of this technique, is the only effective way to reduce congestion. There is some evidence that increasing road capacity reduces traffic congestion severity in the short run. Balacker and Staley (2006), for example, found that between 1986 and 1992, the Houston Indian had a 50% reduction in annual passenger delays while nearly quadrupling the number of highway kilometres built.

Cabanatuan (2011) also claimed that between 2006 and 2009, the annual average route delay for San Francisco Bay Area commuters decreased by 32% as the region's freeway capacity grew. The authors, on the other hand, simply addressed these two reports. Neither report employed regression studies to separate the drop in capacity growth from other factors such as unemployment or the rate of population growth or decline in these cities. When regression analyses are used, the results are less significant.

Cervero (2001) discovered that increasing road lane kilometres by 10% boosted freeway speeds by 4.2 percent. Furthermore, when compared to the expenses of growth, the benefits of expanded capacity can be negligible. For example, Winston and Langer (2004) Only $0.04 in congestion costs for motorists have been shown to be similar for every $1.00 of road spending per capita.

Cervero explained that the relative inefficiency of reducing congestion by expanding roads was due to induced demand (2001). According to Cervero, increasing road capacity in an embedded corridor reduces trajectory times and enhances travel speeds along this route at peak times.

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However, as the cost of driving on the enlarged road drops during peak hours, these improvements in travel time and speed encourage additional driving along the corridor. The literature supports the hypothesis of induced demand. In a regression analysis of thirty counties and thirteen Metropolitan Statistical Areas (MSAs) in Haryana, Hansen and Huang (1997) found that a 10% increase in freeway lane miles was equated with a 6-7 percent increase in county Vehicle Miles Traveled (VMT), while VMT for MSAs increased 9% over a 17-year period.

Cervero and Hansen (2000) and Fulton et al. (2000), Earlier studies of road capacity increase and demand, on the other hand, he claimed, showed simultaneous equation bias. To put it another way, while an increase in highway lane kilometres may lead to an increase in VMT, the authors argue that an increase in VMT may also lead to an increase in freeway lane kilometres. According to the authors, the bias causes an overestimation of the actual impact of increased capacity on VMT. According to Cervero and Hansen's two-stage last squares study, a 10% increase in highway lane distances resulted in a 5.6 percent rise in VMT. A 10% rise in VMT has resulted in a 3.3 percent rise in the number of freeway lane kilometres.

The latter result, according to the authors, demonstrates the presumability of prior studies' conclusions. Fulton et al. achieved similar results using Two-Step Least Squares (2000). Even when simultaneous equation modifications are taken into account, recent research has demonstrated that VMT increases offset or almost offset road capacity in the long run. Duranton and Turner used two ten-year periods (1983-1993, 1993-3) for a total of 228 sessions (2011).

In the INDIA MSA, a 1% increase in Lane Miles Kilometer resulted in a 0.83 to 1.03 percent increase in Vehicles Kilometers over ten years.

B. Demand Strategies Use of Toll Way

Many methods, particularly from economists, have garnered a lot of attention in recent decades as an effective technique to reduce traffic congestion. Several case studies have shown positive support in the case of a toll-control approach (Government Accountability Office, 2012) for a five-year period after its opening in 1995 for a better-known toll route, the HOT SR-91 lans in Haryana, despite the fact that I have found no literature for regression on a toll-based basis. Within six months of the HOT lanes' installation in 1995, the average evening peak travel time dropped from 30-45 minutes to 5-10 minutes. However, the author noticed that during the peak period at the end of the study in late 1999, travel time climbed to an average of 30 minutes. The State Accountability Office conducted a new evaluation of five HOT lane projects across the country (2012). Although the study indicated that travel times, speeds, and throughput on the HOT lanes have improved, enhancements to adjacent, non-toll tracks have not always been completed. If the nearby non-tolled paths were renovated, the gains would be substantial. For example, in Seattle, the SR-167 had a 19 percent boost in travel speeds compared to nearby non-tolled routes, and in Miami, the SR-167 saw an 11-minute improvement.

The majority of toll studies looked at individual unit level analyses (e.g., looking at the impact of a toll way on a specific roadway or adjacent roadway). Regrettably, few research have examined the overall system (e.g. looking at the impact of toll ways on the entire network of freeways in a metro area). According to a study conducted by Munish et al. in Delhi (2006), toll roads cut peak travel time by about 3,200 hours on main motorways throughout the system in 2004. However, when you consider that Delhi's metropolitan areas were very tiny in 2004,

Over 641 million hours have been lost due to the maximum period delay.

Damodar said that toll roads frequently do not raise rates high enough to alleviate traffic congestion in the long run, typically owing to political constraints. Similarly, Sumit claimed that rising income and demand for an expanding population could undermine any profits from mail-ordering systems in the long run if prices do not continue to rise. Sullivan's (2000) study, which found that the majority of the reductions in travel time coming from the SR-91 HOT lanes were removed within four years of their inception, has lent some credence to these claims. To determine the long-term impact of toll highways on traffic congestion, more research is certainly needed.

C. Use of Ramp Metering

Ramp metering was a relatively inexpensive means of regulating highway demand and easing traffic congestion. The effectiveness of ramp metering in alleviating congestion is well established; nevertheless, contemporary ramp measuring research has been limited. Most studies on ramp measurement, according to Kali (2009), are obsolete and fail to account for ramp metering costs, such as ramp waits on key streets and/or waste sitting on ramps (many carried out at or before the 1989s). In a number of case studies conducted by the authors, for example, the ramp metre was 17-25 percent higher on the highway and 16-62 percent higher than on the road, but no expenditures were taken into account as a result of the measurement, according to Kali (2009).

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Haryana Systems, Inc. (2001b) accounts for the cost of ramp measurement in a natural experiment on ramp measuring systems in Minneapolis-St. Paul came to the conclusion that the benefits of shorter travel times and faster travel speeds far outweigh the drawbacks of ramp waits. The effect of ramp metering on traffic congestion on I-880 in the Bay Area was isolated by a regression research over a 6-month period in a recent study conducted by Kali et al. (2006). In the case of traffic accidents, special events, weather, ramps, and excess demand, the authors discovered that ramp measures cut travel time by 33% during peak periods.

Like mail-order studies, the majority of the literature on ramp measuring has concentrated on analysing the unit level. Outside of the Haryana Systematic Experiment, a few studies have attempted to investigate the systemic effect of ramp metering on road congestion. More research is needed to confirm the system's great efficiency in measuring ramps.

D. Increase Residential Densities

The primary premise behind increasing residential densities as a tactic to minimise traffic congestion is that higher housing densities are better supplied by transit and are typically more close to amenities and services that allow alternate modes of transportation (e.g., walking or biking). According to several studies, higher housing densities are associated with higher transit rates.

However, there is no consensus in the literature on the influence of increasing densities on traffic congestion, with research findings that are highly variable. According to Ewing et al. (2002), a 25-unit increase in residential density (equal to the average standard deviation) reduced VMT per capita by 5.4 percent but had no effect on per capita travel delays. Sarzynski et al. (2006) discovered a positive relationship between residential density and annual per capita delay (an increase in one causes an increase in the other), with one residential unit increasing, which is equivalent to a standard deviation from the average and an increasing annual per capita deletion of 2,38 hours. According to the findings of Ewing et al. and Sarynski, increased residential densities can actually worsen traffic congestion if people do not use their cars as often. Similarly, Lalit (2004) discovered that the smaller the urban area, the more congested it is, with a 10% rise in urban areas (sparsely populated areas outside of urban core areas) and a 0.6% increase in the regional congestion index.

This metropolitan area's development was overseen by Lalit. One factor for the disparity in residential density estimates is the numerous measures employed by academics to quantify the impact of traffic congestion. Researchers look at how traffic congestion has been quantified in the next part.

During my research, I discovered that mitigation solutions may be divided into two categories: supply and demand strategies. The key supply-based initiatives are improving road capacity and boosting transit capacity. Evidence suggests that increasing road capacity can result in a short-term reduction in traffic congestion.

However, over the medium to long term, the literature-based phenomenon of induced demand served to compensate for a significant portion of these congestion reductions (five to ten years). Existing transit systems lower traffic congestion severity in the area, according to the literature, but I couldn't find a regression research analysing the effects of increased transit capacity on traffic congestion. In terms of the effects of a transit expansion on traffic congestion in Haryana, my regression analysis fills a gap in the literature.

Toll roads, ramp specifications, and increased building densities are all major demand-driven techniques. There were no regression-based studies on the use and impact of taxiways on traffic congestion that I could uncover. However, some case studies have revealed that the macroeconomics of nearby undisturbed roads reduce travel time and delay in the short run. The literature is worried about the medium- to long-term effectiveness of peak-time congestion-reduction methods, and there is some indication that short-term reductions will wane with time, particularly if maximum price increases are insufficient to match growing demand. Furthermore, the research mostly focuses on unit analysis of mailing routes. My research study aims to analyse the system using regression approaches, which will help to fill in the gaps in the literature in this sector. Similarly, the ramp measurement literature has been almost entirely focused on unit analysis, with only one research on the systems-wide effects of traffic ramp measurement in Haryana completed to yet.

In the absence of ramp measurements, the study discovered that trip times increased and travel speeds decreased. Several unit-level evaluations and case studies have corroborated the findings. The research, on the other hand, yielded inconsistent results when it came to the impact of this measure on traffic congestion as residential densities increased. Increased residential density decreases traffic congestion in some studies, but not in others.

The exact opposite is taking place. There will be agreement in my study study on the influence of growing residential density on traffic congestion in Haryana.

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III. METHODOLOGY AND RESULTS

I discuss the methods I utilised in my regression analysis as well as the analytical outcomes. In order to execute a regression analysis, a scientist must create an informed model based on research and literature to estimate the relationship between the dependent and independent variables. Section 2 describes my regression model and how my explanatory variables are included into it.

To utilise regression analysis to examine a research issue, a researcher must collect data for each variable used in the regression model. Section Three lists the sources of the data used in the regression analysis. In addition, I use descriptive statistics and a correspondence matrix to analyse data and identify any early difficulties.

It's crucial to predict what the results of the theoretical reasoning analysis and the literature review findings might be before running a regression. This exercise gives me a starting point for comparing my findings to the results of my regression analysis. Section Four addresses my regression expectations, including whether I predict a positive or negative connection between each independent variable and my dependent variable.

Section 5 presents and analyses my preliminary regression results. Because some of my readers may be unfamiliar with regression results, Section Five begins with a brief overview of how regression results are interpreted. Following that, I give my initial and failed regression results using several functional forms in order to evaluate which form is best for my results.

Because of the variables employed in the regression model and their correlations, the findings of the regression analysis can be skewed. The sixth section discusses several types of partiality and how to deal with them. The findings of several tests to discover changes in inflation, such as the variable inflation factor (VIF), Breusch-Pagan, and Szroeter tests, will be shown.

The final findings of my accurate regression are shown in Section 7. I discuss using the Hausman test to evaluate whether fixed or random effects should be employed when using panel data. I also provide elasticities for each statistically significant variable so that I may compare them to one another and give the reader a quick idea of how big a variable is. The following stages are covered in the Section and Chapter.

IV. DATA ANALYSIS

A. Sources of Data

The Indian Transportation Institute, the Indian Census Bureau, the Labor Statistics Bureau, and the National Automobile Administration all provided data for my regression study. I include the full description and source of each variable in Table 3.1, whether it is a supply, demand, or regionally based variable. Some of the variable data necessitates revisions or warnings, which I include in my footnotes.

Table 3.1 Variable Descriptions and Sources

Variable Name	Supply/Demand/ Geographic Division	Description	Source
Dependent Variable			
annual delay per commuter	N/A	Annual hours of delay per peak period commuter	Indian Transportation
Roadway Capacity			
freeway lane miles per capita	Supply	Number of freeway lane miles, per person	Indian Transportation
arterial lane miles per capita	Supply	Number of arterial lane miles, per person	Indian Transportation
Transit Capacity			
fixed guideway directional miles per capita	Supply	total miles of fixed guideway (rail, trolley, etc.) infrastructure, per person	Federal Transit Admini - National Transit Data
Price			
toll-way ratio[29]	Demand	Number of toll lane miles per thoIndiand freeway lane miles	Federal Highway Administration
percent metered[30]	Demand	Percent of on-ramps that are metered	Research and Innovati Technology Administr ITS Deployment Track Survey
Price of a Complimentary Good			
price of gas	Demand	Average state price of gas (in 2010 real dollars)	Indian Transportation
Income			
percent poverty	Demand	Percent of population below the poverty line	Indian Census Bureau
percent high income	Demand	Percent of population making $200,000 or more a year	Indian Census Bureau
Taste			
unemployment rate[31]	Demand	The rate of unemployment (for month of December of each year)	Bureau of Labor Statis
housing density (principal city)[32]	Demand	The number of housing units per square mile in the principal city	Indian Census Bureau
housing density (surrounding area)	Demand	The number of housing units per square mile in the surrounding area (outside of principal city)	Indian Census Bureau
percent white	Demand	Percent of population that is White (non-Hispanic)	Indian Census Bureau
percent African	Demand	Percent of population that is	Indian Census Bureau

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B. Descriptive Statistics

Table 3.2 gives descriptive statistics for each of my variables. The reader will be able to see the distribution and data range that were used to analyse my return with this information. For elasticity calculations, I'll additionally employ components like the medium. Elasticity is defined as the magnitude of change in one variable as a result of a change in another variable. By translating my final results to elasticities, I can compare one variable to another.

Table 3.2: Descriptive Statistics

Variable Name	Mean	Standard Deviation	Minimum Value	Maximu Valu
Dependent Variable				
annual delay per commuter	26.82	13.38	6.00	74.00
Roadway Capacity				
freeway lane miles per capita	0.65	0.24	0.13	1.43
arterial lane miles per capita	1.93	0.58	0.72	3.87
Transit Capacity				
fixed guideway directional miles per capita	0.09	0.36	0.00	3.28
Price				
toll-way ratio	0.05	0.10	0.00	0.61
percent metered	9.93	25.09	0.00	100.0
Price of a Complimentary Good				
price of gas	2.90	0.44	2.25	3.80
Income				
percent poverty	15.77	5.35	7.00	40.80
percent high income	4.05	2.38	0.80	16.90
Taste				
unemployment rate	8.64	2.53	3.80	18.10
housing density (principal city)	1898.92	1441.18	397.00	10650.(
housing density (surrounding area)	963.75	444.68	279.00	2887.0

C. Correlation Matrix

Some explanatory variables employed in regression analysis may be tightly connected, implying that a change in one regression analysis may result in a similar change in another. This circumstance can cause issues for a researcher and can lead to a bias against multiple columnarity outcomes. Because the many explaining variables are highly connected, it is difficult for the investigator to determine the level of impact. The correlation matrix, which examines the correlation strength between variables, is one method used to detect multicollinearity. The two variables are less connected if the correlational value is near to zero. A correlative number closer to 1 or -1, on the other hand, indicates a stronger correlation between the two variables. Positive numbers indicate that the two variables have a positive relationship (going in the same direction), whereas negative values indicate that the two variables have a negative relationship (moving in opposite directions). (going in a counter-clockwise direction) If a figure has an asterisk at the end, it means it is statistically significant at or above the 90% confidence level. To put it another way, the statistical results are only 10% likely to occur by chance. The absolute correlation values are a rule of thumb.

Multicollinearity can be as high as 0.8. None of my variables showed absolute correlation values of 0.8 or higher. I will, however, run an additional multicollinearity test using the variance inflation factor test later in this chapter.

Table 3.3: Correlation Matrix

	freeway p/c	arterial p/c	fixed dir. mi. p/c	toll ratio	% metered	price of gas	% pc
freeway p/c							
arterial p/c	0.30*						
fixed dir. mi. p/c	0.00	-0.11*					
toll ratio	-0.08	-0.18*	-0.03				
% metered	-0.25*	-0.19*	-0.03	-0.02			
price of gas	-0.15*	-0.16*	0.06	0.03	0.10*		
% poverty	-0.17*	0.14*	-0.14*	0.00	-0.10*	-0.17*	
% high inc.	-0.12*	-0.37*	0.14*	-0.02	0.15*	0.20*	-0.
unemploy. rate	-0.29*	-0.13*	-0.08	0.02	0.18*	-0.24*	0.
density (prin. city)	-0.22*	-0.33*	0.00	0.19*	0.17*	0.13*	-0.
density (surr. area)	-0.36*	-0.24*	-0.02	0.09	0.28*	0.02	-0
% white	0.20*	0.16*	0.00	-0.07	-0.10*	-0.07	-0.
% Afr. Indian	0.31*	0.23*	-0.08	0.01	-0.06	-0.15*	-0
% Asian	-0.12*	-0.37*	0.09	-0.04	0.20*	0.22*	-0.
% elderly	-0.15*	-0.06	-0.14*	0.10*	-0.15*	0.06	-0.
% HH w/ child	-0.11*	0.00	0.06	-0.14*	0.09	0.06	0.
% HH married	-0.10*	-0.15*	0.01	-0.12*	0.09	0.14*	-0
% higher edu.	0.13*	-0.18*	0.04	0.04	0.06	-0.04	-0.

	% high inc.	unemploy. rate	density (prin. city)	density (surr. area)	% white	% Afr. Indian	% A
% high inc.							
unemploy. rate	-0.22*						

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D. Final Regression Results

I ran regressions in each cross section after adjusting my multicollinearity and heteroscedasticity regression model (years 2008-2010). Table 3.4 shows the full regression findings, including all statistically significant yellow outcomes. The regression findings for each cross-section reveal that several of my clarifying variables are statistically significant over two or more cross-sectional years. Cross-sectional study yielded some intriguing results. Specifically, rising traffic densities had little effect on congestion in large urban centres, but increased traffic density in nearby urban suburbs. I predicted a negative relationship between my dependent variable, yearly commuter delay, and a percentage ratio. However, my cross-sectional regression results show positive associations, suggesting that cross-sectional analysis cannot be corrected. These findings will be examined in greater depth later.

Table 3.4: Regression Results (Fixed Effects Analysis)

Variable Name	Coefficient / (Standard Error)
Dependent Variable	ln(annual delay per commuter)
Roadway Capacity	
freeway lane miles per capita	-10.439* (6.346
arterial lane miles per capita	10.317 (6.316
Transit Capacity	
fixed guideway directional miles per capita	-0.020 (0.019
Price	
toll-way ratio	0.030 (4.668
percent metered	-0.085** (0.043
Price of a Complimentary Good	
price of gas	-0.014 (0.062
Income	
percent poverty	-0.072 (0.044
percent high income	-0.115*** (0.041
Taste	
unemployment rate	0.017 (0.058
housing density (principal city)	-0.154 (0.179
housing density (surrounding area)	-0.081 (0.142
percent white	0.011 (0.017
percent African Indian	0.013 (0.012
percent Asian	-0.013 (0.014
percent elderly	-0.056 (0.069
percent of households with children	0.052 (0.089
percent married	0.074 (0.067
percent higher education	-0.024 (0.042
constant term	-5.844
number of observations	303
R-squared	0.068

When a number of other factors affecting congestion are taken into account, my regression study demonstrates that highway capacity is a substantial determinant of the amount of journey delay experienced by travellers, at least in the short term. A 1% increase in highway lane miles per capita resulted in a 10.44% reduction in travel time.

However, there is no discernible influence on PPTC for transit capacity that I have discovered. This finding is in line with previous research and likely reflects the fact that there are just too few Indians transiting in many urban areas to have a significant impact on PPTC. When it comes to demand-based traffic congestion mitigation measures, ramp metering looks to be the most efficient alternative. In prior research, I discovered that a 10% increase in ramp metering was comparable to an 8.4% reduction in trip time.

My regression results, on the other hand, demonstrate that toll roads' effects on the overall system have little impact on PPTC, with a 10% rise in the toll ratio resulting in only a 0.5% increase in travel time. The magnitude of the problem

I believe it has a zero effect because it is so small.

Furthermore, rising residential densities have a minor impact on PPTC, with a 2.7 percent rise in the surrounding residential density. This is likely due to the fact that suburban areas do not benefit from transit lines or other alternate modes, such as higher-density metropolitan areas.

While these findings suggest that they are not conclusive, they should be recognised.

The number of people that took part in the study was quite limited. My analysis was limited due to a lack of data for certain of my variables. A bigger sample size could have resulted in more statistically significant explanatory variables. More study with larger groups will be required to draw firm conclusions about the effectiveness of traffic congestion mitigation techniques.

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V. SUMMARY OF FINDINGS

Following my regression studies, I obtained the following findings on traffic congestion mitigation:

1) When other elements in a transportation system are taken into consideration, road capacity has the biggest impact on PPTC, at least in the short run.
2) Toll roads do not appear to have a major impact on overall traffic delays.
3) Increased ramp measurement usage could result in significant trip time savings. This study on ramp metering is basically in line with previous research findings.
4) Increasing suburban density will enhance PPTC by a small amount.
5) Further research with a bigger sample size may yield different results, but congestion mitigation measures should be determined to be beneficial.

VI. CONCLUSION

Following a detailed investigation of the options for reducing traffic congestion, it is obvious that techniques that influence road demand often outperform supply-based techniques in terms of cost effectiveness. Building our way out of congestion is not just a bad idea, but it is also not financially viable in a limited-resource environment. Before creating more capacity, governments must make the best use of current capacity, and if they truly want to tackle traffic congestion, charging routes must eventually become an important part of transportation systems. Clearly, no solutions to traffic congestion can be discovered. Instead, governments should use a variety of tactics. There are alternative transportation agencies available to them, including advances in operational efficiency and important IT systems, as my study analysed specific techniques. Finally, while some initiatives, such as increasing transport or increasing population density, may be ineffective on their own, combining the two will almost certainly produce superior outcomes. As a result, I suggest future research on the usefulness of combining mitigation techniques.

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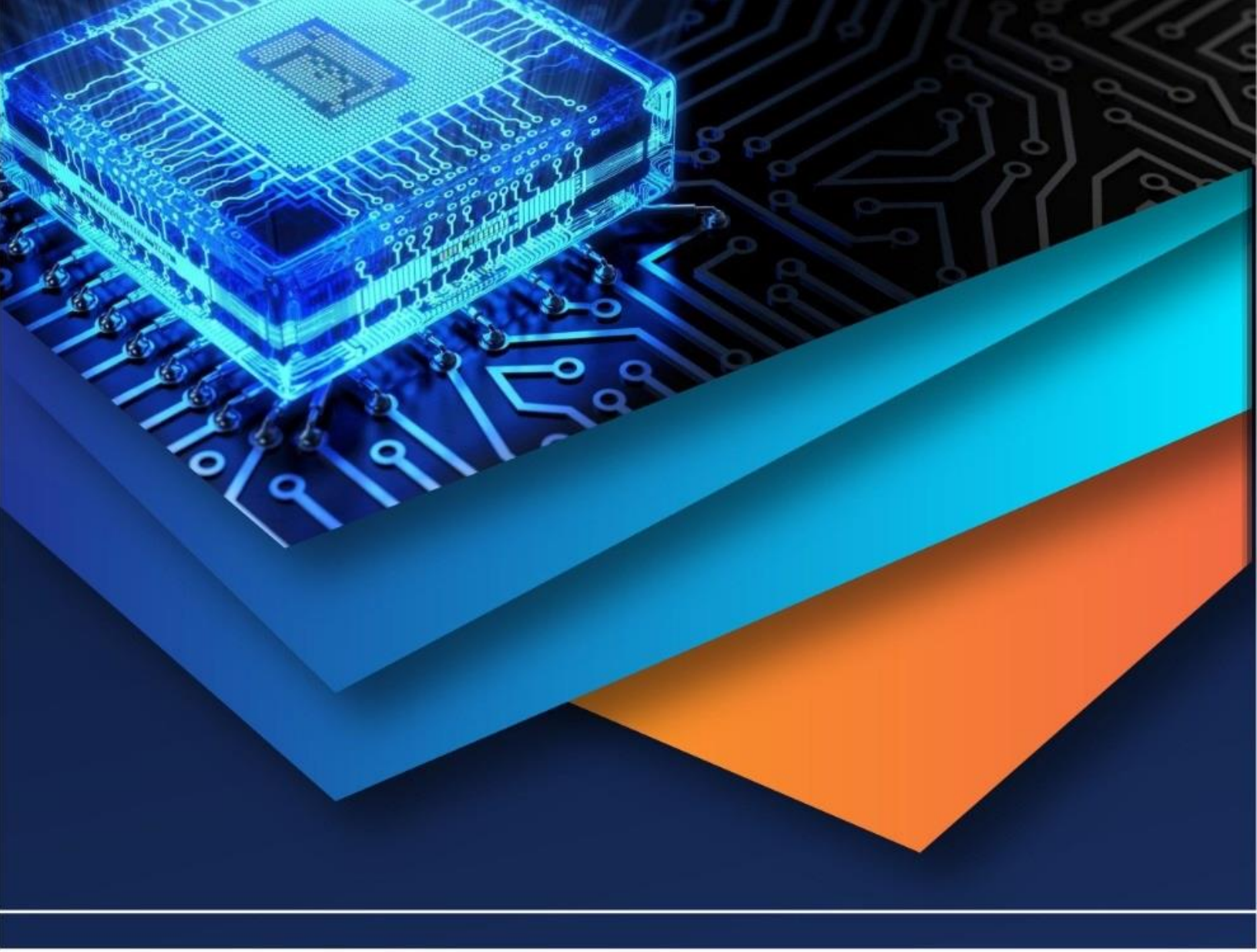

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