ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR

CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.01 (2025)

MATLAB-BASED SIMULATION AND STATISTICAL ANALYSIS OF FUEL PRICE IMPACT ON URBAN MOBILITY: A STUDY IN LAHORE

[1]Khizar Abbas, [2]Ali Asghar ,[3]Muhammad Waqas
[1]Department of Mechatronics and Control Engineering, University of Engineering and Technology Lahore, Pakistan (Khizarabbas103@gmail.com)
[2]The Department of City and Regional Planning, University of Engineering and Technology Lahore, Pakistan (aliasghar607gb@gmail.com)
[3]Solid State Physics , university of the Punjab, Lahore, Pakistan (m.waqas.pu@gmail.com)
Corresponding author: Khizar Abbas*(Khizarabbas103@gmail.com)

Abstract
Urban mobility patterns react substantially to fuel price changes because these price changes force commuters to alter their travel modes and trip frequencies and their complete transport behaviors. The development of public transport infrastructure in Lahore city provides a setting where fuel cost increases trigger substantial changes in how people commute. Travel patterns in the Baghbanpura and Begumpura neighborhoods receive analysis regarding their response to changing fuel prices because these surroundings connect directly to the Orange Line Metro. The study explores how elevated fuel prices affect personal automobile usage together with public transportation dependency and ridesharing adoption and analyzes how income level and career status influence travel preferences. The research study integrated both survey tools for statistical evaluation in SPSS as well as MATLAB-based computational modeling for simulation analysis. SPSS measured the connection between fuel price alterations and travel patterns and MATLAB executed predictive analyses to predict future changes in vehicle ownership and public transport adoption. The research shows that higher fuel expenses decrease travel outings yet automobile ownership remains in upward trend because of limited price sensitivity against car dependency. Lower-income populations show greater sensitivity to price change than higher-income groups which makes them more likely to opt for public transport but the higher-income population is less impacted. Urban sustainability requires multiple transportation improvements because this research demonstrates that city authorities must enhance public transportation effectiveness as well as support bicycle walking and provide vehicle efficiency rewards. The research findings provide essential guidance for government officials to establish integrated transportation approaches which combine financial suitability with long-term urban development in Lahore together with similar fast-growing cities.

Keywords: Fuel Price Fluctuations, Urban Mobility, Travel Behavior, Public Transport Usage, MATLAB Simulation, Statistical Analysis.

1. Introduction

Transporting people and goods from one place to another requires energy, which accounts for around one-fourth of all the energy used by people. By bridging the gap between the production and consuming markets and by making it easier for people to travel, transport supports economic growth both directly and indirectly (IEA & OECD, 2009). Additionally, one of the main consumers of petroleum products is transportation. As an oil-importing country, Pakistan spends a significant portion of its export revenues on importing crude oil and petroleum products, diverting funds that could otherwise be used for other forms of development (Afia Malik, 2019). Transportation uses over 59% of Pakistan's liquid fuel consumption and accounts for around 34% of the country’s total final energy consumption, making it the second-largest energy consumer behind the industry (Pakistan Vision 2025).
More than half of oil is consumed by the electricity sector, followed by industry (8%), and then by air, sea, and land transportation (Government of Pakistan, 2018). Transport accounts for over 15% of Public Sector Development Projects (PSDPs), 10% of the GDP, and employs over 6% of the labor force in Pakistan (Pakistan Vision 2025). As Pakistan’s economy grows, the demand for road transport and energy will rise, with the number of registered vehicles expected to increase from 17 million to 30 million by 2025 (Afia Malik, 2019).

Transportation is a major contributor to global CO_2 emissions, generating 25–30% of the world's energy-related emissions (IEA & OECD, 2009; OECD & ITF, 2010). The International Energy Agency (2009) predicts that global transport energy demand and CO_2 emissions will rise by over 80% by 2050, exacerbating sustainability challenges, including reliance on fossil fuels, traffic safety issues, and environmental degradation (Ribeiro et al., 2007). Such challenges are particularly acute in rapidly developing countries like Pakistan (World Bank, 2006). Sustainable development of the transportation industry could help mitigate these issues, though the costs of accidents, pollution, and congestion are rising with urbanization and sprawl (Dalkmann et al., 2011).
The increase in fuel costs directly modifies the options people have for travel and specifically alters how passengers view the use of public transportation. Students who sustain themselves with scholarships and loans experience a major impact specifically due to the rising fuel costs (Mohd Azizul Ladin, 2014). This paper studies the travel behavior modifications caused by rising fuel prices within the Lahore districts of Baghbanpura and Begumpura. The Orange Line metro serves these areas perfectly for research on fuel cost effects on transportation mode changes and public transport adoption as a substitute. A research design using mixed methods applies statistical SPSS data analysis to survey results while implementing MATLAB computation to measure relationships between fuel cost changes and vehicle purchase patterns and public transit usage. The research investigates the impact of economic status alongside employment types while studying fuel pricing changes on transportation decisions to build sustainable urban transportation frameworks in Lahore and other Pakistani cities.

2. Literature Review

2.1 In developing countries

2.1.1 Malaysia

2.1.1.1 Respondents' Travel Patterns Before the Increase in Fuel Prices
In Malaysia, a study of the impact of fuel price fluctuations on travel behavior was carried out. Results of the survey indicated that 73% of the respondents used their private vehicles more than three times a week for going to work while 19% mentioned using their cars less than or equal to twice or once a week. At the same time, 8 per cent of respondents never used private vehicles for workplace travel. 33 percent reported that they use personal vehicles more than three times a week for the leisure trips, while 8 percent said they never use private transport for leisure activities.
More breakdown of travel habits showed that those who did not utilize their personal vehicle for work or play was predominately dependent on public transportation. In addition, 82.5 percent of the respondents took their own vehicles for personal trips during workdays, such as banking, shopping and lunch breaks. These included most of them, who drove themselves or participated in carpooling arrangements to their workplace.
When it comes to the usage of public transport, 44.5 percent of respondents stated that they never took public transit for daily commuting, and 22.5 percent said they used public transport three or more times per week. In particular, of the regular public transport users, young workers aged 18–25 years and monthly income ranging between RM1000 and RM3000 were mostly observed (Rohani & Pahazri, 2018).

2.1.1.2 Comparison of Travel Patterns Before and After the Fuel Price Increase
The study also looked into how rising fuel prices affect commuting behavior. There were noticeable reduction in frequency of private vehicles usage in all trip types shown by the

findings. The amount of traveled decreased from 2 to 7 percent among respondents who had previously used the vehicles three or more times a week.

As is evident, after the fuel price increase 9.5% of respondents were willing to stop using their cars and take public transport - something they were not doing before the increase. Also, more and more people were using public transportation at least three times per week. About 14 percent less respondents had used public buses and added to their daily commutes the previous year.

In addition, it probed into the alternative travel strategies adopted by the commuters to the fuel price hikes. After the fuel prices went up there was a notable increase in carpooling, with 17.2 percent of respondents choosing to use a car instead of a solo vehicle. It signals that commuters are abandoning more expensive methods of travel as a result of financial concerns (Rohani & Pahazri, 2018).

2.1.1.3 Alternative Travel Practices in Response to Rising Fuel Prices

The study also examined other adaptive measures that commuters took after fuel price increases. A response was the move from the use of private cars to motorcycle travel. The results from the survey showed an increase in motorcycle usage of 6% among users who were taking the car for riding to work after the fuel prices increased.

It also surveyed how respondents come to change their attitude towards motorcycle use. A comparison between responses before and after price increase showed that motorists who were made to consider motorcycles as cost effective and viable alternative to cars increased. This shift emphasizes that commuters can make decisions based on the fuel price hike by trying out the cheaper and fuel efficient transportation modes (Rohani & Pahazri, 2018).

2.2 In developed country

2.2.1 Netherlands

Previous studies show that fuel price elasticity relationship has been widely studied and this has been done mostly in developed countries, such as the Netherlands. Both of these can be grouped into the literature generally, under two main perspectives. The first perspective looks at how fuel prices, car usage and household attributes are related. While there are many studies that document how car usage responds to changes in fuel price, these changes can have a significant effect on vehicle miles traveled, car ownership or both. However, there are some indications that this effect is not fully reversible, as the response of individuals depends on: necessity, commuting distance, and providing alternative transport (Dargay et al., 1997; Gillingham, 2010b).

Empirical evidence supports this notion. For example, in Columbia, South Carolina, research demonstrated that fuel supply issues were an important factor in affecting travel patterns by asking people if they drove smaller, fuel efficient vehicles if there was less available fuel, or if they drove 'more judiciously.' A reduction of socio-recreational trips and, more generally, non-essential trips, accompanied this shift with public transport usage, at the most, only marginally increasing (Sacco & Hajj, 1976). Studies similar to this one had found that in Riyadh, fuel price hikes reduced the number of daily trips, especially for households with larger numbers of people living there (Koushki, 1991). Furthermore, income levels are just as important as they vary in fuel price sensitivity: lower income levels lead to less vehicular usage in response to increasing fuel costs, whilst higher income levels are less responsive to high fuel costs (Dargay 2007). This was reinforced in studies by (Hymel et al, 2010 and Li et al, 2011) which showed that higher fuel taxes lead to greater number of sales of fuel efficient vehicles but may not necessarily translate to proportional reduction in vehicle miles traveled.

The second type of studies relates fuel price on total fuel demand. Evidence in the literature of research in this domain often recommends that fuel demand is not very responsive to changes in price. For instance, Brons et al. (2008) demonstrated in both short and long run cases that gasoline demand was inelastic at least up to the short run, and price change mainly induced fuel efficiency and driving habits rather than the level of consumption. For example, in Spain, it was found that fuel demand was relatively price inelastic, but more income elastic, reducing fuel demand for private transport only among the lowest income groups because responses to higher fuel costs were more pronounced among those with lower income (Romero-Jordán et al., 2010).

While these studies are helping fill in some gaps in the fuel prices and travel behavior relationship, there still exists a major gap that cannot be addressed using these studies. Little work has been done however, on the effect that energy prices have on daily travel patterns by trip purpose. For instance, commuting trips are usually nonnegotiable but discretionary trips (shopping and leisure travel) may react more to fuel price variations. Second, although their behavior is not consistent, past research ({Sacco & Hajj, 1976; Yun & O'Kelly, 1997; Sugie et al., 2003}) indicates that travel behavior is drastically different between weekday and weekend periods, no studies have examined weekday versus weekend fuel consumption trends. Some researchers also suggest that fuel price elasticity of demand may be higher on the weekend as commuters have more flexibility in planning trips and therefore more adaptive travel choices on non-work days (Frondel & Vance, 2010).

To fill in these gaps, a study in the Netherlands was carried out to see how travel behavior is affected differently by fluctuations in energy prices by trip purpose and by the time of the week. A multi-group structure simultaneous equational model was applied in the study alongside a Seemingly Unrelated Regression (SUR) analysis that takes into consideration possible interdependencies among different travel behaviors. The data used for this analysis was a national activity travel journey diary survey, which provided comprehensive information on people’s story frequency, distance travel and mode choice.

The results from the Netherlands match earlier research that higher fuel prices lower vehicle usage and encourage substitution of fuel inefficient transport modes. Nevertheless, the study also showed that public transport adoption was not as universal as was thought, and in certain already developed urban areas having a strong transit network, commuters may already have optimised their mode choice, and therefore be less sensitive to additional fuel price increases. Therefore, this provides an important policy consideration: in advanced transit systems, incremental additional fuel price hikes may reach diminishing effect on reducing car dependency, whereas alternative policies, including congestion pricing or telecommuting incentives, might be more influential in shaping travel behaviour.

2.3 Determinants of Fuel Price Variation

2.3.1 The components of fuel price

2.3.1 Determinants of Fuel Price Variation

The change in crude oil prices is a function of multiple economic and policy determinants that either magnify or dampen the impact of changes in the crude oil prices on fuel price. These variations are dependant on four primary elements: exchange rate ‘flickness’, excise duty policies, value added taxed (VAT) changes, and mark up components, representing profit margins in the chain of the distribution of fuel. These factors are analysed and help to explain how different economic policies and market structures influence fuel price behaviour across regions. A recently studied example that analyzes fuel price variation across European countries over three periods: the first half of 1996, the first half of 1999, and the second half of 2000, shows that the combination of these two components cause an overall variation of fuel prices to the consumer (Delsalle, 2002).

2.3.1.1 Evolution of Exchange Rates

Exchange rate of the national currency against the US dollar is one of the key determinant of the fluctuations of fuel price, because crude oil is traded globally in USD. During the five years before 2000, the US dollar experienced a big appreciation against most European currencies, as much as 50% in Greece and 28% in Italy. Higher fuel prices for European consumers became the result of this appreciation as crude oil and refined petroleum products were imported and the rates of doing so increased proportionally; thus, the cost of such increased.

When the Euro came into existence in 1999, exchange rates of the 11 Eurozone countries were pegged to the €/$ exchange rate connecting the fuel prices among these countries. On the other hand, the fuel price volatility for non Eurozone countries was higher as they are not tied to the currency, allowing their own fluctuations to lead to higher volatility in fuel prices. As an example, fuel prices in Sweden had been less volatile as their currency depreciated less than the Euro's, while Greece had a higher currency worth of depreciation, putting their prices even more astray. Like the British pound, the fuel price trends in the UK deviated from the rest of Europe as the exchange rate fluctuation band was within a relatively narrow move of -9% to +3%, which then shielded the UK fuel prices from the global currency volatility (European Central Bank, 2024).

2.3.1.2 Excise Duties and Taxation Policies

Fuel excise duties have an important role in shaping final consumer prices and are particularly variable by countries. Despite this, some states only impose their set minimums coupled with rates according to the requirements of the European Union (Directive 92/82/EEC), while some others adjust their excise duty rates for economic as well as environmental reasons. In some countries, excises are used as a tool for public finance restructuring from labor taxes to environmentally motivated fuel taxation policies.

The principle of the fuel escalator is using excise duties to control fuel consumption and reduce emissions, whereby taxes on fuel were steadily raised above inflation. But this policy provoked public hostility, and in 2000, when big oil prices were increasing, it was also ended in light of the need to reconcile economic workability with political acceptability. Like Portugal's policy, Japan chose also to adopt a stabilizing mechanism by means of excise duty to damp sudden spikes in fuel price by using an ad hoc rule to change excise duty dynamically. The objective was to protect the consumers from the extreme volatility and maintain fiscal stability (Delsalle, 2002).

However, it can be argued that the intersection between exchange rate changes, excise duty handling, and other tax policy games has a crucial influence on fuel price variability among diverse areas over all. Knowledge of these determinants gives us valuable clues to formulating strategic pricing policies keeping in view the balancing of excessive fuel price fluctuations while ensuring economic stability and promoting sustainable energy use.

3. Methodology

The research approach for analyzing how fuel prices affect mobility in Lahore cities is presented in this section. The research utilized mixed methodologies which integrated survey-based SPSS statistical analysis with MATLAB computational modeling to evaluate travel behavior alterations completely. The research analyzes fuel price impacts on vehicle ownership together with trip frequency and public transport usage by collecting data at primary and secondary levels followed by statistical checks and linear regression tests to generate predictive simulations. A survey and model analysis combination using SPSS and MATLAB creates a comprehensive view of economic and transportation systems in Lahore.

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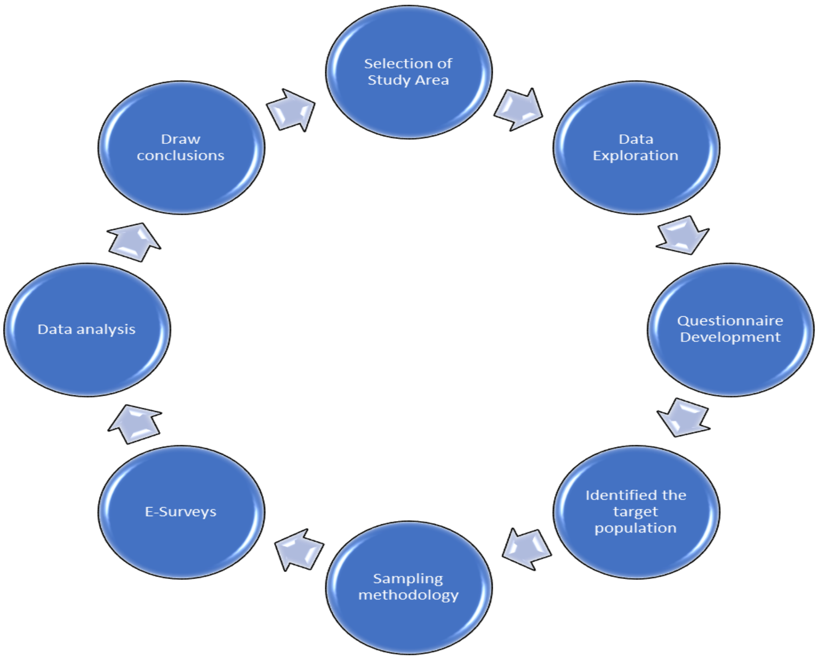

Figure 1 Flow Chart

3.1 Study Area Selection

The research will be conducted in the two neighborhoods of Baghbanpura and Begumpura in Lahore. The reason for their selection is their proximity to the Orange Line metro, which is a viable public transportation alternative to the residents. The areas are suitable to observe potential changes in travel behavior in response to fuel price changes because of the presence of the metro.

3.2 Data exploration

First of all, to make this report, we started to see the literature available on Google to see how can proceed on this topic. We started to search on this topic we found a lot of work on this topic from many developing and developed countries. We took out some important factors for our research like what is the travel before and after fuel price change and many others.

3.3 Questionnaire development

Development of the questionnaire for our research project involved key steps that we considered in making sure that it effectively collected data required for analysis. These include the first step, where the main factors and variables of our research topic are identified. Factors that were determined based on objectives of research and information needed to be gathered. We took time to carefully consider our research questions that would guide us in creating our questionnaire, with each question closely aligned with our research goals.

3.3.1 Identifying Target Population

Residents in such neighborhoods would comprise the target population of our study. Given this heterogeneity of population, it would mean targeting populations at multiple levels of incomes, different occupational levels, types of commuters such as non-commuters, owners or users of car versus other types of transports or even public or ride-hailing application users.

3.3.2 Sampling Methodology

A sample of 100 respondents was selected by a non-probability sampling technique, namely convenience sampling, considering the nature of the research and the time factor. Respondents were solicited from the neighborhoods of Baghbanpura and Begumpura. The questionnaires were distributed across different channels in order to cater to diverse groups. This can be done both online and direct distribution in the selected area.

3.4 E- survey

We created a Google Form for our survey. We shared the link with all group members. Each of us collected 33 responses. It took us several days to gather the required data because we sent the link of our survey to our friends, family members, and relatives living in Baghbanpura and Begampura Lahore. This method of distribution helped us to have a variety of responses for our analysis.

3.4.1 Data Analysis

Once we've looked through the data, we need to perform more advanced types of analysis:

- **Descriptive statistics**: Summary of the main trends such as the number of people moving from personal transportation to public.
- **Correlation analysis:** Investigate how fuel price changes are correlated with changes in travel behavior.
- **Regression Analysis** -allows for you to fit an explanatory relationship for travel behavior on account of prices in gasoline after taking account for variables that determine their incomes, educations.

3.5 MATLAB-Based Computational Analysis

3.5.1 Introduction to MATLAB for Fuel Price Impact Analysis

Glancing through the computational tool used, MATLAB, will be used to simulate the effect of fuel price fluctuation on urban mobility in Lahore in this study. The data can be processed in an efficient manner using MATLAB for statistical modeling and simulation of the fuel price fluctuations and its impact on transportation patterns. The methodology implemented for integrating real world data, carrying out statistical analysis and model run trend for travel behavior trends using MATLAB is given in this section.

3.5.2 Data Integration and Processing

To achieve accuracy in the computational analysis, historical fuel prices, vehicle ownership, travel behavior, and public transport usage in Lahore was collected from different source. The datasets were structured in MATLAB so that it could easily be processed without reads of external files. For MATLAB simulations, the key datasets used were:

3.5.2.1 Fuel Price Data

From 2013 to 2024, official records were manually incorporated into MATLAB to integrate the monthly average fuel prices from Lahore. This dataset will help to understand how fuel prices and its relation to it.

3.5.2.2 Vehicle Registration Data

Trends of registration of private vehicles by year were analyzed taking in consideration the total number of registered vehicles in Lahore. These data was important to validate the operational demand elasticity in relation to fuel price fluctuations.

3.5.2.3 Travel Behavior Data

Average daily trips per head and the proportion of passengers shifting to public transport in the years were incorporated. The datasets contain a behavioral perspective on commuting patterns, mode shifts and urban transport choices altogether.

3.5.3 Statistical Analysis and Modeling

To find trends and correlations between fuel price fluctuations and urban mobility parameters, MATLAB's statistical functions were used.

3.5.3.1 Correlation Analysis

The latter relationship was studied to determine how fuel prices modify Urban Mobility Metrics using MATLAB's correlation coefficient function (corrcoef). Using vehicle ownership, trip frequencies, adoption of public transport as proxies, this analysis evaluated how changes in fuel prices are correlated.

3.5.3.2 Regression Modeling

A linear regression model was developed in MATLAB to determine the quantitative impact of fuel price variations on vehicle ownership. The regression equation was formulated as:

$$V_t = \beta_0 + \beta_1 P_t + \epsilon_t$$

where:

- V_t represents the total number of registered vehicles at time t,
- P_t denotes the fuel price at time t,
- β_0 is the intercept,
- β_1 is the coefficient representing the effect of fuel prices on vehicle ownership,
- ϵ_t is the error term.

MATLAB's regression analysis function (regress) was used to estimate the model parameters and determine the statistical significance of the relationship.

3.5.4 Simulation of Fuel Price Impact on Urban Mobility

To predict how transportation choices in Lahore would change given likely future fuel price increases, MATLAB simulations were used.

3.5.4.1 Predictive Modeling for Vehicle Ownership

Vehicle ownership trend predictions were conducted through a predictive model by forecasting a change in vehicle ownership under different fuel price increase scenario. The Matlab was run to simulate 0% to 100% price hikes and corresponding private vehicle ownership changes.

3.5.4.2 Public Transport Mode Shift Analysis

To determine if the increasing use of fuel prices to encourage the uptake of consuming less public transport, MATLAB was used to develop the public transport adoption rate. Fuel price increment was simulated and a projected shift of public transport preference was simulated.

3.5.4.3 Sensitivity Analysis

Elasticity analysis was made to measure the responsiveness of vehicle ownership to changes of fuel price. Vehicle demand estimates were provided in terms of how sensitive they are to fuel price variations by MATLAB's computation methods. The elasticity formula used was:

$$E = \frac{\%\ \text{Change in Vehicle Ownership}}{\%\ \text{Change in Fuel Price}}$$

3.5.5 Visualization and Interpretation

Graphical representations were generated in MATLAB to visualize the analyzed trends and simulation outcomes. The following plots were implemented:

- A bar chart was plotted to illustrate historical fuel price variations over the study period.
- A bar chart displaying the increase or decrease in vehicle registrations in Lahore was plotted to analyze fuel price influence on private vehicle ownership.
- A line graph was created to show the predicted decline in private vehicle ownership as fuel prices increase.
- A bar chart was plotted to forecast public transport usage growth in response to fuel price hikes.

3.4 SPSS-Based Statistical Analysis

3.4.1 Introduction to SPSS for Data Analysis

Survey data collected on the use of various modes of urban mobility in Dhaka were statistically tested using SPSS (Statistical Package for the Social Sciences) to gauge the effect of variations in fuel prices on urban mobility. Quantifying relationships between transportation choices and changes in fuel pricing, fuel price changes were tested for data reliability, correlated, and regressed to quantify the software.

3.4.2 Data Preparation and Processing

They were compiled into SPSS for data analysis of the resident's responses to survey collected from Baghbanpura and Begumpura in Lahore. Socioeconomic factors (income, profession, vehicle ownership), commuters' behavior (trip frequency and commuting modes), and fuel price changes were included as dataset.

The cleaned and standardized data was used to run statistical tests before running.

3.4.3 Statistical Tests Performed

3.4.3.1 Reliability Test (Cronbach's Alpha)

Cronbach's Alpha reliability test was performed to ensure a consistent survey results. When above 0.7, we considered this value acceptable in order to ensure the collected data was statistically reliable for further analysis.

3.4.3.2 Correlation Analysis

A Pearson correlation test was conducted in SPSS to examine the relationships between:

- Fuel prices and vehicle ownership
- Fuel prices and trip frequency (commuting and non-commuting trips)
- Fuel prices and public transport adoption

The correlation values and significance levels were used to determine the strength and direction of these relationships.

3.4.3.3 Regression Analysis

A multiple linear regression model was applied in SPSS to predict the effects of fuel price increases on travel behavior. The dependent variables included:

- Private vehicle ownership
- Daily commuting frequency
- Public transport usage trends

The regression model identified whether fuel price fluctuations significantly influence mobility choices and quantified the extent of the impact.

4. Data analysis

4.1 Analysis using MATLAB

To investigate the impacts of the variations in a fuel price leading to changes in urban mobility in Lahore, the study conducted in this paper utilised the computational analysis based on MATLAB. Thus, MATLAB offered insight into the impact of rising fuel prices on vehicle ownership, travel frequency, and adoption of public transport using real world data, statistical modeling and predictive simulations.

This section will present the results of key findings from MATLAB simulation, with correlation and regression analyses, predictive modeling for vehicle ownership, and project the shift of travel behavior. Bar charts and line graphs are then used to visualize the results for fuel price trends and transportation choice patterns in Lahore.

4.1.1 Correlation Analysis

By simply using fuel price as the predictor variable and total registered vehicles in Lahore as the response variable lead to a correlation analysis of 0.99785, or a high correlation, which means that though the fuel prices increase, the total number of vehicles registered within Lahore actually continues to increase. This contradicts the accepted conclusion that such fuel price increases would discourage vehicle ownership. The strong correlation indicates that fuel price changes do not much impact vehicle ownership in Lahore, which might be because public transport options are limited and have less vehicle ownership for it. The trend shows that fuel price on its own is not a sufficient deterrent, other socioeconomic factors including income growth, urban expansion and cultural preference of private ownership need to be taken into account in transport planning.

On the contrary, the negative speaker (fuel prices, -0.98496) average daily trips which shows that when the fuel prices increase, the number of trips decreases. This demonstrates the monetary price that commuters are paying for high fuel prices which forces them to stay away from non necessary travel. This is in line with expectation but the question is: are commuters moving to public transport or just cutting their travel?

That is, the positive correlation (0.99833) between fuel price and public transport use indicates that higher fuel costs spur people to utilize public transport options. It strengthens the case for a well functioning public transport to take its place as the car is hit in a fuel price surge. Public transport in Lahore however, is too unreliable. Without expansion in transit infrastructure in step with rising demand, overcrowding and inefficiencies could make transit infrastructure ineffective in the long term.

4.1.2 Regression Analysis

The regression model succeeds in proving that there is a statistically significant relationship between changes in fuel prices and changes vehicle ownership trends, with an R square value of 0.99569, which means that more than 99.5% of the variance in vehicle ownership trends is explained by changes in fuel prices. Given this exceptionally high value, fuel prices clearly have a big sway in terms of registering new vehicles. Although rising fuel prices would be expected to deter vehicle purchases based on the assumption that higher costs would reduce vehicle ownership, the positive regression coefficient (7758.172196) suggests that vehicle ownership continues to increase.

A closer examination of this phenomenon implies that there are a better measure of determinal factors of vehicle ownership than fuel prices in Lahore. Factors pointing to continued rise in registrations include urbanisation, increased incomes of families, and inadequate alternative modes of transportation. Fuel costs may caution individuals from excessive usage of vehicles, but do not rule them from buying vehicles.

```
Correlation Analysis:
Correlation between Fuel Prices and Total Vehicles: 0.99785
Correlation between Fuel Prices and Average Daily Trips: -0.98496
Correlation between Fuel Prices and Public Transport Shift: 0.99833
Regression Analysis:
Regression Coefficients (Intercept, Fuel Price Effect): -291324.9165      7758.172196
R-squared Value: 0.99569
Elasticity of Vehicle Usage with respect to Fuel Price: 1.1698
```

Figure 2 MATLAB Results for Correlation and Regression Analysis results

4.1.3 Fuel Price Trend Analysis

The analysis of fuel price trend shows that fuel price has been increased from 2013 to 2024 in Lahore. The upward trajectory is due to the global oil prices as well as to the domestic economic ones, such as inflation, currency devaluation, and the energy policy changes. Fuel has become too costly, especially to lower income commuters, the charge that rises steadily.

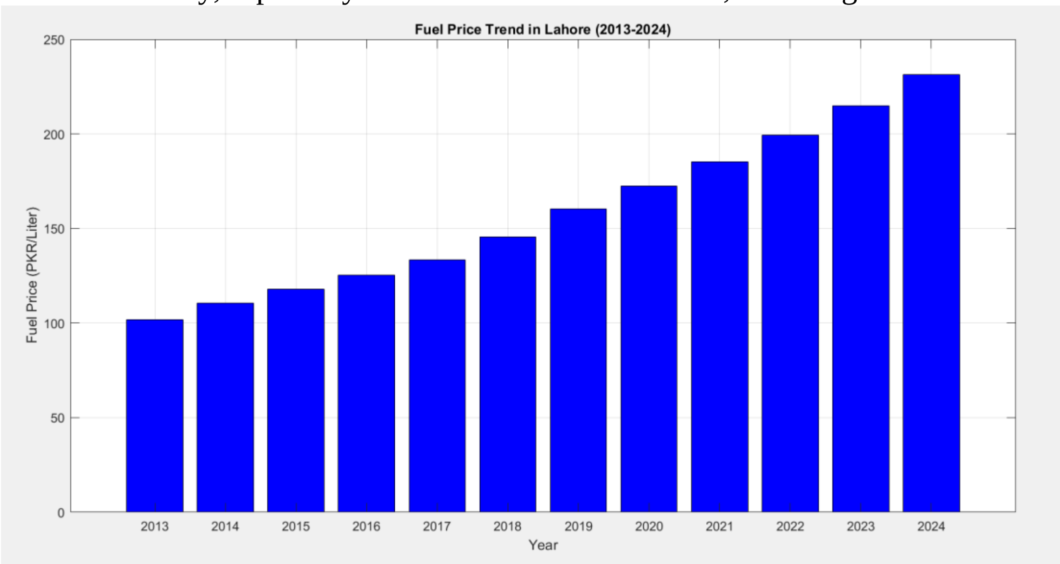

Figure 3 Fuel Proce Trend Analysis

This trend adds weight to the attractiveness of fuel efficiency policies, alternative and renewable energy sources and transport subsidies for the lower income groups. Although the rise in fuel prices might be an inexorable economic consequence, policymakers should counteract its implications by boosting in energy efficient motor vehicles as well as making public transport cheaper.

4.1.4 Vehicle Registration Trend

Despite rising fuel prices, the total registered vehicles continue to increase from 2013 to 2024. This implies that fuel cost is not a sufficiently strong deterrent against private vehicle ownership. The actual increase in vehicle registrations is very likely not related to the rise of the car, but rather to economic growth, the liberalization of access to vehicle financing, and the absence of a severe restriction on purchase of cars.

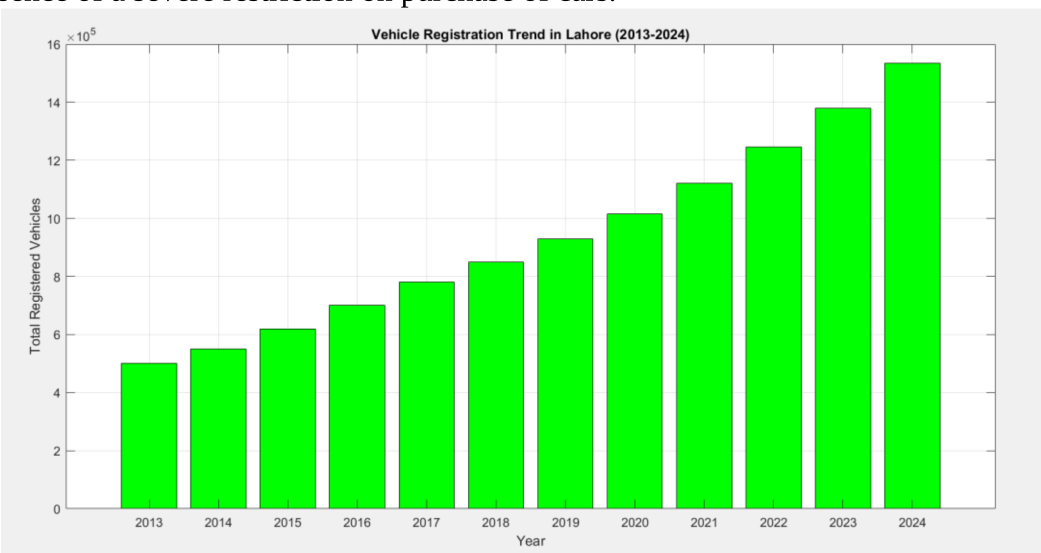

Figure 4 Vehicle Registration Trend

This trend has a major implication in that fuel prices are not a good policy tool to manage demand when other tools like congestion pricing, high parking fees or vehicle quotas are not available. But without these measures, traffic in cities like Lahore will only become worse with increasing fuel prices. What this result demonstrates, however, is that effective policies, integrating economic deterrents (fuel price hikes) with infrastructure improvements (public transit expansion), are needed.

4.1.5 Impact of Fuel Price Increase on Vehicle Usage

Below are the simulation results of predicted impact of a fuel price increase on total vehicle usage. Furthermore, this results in a linear relationship implying that as the price of fuel rises, the usage of the vehicle falls. But the rate of drop is not steep enough: While some people cut down on how often they travel, others don't budge and keep using their personal vehicles.

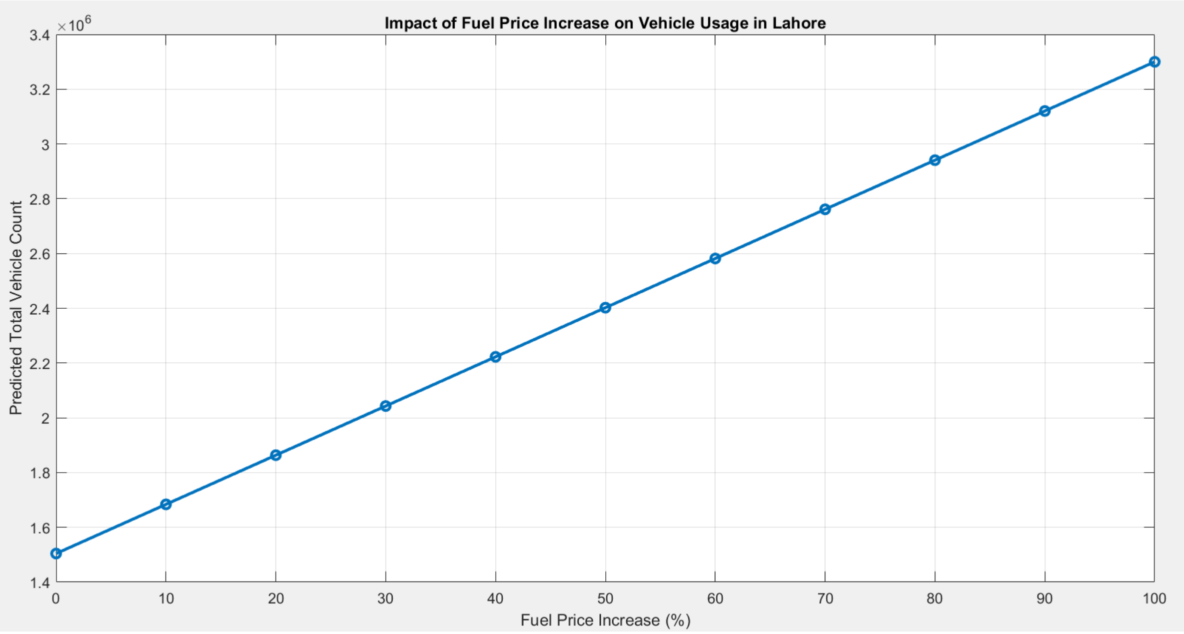

Figure 5 Impact of Fuel Price Increase on Vehicle Usage

The significance of this finding is that alone, when you increase fuel prices, traffic congestion and emission levels will not go down substantially. The reduction in vehicle usage is gradual, and in fact, many absorb increased fuel costs or re-adjust their budgets so as to keep up private car use. This justifies the need to implement some alternative policies that would encourage a change in travel behavior, like carpool incentives, telecommuting options, or better, cheaper public transit.

4.1.6 Projected Public Transport Shift Due to Rising Fuel Prices

The bar chart shows an expected growth in usage of public transport as fuel prices keep growing. Results indicate significant positive relationship between fuel price hikes and public transit adoption. Nevertheless, while the pattern points to more people desiring to travel by public transportation, lack of availability and reliability of transit services continues to be a problem.

ISSN E: 3006-1466
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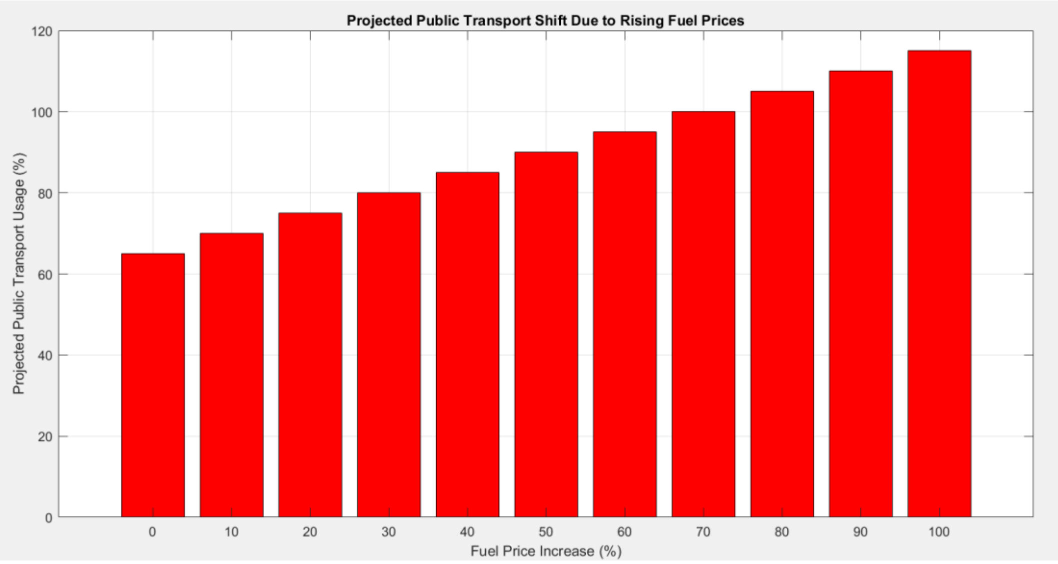

Figure 6 Projected Public Transport Shift Due to Rising Fuel Prices

Another critical issue is that can public transport infrastructure cope with this shift. In many developing cities public transport systems are overcrowded, under maintained and unreliable. This shift is effective only if there are companion investments in transit infrastructure. Increased demand for public transport may not be serviced without improved service quality and accessibility, which may result in commuter dissatisfaction and a possible return to private vehicle use.

4.1.7 Elasticity of Vehicle Usage with Respect to Fuel Price

The value of elasticity is 1.1698 which means that vehicle usage is slightly elastic with respect to changes in fuel price. Consequently, this indicates that for each one percent increase in fuel price, there is an approximate drop of 1.17% in vehicle usage. This implies that the sensitivity is not strong, but the decline is not too large to signal a drastic behavioral change.

This finding provides support for the proposition that fuel price increases alone do not offer an effective policy for the reduction of vehicle use. Despite that, the response is measurable still, but vehicle usage isn't reduced sufficiently to solve congestion or environmental problems. In order to get more important changes, authorities are responsible for additional incentives, for instance, tax rebates for fuel efficient vehicles, congestion charges or better support of public transport.

4.2 Analysis using SPSS

4.2.1 Reliability Test Analysis

Table 1 Reliability Statistics

Cronbach's Alpha	N of Items
.766	33

- If Cronbach's Alpha value is 0.7 and above, the result is reliable
- In this case Cronbach's Alpha value is .729 which is greater than 0.70, so there is no issue of reliability.
- So the Data is reliable.

4.2.2 Correlation Analysis

4.2.2.1 Effect of change in fuel prices on commuting trips and income

Table 2 Correlations

		Monthly households income	Past price (150 PKR/liter) for commuting	Current price (270 PKR/liter) for commuting	Future price (320 PKR/liter) for commuting
Monthly household income	Pearson Correlation	1	-.254**	-.341**	-.244**
	Sig. (2-tailed)		.003	.000	.004
	N	137	137	137	137
Past price (150 PKR/liter) for commuting	Pearson Correlation	-.254**	1	.702**	.499**
	Sig. (2-tailed)	.003		.000	.000
	N	137	137	137	137
Current price (270 PKR/liter) for commuting	Pearson Correlation	-.341**	.702**	1	.647**
	Sig. (2-tailed)	.000	.000		.000
	N	137	137	137	137
Future price (320 PKR/liter) for commuting	Pearson Correlation	-.244**	.499**	.647**	1
	Sig. (2-tailed)	.004	.000	.000	
	N	137	137	137	137

**. Correlation is significant at the 0.01 level (2-tailed).

In this test there is negative relationship between increase in fuel prices and household income which mean due to effect of increase in fuel prices our income is decreasing. Relationship is significant because its value is less than 0.05.

4.2.2.2 Effect of change in fuel prices on non-commuting trips and income

Table 3 Effect of change in fuel prices on non-commuting trips and income

		Past price (150 PKR/liter) for commuting	Current price (270 PKR/liter) for commuting	Future price (320 PKR/liter) for commuting	Monthly Houshold income
Past price (150 PKR/liter) for commuting	Pearson Correlation	1	.702**	.499**	-.254**
	Sig. (2-tailed)		.000	.000	.003
	N	137	137	137	137
Current price (270 PKR/liter) for commuting	Pearson Correlation	.702**	1	.647**	-.341**
	Sig. (2-tailed)	.000		.000	.000
	N	137	137	137	137
Future price (320 PKR/liter) for commuting	Pearson Correlation	.499**	.647**	1	-.244**
	Sig. (2-tailed)	.000	.000		.004
	N	137	137	137	137
Monthly Houshold income	Pearson Correlation	-.254**	-.341**	-.244**	1
	Sig. (2-tailed)	.003	.000	.004	
	N	137	137	137	137

**. Correlation is significant at the 0.01 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

In this test there is again negative relationship between increase in fuel prices and household income which mean due to effect of increase in fuel prices our income is decreasing. Relationship is significant because its value is less than 0.05.

4.2.2.3 Effect of change in fuel prices on ride-hailing for commuting trips and income

Table 4 Correlations

		Monthly Houshold income	Past price (150 PKR/liter) for commuting	Current price (270 PKR/liter) for commuting	Future price (320 PKR/liter) for commuting
Monthly Houshold income	Pearson Correlation	1	.075	.169*	.057
	Sig. (2-tailed)		.381	.048	.505
	N	137	137	137	137
Past price (150 PKR/liter) for commuting	Pearson Correlation	.075	1	.618**	.529**
	Sig. (2-tailed)	.381		.000	.000
	N	137	137	137	137
Current price (270 PKR/liter) for commuting	Pearson Correlation	.169*	.618**	1	.738**
	Sig. (2-tailed)	.048	.000		.000
	N	137	137	137	137

Future price (320 PKR/liter) for commuting	Pearson Correlation	.057	.529**	.738**	1
	Sig. (2-tailed)	.505	.000	.000	
	N	137	137	137	137

There is positive relationship between uses of ride hailing with change in fuel price and saving of income is increasing.
But this relationship is not significance because significance of this relationship is >0.05.

4.2.3 Regression Analysis

4.2.3.1 Income and motorcycle ownership:

Table 5 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.289[a]	.084	.070	.979

a. Predictors: (Constant), Bicycle Ownership, Motorcycle Ownership

In above table, the value of R-square is .070 which means motorcycle ownership causes 7% change in income.

Table 6 ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	11.698	2	5.849	6.109	.003[b]
	Residual	128.302	134	.957		
	Total	140.000	136			

a. Dependent Variable: Monthly household income
b. Predictors: (Constant), Bicycle Ownership, Motorcycle Ownership

Anova results shows that p-value is .003[b] which is less than 0.05, hence we say that there is a significant relationship.

Table 7 Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.576	.461		7.764	.000
	Motorcycle Ownership	-.281	.172	-.137	-1.631	.105
	Bicycle Ownership	-.641	.231	-.233	-2.775	.006

a. Dependent Variable: Monthly Household income

As we can see that the beta value is -.233 and -0.137, which means that the increase in bicycle or motorcycle by one unit will change the Income by -0.233 and -0.137 units.
The beta value is negative, which indicates the negative relationship between ownership and Income.

4.4.4. Income and average commuting/non-commuting distance

Table 8 Model Summary

ISSN E: 3006-1466
ISSN P: 3006-1458
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
CJSSR
CONTEMPORARY JOURNAL OF SOCIAL SCIENCE REVIEW
Vol.03 No.01 (2025)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.332[a]	.110	.097	.964

a. Predictors: (Constant), Your average non-commuting

In above table, the value of R-square is .110 which means motorcycle and bicycle ownership causes 11% change in income.

Table 9 ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	15.448	2	7.724	8.310	.000[b]
	Residual	124.552	134	.929		
	Total	140.000	136			

a. Dependent Variable: Monthly Houshold income

Anova value is less than 0.05, hence we say that there is a significant relationship

Table 10 Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.141	.239		4.774	.000
	Your average commuting (work/education) distance per day (two sides)?	.133	.104	.117	1.279	.203
	Your average non-commuting (shopping/social/recreational/health) distance per day (two sides)	.322	.112	.262	2.867	.005

a. Dependent Variable: Monthly household income

As we can see that the beta values are 0.117 and 0.262, which means that the increase in commuting/non-commuting distance by one unit will change the Income by 0.117 and 0.262 units.
The beta value is positive, which indicates the positive relationship between commuting/non-commuting distance and Income.

5. Conclusion

This research studied fuel price increases' influence on Baghbanpura and Begumpura Lahore residents' travel behaviors by employing survey statistics in SPSS and MATLAB computational models. The research findings showed that higher fuel prices cause people to use their vehicles less frequently for all their trips both to and from work and other destinations. The research data showed that the growing ownership of vehicles even though fuel costs increased which demonstrates that rising fuel prices alone failed to diminish motor vehicle dependency.
Public transportation usage significantly increased as people started using the Orange Line Metro services more often which emphasized the essential role of public transportation during fuel price surges. Ride-hailing options increased at a limited pace that did not enough to substitute conventional driving patterns. MATLAB simulations demonstrated that greater

fuel prices decrease trip rates at a slow pace due to the widespread adaptation behavior of private vehicle users.

The statistical analysis done in SPSS delivered significant findings about how socioeconomic factors influence transportation choices. Research findings demonstrated that household income levels strongly influence the sensitivity to rising fuel prices because higher-income groups remain unbothered by price increments. Motorcycle ownership demonstrates a weak negative relationship with household income because better-off families instead opt to use private cars or find different transportation options.

The MATLAB-based mathematical evaluation confirmed that changes in fuel costs affect travel selections but multiple variables determine vehicle ownership patterns. The growing price of fuel does not impact vehicle registrations which continue to rise because urban development combined with economic progress and inadequate public transportation systems drive continuous dependence on personal vehicles.

The study exposes the importance of developing sustainable transportation systems throughout Lahore. The increase in fuel prices stimulates public transport usage but alone cannot reduce private vehicle dependence because necessary complementary policies must be implemented for long-term results. A comprehensive transportation policy needs to move past fuel price modifications because researchers confirm its necessity to enhance transit infrastructure development alongside promoting fuel-efficient mobility along with urban planning approaches enabling lasting sustainability.

6. Recommendations

Based on the findings, several recommendations can be made to mitigate the impact of rising fuel prices and promote more sustainable travel behavior. Improvement should be seen in the public transport system, most essentially the Orange Line metro, through intensification of service frequency, extension of routes, as well as provision of fares subsidies to make traveling more accessible and affordable. The encouragement of the use of non-motorized transport, that is, walking and cycling, should be emphasized by designing specific bike lanes, refurbishing pedestrian infrastructure, and increased public education to enhance these modes of travel. Third, strategies in urban planning should emphasize mixed-use development, reducing the need for private car travel, and walkable and bikeable environments within neighborhoods. Finally, there is a need to promote fuel-efficient vehicles and to consider alternative fuels, such as electric vehicles, to reduce dependence on fossil fuels and minimize environmental impact.

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