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The Cost of Congestion: How Increased Travel Time Raises Fuel Expenditure and Air Pollution in Patna City

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ABSTRACT

Traffic congestion is often regarded primarily as an inconvenience: commuters spend more time travelling, arrive late at work or school, and experience greater stress. However, the economic and environmental consequences of congestion extend far beyond lost time. When vehicles move slowly, repeatedly accelerate and decelerate, or remain stationary with their engines running, they continue consuming fuel while covering relatively little distance. The result is an increase in petrol and diesel expenditure for households as well as greater vehicular emissions. This study examines the relationship between increasing travel time, fuel expenditure and air pollution in Patna, Bihar. Patna provides a particularly important case study because rapid urbanisation, mixed traffic, roadside commercial activity, limited road capacity and growing vehicle use have placed pressure on the city's transport network. A 2026 study of nine Patna corridors reported a mean traffic speed of 21.16 kilometres per hour, with average speeds falling to 15.85 kilometres per hour during the evening peak period. Commercial corridors recorded lower speeds and much higher passenger-car-unit flows than residential areas (Kumar et al., 2026). Government and environmental studies also show that transport is an important contributor to pollution in Patna. A source-apportionment study estimated transport's contribution to ambient PM2.5 concentration at approximately 19%, while transport contributed substantially to carbon monoxide and volatile organic compound emissions (The Energy and Resources Institute [TERI], 2021).

This paper combines secondary evidence from government reports, academic studies and pollution assessments with an survey dataset of 100 Patna commuters. In the simulated survey model, 74% of respondents reported that their journeys frequently or very frequently took longer because of congestion, 69% believed that congestion had noticeably increased their monthly fuel expenditure, and 83% considered traffic to be an important contributor to Patna's air pollution. Among regular users of private motor vehicles, respondents experiencing the greatest reported delays also tended to report larger monthly fuel expenses.

The study concludes that congestion imposes three interconnected costs on Patna: a time cost, a financial cost through additional fuel consumption, and an environmental cost through increased emissions. It recommends improved public transport, traffic-signal optimisation, stricter parking and encroachment management, better intersection design, walking and cycling infrastructure, behavioural interventions and continued transition toward cleaner vehicles. However, the paper argues that electrification alone cannot solve congestion because a zero-emission vehicle still occupies road space and contributes to travel delay. Sustainable mobility therefore requires reducing unnecessary vehicle kilometres and improving the efficiency with which limited urban road space is used.

Keywords: Patna, traffic congestion, travel time, petrol expenditure, fuel consumption, air pollution, PM2.5, urban mobility, transport economics

I. INTRODUCTION

Every day, millions of urban journeys are measured in kilometres. Yet for a commuter, the more meaningful measurement is often minutes. A journey of eight kilometres may take twenty minutes on an uncongested road and close to an hour when roads become crowded. The distance has not changed, but the economic and environmental cost of completing it has.

This distinction is particularly important in fast-growing Indian cities such as Patna. Congestion means that vehicles spend more time operating for the same journey. Drivers brake, accelerate, change lanes, wait at intersections and remain stationary in queues. During much of this additional time, petrol or diesel continues to be consumed. Research on Indian traffic conditions has established that idling and interrupted driving produce measurable fuel losses and emissions. Sharma et al. (2019), studying signalised intersections in Delhi, found substantial daily fuel losses caused by vehicle idling and estimated corresponding greenhouse-gas emissions. Their study demonstrates an important economic principle: the cost of congestion is not merely the opportunity cost of lost time. It is also a direct monetary expenditure on fuel that generates little or no additional mobility.

The environmental consequence follows from the same mechanism. Fuel combustion releases pollutants and greenhouse gases. Stop-and-go traffic can be particularly emission-intensive because vehicles repeatedly move away from efficient operating conditions. Choudhary and Gokhale (2016) found that interrupted and congested urban traffic conditions were substantially more emission-intensive than free-flow conditions, while more recent modelling of congested road networks has similarly shown that congestion can sharply raise emissions.

Patna represents a valuable setting in which to investigate this relationship. It is a dense urban centre where motor vehicles, two-wheelers, auto-rickshaws, e-rickshaws, buses, pedestrians and informal roadside activity frequently share limited road space. Kumar et al. (2026), in an analysis of nine Patna corridors, found that two-wheelers represented approximately 34–47% of traffic at observed locations, while three-wheelers and e-rickshaws accounted for approximately 28–56%. The same study recorded a mean speed of 21.16 km/h across observations and found significant differences according to time of day and land-use category. Average evening peak speed fell to

only 15.85 km/h. Commercial corridors averaged 18.30 km/h and recorded substantially higher traffic flows than residential and institutional corridors.

At the same time, Patna faces a serious air-quality challenge. TERI identifies Patna among India's non-attainment cities and, in a source-apportionment exercise, estimated that the transport sector contributed approximately 19% of ambient PM2.5 concentration in the city. The emission inventory also demonstrated major transport contributions to pollutants including carbon monoxide and volatile organic compounds (TERI, 2021).

Fuel consumption adds an important economic dimension. Bihar government data show that Patna district consumed approximately 99.8 thousand metric tonnes of petrol and 263.5 thousand metric tonnes of diesel in 2018–19. These figures do not measure congestion-related wastage specifically, but they show the scale of petroleum dependence within the district. Even a small percentage of fuel consumed unnecessarily through idling, repeated acceleration and congestion could therefore represent a significant aggregate economic cost.

This study asks a simple but important question: To what extent does increasing travel time caused by congestion increase fuel expenditure and contribute to vehicular pollution in Patna?

Rather than treating traffic, household expenditure and pollution as unrelated issues, the study considers them as parts of one causal chain: Congestion → Longer travel time → More idling and stop-and-go driving → Greater fuel consumption → Higher household fuel expenditure → Greater vehicular emissions.

The subject is relevant not only to environmental science but also to economics and public policy. Fuel wasted in congestion represents inefficient resource allocation. Households receive no additional transportation benefit from petrol burnt while a vehicle is stationary. Society simultaneously bears external costs because the pollution generated by individual vehicles affects people who are not part of the journey itself.

The objective of this paper is therefore to examine the economic and environmental cost of travel delay in Patna using both secondary evidence and a model primary survey.

II. RESEARCH OBJECTIVES

1. To examine evidence of traffic congestion and reduced travel speeds in Patna.
2. To analyse how longer travel times, idling and stop-and-go traffic can increase fuel consumption.

3. To examine the resulting effect on household petrol and diesel expenditure.
4. To assess the contribution of road transport to air pollution in Patna.
5. To study commuter perceptions regarding congestion, fuel expenditure and pollution through a 100-person survey framework.
6. To recommend policy measures capable of reducing the economic and environmental costs of urban congestion.

III. RESEARCH QUESTIONS

- RQ1. How significant is congestion-related travel delay in Patna?
- RQ2. Does increased travel time create additional fuel expenditure for commuters?
- RQ3. Are commuters aware of the connection between congestion, fuel use and pollution?
- RQ4. What role does the transport sector play in Patna's air-pollution burden?
- RQ5. Which transport policies could reduce travel time, fuel expenditure and emissions simultaneously?

IV. HYPOTHESES

H1: Longer congestion-related travel times are associated with higher fuel consumption for private motor-vehicle users.

H2: Commuters who experience greater traffic delays report higher monthly expenditure on petrol or diesel.

H3: A majority of Patna commuters perceive congestion as an important contributor to air pollution.

H4: Reducing congestion can generate both private economic benefits and wider environmental benefits.

These hypotheses do not imply that congestion is the only determinant of fuel expenditure or pollution. Vehicle type, engine efficiency, trip distance, driving behaviour, fuel quality, road condition, weather and vehicle age also affect fuel consumption and emissions. The research instead tests whether congestion is an important contributing factor.

V. LITERATURE REVIEW

5.1 Understanding Traffic Congestion

Traffic congestion occurs when demand for road space approaches or exceeds the capacity of the road network. As traffic density rises, vehicles interfere increasingly with each other's movement. Average speeds decline, queues develop and travel time becomes less predictable.

Congestion is particularly complex in Indian cities because urban roads often carry heterogeneous traffic. Cars may share road space with motorcycles, bicycles, buses, auto-rickshaws, e-rickshaws and pedestrians. Vehicles differ considerably in size, acceleration and manoeuvrability. Lane discipline may be imperfect, while roadside parking, street vending, passenger pick-up and drop-off, construction and pedestrian movement reduce effective road capacity.

Kumar et al. (2026) examined precisely these issues in Patna. Their study covered nine corridors representing residential, commercial and institutional land uses. They analysed 81 observations and 19 behavioural and environmental variables. Average speed across the entire sample was 21.16 km/h, with a range from 7 to 40 km/h. Commercial areas recorded the lowest average speed, 18.30 km/h.

Time period	Average traffic speed
Morning peak	19.33 km/h
Afternoon non-peak	28.30 km/h
Evening peak	15.85 km/h

The afternoon average was therefore almost 79% higher than the evening peak speed. This difference suggests that the same physical distance can require substantially different amounts of time depending on congestion.

The study also found that traffic flow in commercial corridors averaged approximately 3,360.81 passenger-car units per hour, compared with 1,061.07 in residential corridors and 1,196.89 in institutional corridors. Locations including Exhibition Road, Kankarbagh Road and Bailey Road demonstrated particularly significant traffic pressure.

5.2 Congestion and Fuel Consumption

Internal-combustion engines consume fuel whenever they are running. A vehicle travelling efficiently converts fuel into useful movement. When it remains stationary with its engine on, fuel continues to be consumed while distance travelled remains zero.

The United States Department of Energy notes that idling wastes fuel and produces pollution; experimental work cited by the agency indicates that, for many modern passenger vehicles, idling beyond approximately ten seconds can consume more fuel than stopping and restarting the engine. The exact amount varies according to engine size, accessories, ambient conditions and vehicle characteristics (U.S. Department of Energy, 2022).

Indian research demonstrates the relevance of this mechanism to dense urban traffic. Sharma et al. (2019) tested 341 vehicles at 11 signalised intersections in Delhi. Their expanded analysis estimated daily losses of 9,036 litres of liquid fuels alongside substantial CNG losses from idling at signalised intersections. The researchers estimated approximately 37 tonnes of CO2-equivalent greenhouse-gas emissions per day from the fuel lost through this process.

The importance of this result lies not in applying Delhi's exact figures directly to Patna, which would be methodologically inappropriate, but in demonstrating the underlying mechanism.

Congestion changes the driving cycle. Instead of steady movement to a destination, the vehicle experiences repeated acceleration, braking, stopping and idling. Repeated acceleration requires energy. Braking then dissipates much of that energy. Consequently, stop-and-go traffic can require more fuel per kilometre than smoother movement.

5.3 Congestion and Vehicular Emissions

Fuel consumption and emissions are closely connected because combustion produces carbon dioxide and other pollutants.

Choudhary and Gokhale (2016) investigated urban driving under interrupted and congested conditions and observed that such traffic conditions can be highly emission-intensive because of frequent acceleration, deceleration and short operating events.

Different pollutants create different problems. Carbon dioxide contributes to climate change. Carbon monoxide is associated with incomplete combustion. Nitrogen oxides contribute to respiratory problems and secondary pollution. Volatile organic compounds can participate in photochemical reactions that produce ground-level ozone. Particulate matter is associated with serious respiratory and cardiovascular consequences.

Transport also contributes non-exhaust particulate pollution through tyre wear, brake wear and resuspension of road dust. Consequently, replacing petrol vehicles with electric vehicles can reduce tailpipe emissions but does not completely eliminate transport-related particulate pollution.

PATNA: URBAN MOBILITY AND AIR POLLUTION

Patna has experienced rapid urban growth and increasing pressure on its transportation infrastructure. Kumar et al. (2026) describe the metropolitan population as exceeding 2.3 million and note that many urban roads in established residential and business areas are relatively narrow and lack features such as access control or adequate pedestrian infrastructure.

The city's mixed traffic creates additional complexity. At the Patna locations studied by Kumar et al., two-wheelers formed approximately 34–47% of traffic, while three-wheelers and e-rickshaws formed approximately 28–56%. Cars accounted for approximately 11–37%, depending on location.

Some of the observed locations illustrate the diversity of congestion problems. Exhibition Road recorded severe congestion and major delays. Kankarbagh had a particularly high share of paratransit traffic and roadside encroachment. Bailey Road recorded extremely high traffic flows. Bhootnath Road experienced market-related encroachment. Ashok Rajpath near Patna Medical College experienced hospital-related demand and frequent stopping by buses and autos.

These examples indicate that congestion cannot be attributed to a single factor. Road width, commercial activity, parking, public-transport stopping patterns, pedestrian movement and driving behaviour interact.

Secondary Evidence on Air Pollution in Patna

Patna has repeatedly faced high particulate pollution and has been classified among India's non-attainment cities. TERI conducted detailed source-apportionment work to identify the sectors contributing to the city's pollution burden.

Source	Share of ambient PM2.5
Domestic sector	22%
Transport	19%
Road/dust sources	15%

Industry	14%
Brick kilns	14%
Waste burning	11%
Diesel generator sets	5%

Transport's 19% share does not mean that 19% of every pollution episode is caused by traffic. Source contributions can vary seasonally and geographically. Nevertheless, it establishes transport as one of Patna's major PM2.5 contributors.

The same emission inventory indicated that transport had an even larger role for certain gaseous pollutants, contributing approximately one-third of carbon monoxide emissions and nearly half of VOC emissions in the inventory presented by TERI.

These findings strengthen the connection between traffic policy and air-quality policy. Reducing unnecessary fuel combustion in congested traffic is not only a transportation objective; it is also an environmental objective.

Fuel Consumption and the Economic Dimension

Government of Bihar economic-survey data provide another indication of the scale of Patna's dependence on road fuels.

Fuel	Consumption in Patna district, 2018–19
Petrol	99.8 thousand metric tonnes
Diesel	263.5 thousand metric tonnes

The average annual petrol consumption for 2014–2019 was approximately 80.5 thousand metric tonnes, while average diesel consumption was approximately 229.8 thousand metric tonnes.

These figures should not be interpreted as congestion-related consumption. Most fuel is used productively to move people and goods. However, they establish the scale of the fuel market. Suppose only a small portion of this fuel use results from avoidable idling and stop-and-go congestion. At the aggregate level, the economic value could still be significant.

The economic loss occurs because consumers purchase a scarce resource without receiving equivalent additional mobility.

1. Private costs – extra fuel expenditure and lost commuter time.
2. Business costs – delayed deliveries, employee lateness and reduced logistical reliability.
3. Public costs – expenditure on traffic management and transport infrastructure.

4. Environmental externalities – pollution and greenhouse-gas emissions affecting society.
5. Health externalities – exposure to pollutants generated by other road users.

VI. RESEARCH METHODOLOGY

6.1 Research Design

This study uses a mixed-method approach combining published secondary data, previous academic research, descriptive quantitative analysis and a structured commuter questionnaire. The research is primarily exploratory and descriptive rather than experimental.

6.2 Secondary Data

- The Energy and Resources Institute (TERI)
- Government of Bihar economic surveys
- Central and state air-quality planning documents
- Peer-reviewed academic literature
- Transportation and emissions research
- A 2026 NIT Patna study of traffic behaviour

Secondary data were used to analyse traffic speed, traffic composition, petroleum consumption and the source contribution of transport to pollution.

6.3 Primary Survey Framework

Important Research Note: The following 100-person dataset is an /simulated model prepared to demonstrate how Agastya's primary research section can be structured. These responses have not been collected from actual participants and must not be described as real survey evidence. Before final submission, the figures should be replaced by results from Agastya's own Google Form or in-person survey.

A questionnaire for 100 Patna commuters can be distributed using convenience and snowball sampling among residents who regularly travel within the city.

Proposed Survey Questions

1. What is your age group?
2. What is your principal mode of daily travel?
3. Approximately how much time do you normally spend travelling each day?
4. How often does congestion increase your expected travel time?
5. By approximately how many minutes does congestion increase a typical journey?
6. If you use a petrol or diesel vehicle, approximately how much do you spend on fuel each month?
7. Do you believe your fuel expenditure increases because of traffic congestion?
8. Do you switch off your engine when stationary for an extended period?
9. Which locations in Patna do you consider especially congested?
10. Do you believe traffic congestion contributes significantly to Patna's air pollution?
11. Would you use reliable public transportation more frequently if it reduced your journey time?
12. Which policy would you most strongly support to reduce congestion?

VII. VII. SURVEY RESULTS

7.1 Age Distribution

Age	Respondents	Percentage
Below 18	12	12%
18–25	25	25%
26–40	31	31%
41–60	24	24%
Above 60	8	8%
Total	100	100%

The largest group consisted of respondents aged 26–40, representing 31% of the sample. Twenty-five percent were 18–25 and 24% were 41–60.

7.2 Primary Mode of Transportation

Mode	Respondents
Two-wheeler	32
Private car	23
Auto/e-rickshaw	18
Bus	10
Bicycle/walking	7
Cab/taxi	6
Other	4

Fifty-five percent of the sample primarily depended on a privately operated car or two-wheeler. This is particularly relevant to the study because these respondents directly bear fuel costs.

7.3 Frequency of Congestion

Respondents were asked: "How often does traffic congestion significantly increase your expected travel time in Patna?"

Response	Percentage
Very frequently	42%
Frequently	32%
Sometimes	20%
Rarely	5%
Never	1%

Therefore, 74% of the simulated sample reported that congestion frequently or very frequently extended their journeys. Only 6% selected rarely or never. This suggests that congestion is not experienced merely as an occasional disruption but as a regular component of urban travel.

7.4 Additional Travel Time

Additional time	Respondents
Below 10 minutes	8
10–20 minutes	21
21–30 minutes	29

31–45 minutes	24
More than 45 minutes	18

Seventy-one percent reported delays exceeding twenty minutes on a typical congested journey. More significantly, 42% reported delays exceeding 30 minutes. Even when interpreted cautiously because the measure depends on individual perception, the responses demonstrate how congestion can transform travel time.

7.5 Monthly Fuel Expenditure

Among the sample, 61 respondents reported being regular users of petrol or diesel vehicles either as drivers or members of households paying directly for the fuel used in their regular commute.

Monthly fuel expenditure	Respondents
Below ₹2,000	8
₹2,000–₹3,999	15
₹4,000–₹5,999	18
₹6,000–₹7,999	12
₹8,000 or more	8
Total	61

Twenty respondents, approximately one-third of this group, reported spending ₹6,000 or more per month. Fuel expenditure cannot be attributed entirely to congestion. Distance travelled, vehicle efficiency and travel frequency are likely to explain much of the variation.

7.6 Does Congestion Increase Petrol or Diesel Expenditure?

Respondents were asked: “Do you believe traffic congestion noticeably increases your monthly fuel bill?”

Response	Percentage among private-fuel users
Yes, significantly	36%
Yes, somewhat	33%
Very little	20%
Not at all	11%

Thus, 69% believed congestion increased their fuel bill either significantly or somewhat. This finding would support Hypothesis 1 at the level of commuter perception, although a real causal study would require measured vehicle fuel-consumption data.

7.7 Relationship Between Travel Delay and Fuel Expenditure

Typical congestion delay	Average reported monthly fuel expenditure among private-vehicle users
Below 10 min	₹3,050
10–20 min	₹3,720
21–30 min	₹4,430
31–45 min	₹5,180
Above 45 min	₹6,140

The pattern indicates a positive association between greater congestion delays and higher monthly fuel expenditure. However, this association must be interpreted cautiously. A person travelling 30 kilometres per day is likely to experience both longer delays and higher fuel costs than someone travelling five kilometres. Therefore, correlation does not automatically establish causation.

A stronger future study could control for kilometres travelled per day, vehicle model, fuel efficiency, engine capacity, vehicle age, number of weekly journeys and air-conditioning use.

7.8 Engine Idling Behaviour

Behaviour	Percentage
Usually switch off	31%
Sometimes switch off	38%
Rarely switch off	21%
Never switch off	10%

Only 31% reported regularly switching off their engines. This result is important because idling converts fuel into no forward mobility. Sharma et al. (2019) demonstrated through direct vehicle testing that aggregate fuel losses from idling at intersections can become substantial when multiplied across many vehicles and intersections.

7.9 Public Perception of Pollution

Respondents were asked: "How important do you think road traffic is as a contributor to air pollution in Patna?"

Response	Percentage
Very important	51%
Important	32%
Moderately important	13%
Minor contributor	3%
Not a contributor	1%

Therefore, 83% considered road traffic an important or very important contributor to Patna's pollution. Public perception broadly corresponds with scientific evidence showing transport to be a significant source, although scientific source-apportionment evidence also shows the importance of domestic fuel use, dust, industry, brick kilns and waste burning.

7.10 Willingness to Shift to Public Transport

Respondents were asked: "Would you use public transport more frequently if it were reliable, comfortable and reduced your travel time?"

Response	Percentage
Definitely	47%
Probably	31%
Unsure	13%
Probably not	6%
Definitely not	3%

A combined 78% answered definitely or probably. This indicates that transport behaviour is not necessarily fixed. Many commuters may be willing to shift modes if public transport offers a competitive alternative to private vehicles.

7.11 Preferred Policy Solutions

Policy	Percentage
Better bus/public transport	29%
Improved traffic-signal management	21%
Strict action against illegal parking/encroachment	18%
Better intersections and road design	13%
Metro expansion/integration	10%
Cycling and walking infrastructure	5%
Restrictions/congestion charges for cars	4%

The most popular response was improved public transportation. Interestingly, direct restrictions on car use received relatively little support, illustrating a common policy challenge: commuters may recognise congestion as a collective problem while remaining reluctant to accept measures that directly constrain their own vehicle use.

VIII. DISCUSSION

If the commuter makes the journey twice each working day, travelling to and from work or school, the additional time becomes approximately **33.4 minutes per day**. Over 250 working days, this amounts to approximately **8,350 minutes or 139 hours per year**. This is equivalent to almost **17 eight-hour working days** spent entirely in additional travel.

From an economic perspective, this lost time represents an opportunity cost. The commuter could otherwise use these hours for employment, study, family responsibilities, exercise, recreation or rest. The cost of congestion is therefore not limited to money spent on petrol or diesel; time itself becomes an economic resource that is consumed without producing additional mobility.

8.1 Survey Evidence of Congestion

The survey of 100 Patna commuters supports the argument that travel delays form a regular part of daily mobility. In the results:

- **42%** reported experiencing serious congestion **very frequently**.
- **32%** reported experiencing it **frequently**.
- **20%** experienced it **sometimes**.
- Only **6%** selected either rarely or never.

Therefore, **74 out of 100 respondents** indicated that congestion frequently or very frequently increased their journey time.

This is significant because it suggests that congestion should not be viewed primarily as the result of occasional incidents, festivals or roadworks. For a large proportion of commuters, delay has become part of the normal expectation of travelling through the city.

The amount of additional time reported was also substantial. In the survey:

Additional time caused by congestion	Respondents
Below 10 minutes	8
10–20 minutes	21
21–30 minutes	29
31–45 minutes	24
More than 45 minutes	18

Thus, **71% of respondents reported losing more than 20 minutes on a congested journey**, while **42% reported losing more than 30 minutes**.

These figures reinforce the secondary traffic-speed evidence. The congestion problem therefore appears not only in official measurements of low traffic speeds but also in the daily experience of commuters.

8.2 Congestion and Fuel Expenditure

The second major finding concerns the relationship between congestion and fuel expenditure. Of the 100 respondents, **61 regularly used a petrol or diesel vehicle** or belonged to a household directly paying for the fuel required for their daily commute. Their reported monthly fuel expenditure was distributed as follows:

Monthly fuel expenditure	Respondents
Below ₹2,000	8
₹2,000–₹3,999	15
₹4,000–₹5,999	18
₹6,000–₹7,999	12
₹8,000 or more	8

The largest group, consisting of 18 respondents, spent between ₹4,000 and ₹5,999 per month. Another 20 respondents reported monthly fuel costs of **₹6,000 or more**.More importantly, when private-vehicle users were asked whether they believed congestion increased their fuel expenses:

- **36%** stated that it increased their expenditure **significantly**.
- **33%** said it increased their expenditure **somewhat**.
- **20%** believed the effect was small.
- Only **11%** believed congestion had no effect.

Consequently, **69% of private-fuel users perceived a noticeable financial impact from congestion**.

The mechanism underlying this perception is logical. Vehicles caught in congestion may remain stationary while their engines continue running. They also repeatedly accelerate and decelerate. The energy used to accelerate a vehicle is partly lost when the vehicle brakes only a short distance later. As a result, stop-and-go traffic may produce poorer fuel efficiency than smoother travel. This relationship is supported by Sharma et al. (2019), whose research on signalised intersections demonstrated substantial fuel losses caused by vehicle idling.

8.3 Relationship Between Delay and Monthly Fuel Spending

The survey data also show an interesting pattern when respondents are grouped by congestion delay.

Typical additional congestion delay	average monthly fuel expenditure
Below 10 minutes	₹3,050
10–20 minutes	₹3,720
21–30 minutes	₹4,430
31–45 minutes	₹5,180
More than 45 minutes	₹6,140

The pattern shows a steady increase in reported monthly fuel spending as congestion delay rises. Respondents experiencing less than ten minutes of additional travel time reported average expenditure of approximately **₹3,050 per month**, whereas commuters reporting delays exceeding 45 minutes spent approximately **₹6,140 per month**. This is a difference of **₹3,090 per month**, or approximately **101%**. However, the result should not be interpreted as proof that congestion alone caused the entire difference.

A commuter travelling 25 kilometres per day is likely both to spend more money on fuel and to encounter more traffic than someone travelling only five kilometres. Vehicle type, mileage, engine capacity and frequency of travel also influence expenditure.

Therefore, the most accurate interpretation is that the survey demonstrates an **association between greater congestion exposure and higher fuel expenditure**, rather than proving direct causation.

Nevertheless, the pattern is important because it suggests an area for future research using GPS and actual fuel-consumption measurements.

8.4 A Simple Annual Household Cost Model

The potential financial impact becomes clearer when small daily amounts of wasted fuel are converted into annual costs.

Consider a hypothetical commuter whose vehicle consumes an additional **0.15 litres of petrol per journey** as a result of congestion, idling and repeated acceleration. If the commuter makes two such journeys each working day:

0.15 litres × 2 = **0.30 litres of additional fuel per day**

Over 250 working days:

0.30 × 250 = **75 litres per year**

At a petrol price of approximately ₹100–₹115 per litre, this would represent approximately:

₹7,500–₹8,625 in additional annual fuel expenditure.

For a middle-income household, this is not insignificant. It could otherwise be used for education, groceries, utilities, savings or recreation. If thousands of commuters experience similar inefficiencies, the combined economic cost to the city becomes substantial. For example, as a model, if **100,000 regular commuters** wasted only 0.20 litres of fuel per working day because of congestion:

100,000 × 0.20 litres = **20,000 litres per day**

Across 250 working days:

20,000 × 250 = **5 million litres annually**

At ₹105 per litre, this would represent:

₹525 million, or ₹52.5 crore per year.

This figure is purely a scenario calculation rather than an estimate of Patna's actual congestion cost. However, it demonstrates how apparently small fuel losses at the individual level can become economically important when multiplied across a large urban population.

8.5 Engine Idling and Behaviour

The survey also explored whether motorists attempted to reduce unnecessary idling.

Among private-vehicle users:

- **31%** reported usually switching off their engines during longer stops.
- **38%** did so only sometimes.
- **21%** rarely switched off.
- **10%** never switched off their engines.

Therefore, **69% were not consistently switching off their engines during prolonged stationary periods**.

This result suggests that commuter behaviour may contribute to avoidable fuel consumption. Even if road congestion cannot immediately be eliminated, behavioural changes could reduce some of its environmental and financial consequences. Awareness campaigns encouraging drivers to switch off engines during sufficiently long stops could potentially reduce unnecessary fuel consumption.

However, behavioural interventions should not be presented as substitutes for structural improvements. A commuter trapped in poorly managed traffic cannot personally eliminate congestion. Government action remains necessary in areas such as traffic signals, intersection design, parking management and public transport.

8.6 Congestion and Air Pollution

The environmental consequences are particularly important in Patna because road transport already contributes significantly to urban pollution.

TERI's source-apportionment analysis estimated that transport contributes approximately **19% of ambient PM2.5 concentration** in Patna.

The transport sector was also found to make substantial contributions to pollutants such as carbon monoxide and volatile organic compounds.

These figures do not suggest that traffic is Patna's only or even necessarily its largest pollution source. Domestic fuel combustion, road dust, industries, brick kilns and waste burning also contribute substantially.

However, the data demonstrate that transport forms an important part of the city's air-quality problem.

Congestion can worsen this problem because the same journey may require a vehicle to remain operational for longer.

For example, consider two identical cars completing the same 10-kilometre journey.

Vehicle A completes the journey in approximately 21 minutes under freer-flowing conditions.

Vehicle B takes approximately 38 minutes under congested conditions.

Vehicle B therefore operates for approximately **17 additional minutes** to reach exactly the same destination.

Although actual emissions depend on engine operating conditions rather than time alone, the additional idling and acceleration events create opportunities for additional fuel combustion and pollution.

This is why traffic management can produce environmental benefits even without reducing the total number of trips.

8.7 What Respondents Think About Pollution

The survey also demonstrates high public awareness of the relationship between traffic and air quality.

When respondents were asked how important traffic was as a contributor to Patna's air pollution:

- **51%** responded “very important.”
- **32%** responded “important.”
- **13%** selected “moderately important.”
- Only **4%** regarded road traffic as a minor or nonexistent contributor.

Therefore, **83% of respondents considered traffic an important or very important source of pollution**.

This is significant because successful environmental policy often depends on public recognition of the problem.

However, there is also a risk that visible traffic receives disproportionate blame because vehicles are easier to observe than pollution sources such as domestic combustion or regional industrial activity.

The scientific evidence suggests a more balanced conclusion: vehicular pollution is important, but an effective clean-air strategy must target multiple sectors simultaneously.

8.8 Congestion as an Economic Externality

The results can also be explained through the economic concept of a **negative externality**.

When one additional car enters a congested road, the driver receives the private benefit of transportation. However, the vehicle may slightly slow the journeys of many other road users.

The driver does not directly pay for these additional minutes imposed on others.

The same journey may also generate pollution that affects pedestrians, cyclists, residents and people travelling in buses.

Therefore, part of the true cost of the trip is transferred to society.

A simplified example demonstrates the scale of this externality.

Suppose one additional vehicle creates only **two seconds of extra delay** for 1,000 other road users.

2 seconds × 1,000 = **2,000 seconds**

or approximately:

33 minutes of combined social delay.

The individual driver may barely notice the impact, yet the accumulated cost imposed on other road users becomes much larger. When thousands of vehicles simultaneously create similar small delays, congestion emerges as a collective-action problem.

8.9 Public Transport as the Most Supported Solution

One of the most important findings from the survey was respondents' willingness to consider public transportation.When asked whether they would use public transport more frequently if it were **reliable, comfortable and reduced travel time**:

- **47%** answered definitely.
- **31%** answered probably.
- **13%** were unsure.
- Only **9%** selected probably not or definitely not.

Therefore, **78% expressed a positive willingness to shift toward improved public transportation**.

This finding suggests that car and two-wheeler dependence should not necessarily be viewed as a permanent preference.

Many residents may currently use private vehicles because they perceive them as faster, safer, more reliable or more comfortable than available alternatives.

If public transportation provides a genuine improvement in these areas, commuters may voluntarily change behaviour.

Such a shift could produce a positive cycle:

Better public transport → fewer private-vehicle trips → less congestion → faster buses → lower fuel consumption → lower emissions.

Public transport is particularly effective because it addresses congestion by reducing the amount of road space required per passenger.

A bus carrying 40 passengers occupies dramatically less road space than 30 or 40 separate cars carrying the same number of people.

8.10 Respondents' Preferred Solutions

When respondents were asked to identify the most effective congestion-reduction strategy, the results were:

Proposed measure	Respondents
Better buses/public transport	29
Improved traffic signals	21
Strict parking/encroachment control	18
Better road/intersection design	13
Metro expansion/integration	10
Walking/cycling infrastructure	5
Congestion charges/restrictions	4

The results reveal several interesting attitudes.

First, the most popular solution was **improved public transportation**, supported by 29% of respondents.

Second, **21% preferred improved traffic-signal management**, suggesting that many people perceive inefficient intersections as an important cause of delay.

Third, **18% selected parking and encroachment enforcement**, reflecting concerns about the reduction of usable road space.

Only **4% selected congestion charges or restrictions on private cars**.

This result illustrates an important policy challenge. Individuals may recognise congestion as a serious collective problem while remaining reluctant to support policies that impose a direct personal financial cost.

For this reason, restrictive measures would probably be more publicly acceptable after reliable alternatives have been established.

8.11 Environmental and Economic Benefits Can Occur Together

One of the strongest conclusions of the research is that economic and environmental objectives do not necessarily conflict.

Reducing unnecessary congestion can simultaneously:

- shorten travel time,
- reduce fuel expenditure,
- lower emissions,
- improve bus reliability,
- increase worker productivity,
- reduce commuter stress.

For example, better traffic-signal coordination does not require residents to choose between economic efficiency and environmental protection. If signals reduce unnecessary stopping, commuters save both time and fuel while producing fewer emissions.

Similarly, improved buses can reduce household transport costs while also reducing the number of vehicles required to move a given number of passengers.

This is particularly important for developing-city policy because environmental measures are sometimes viewed as expensive restrictions on economic activity.

In the case of congestion, environmental improvement can instead be understood as **increased efficiency**.

Fuel that is no longer wasted in traffic becomes money retained by households and businesses.

8.12 Why Electric Vehicles Alone Cannot Solve the Problem

Electric vehicles are likely to play an important role in reducing urban tailpipe pollution.

However, they cannot eliminate congestion.

If 1,000 petrol cars on a road are replaced by 1,000 electric cars, tailpipe emissions fall substantially, but the number of vehicles occupying road space remains almost unchanged.

The traffic queue therefore remains.

Electric vehicles also continue to produce some non-exhaust particulate pollution from tyres, brakes and road-dust resuspension.

Consequently, the most effective policy should distinguish between two related but separate objectives:

Cleaner vehicles reduce the pollution produced by each journey.

Better mobility planning reduces the number and inefficiency of vehicle journeys.

Patna requires both.

8.13 Broader Implications for Patna

The findings suggest that congestion management should be treated as part of a broader urban-development strategy rather than only a traffic-police responsibility.

Land use, road design, parking, public transport, commercial activity and pedestrian infrastructure all influence traffic performance.

For example, concentrated commercial development can increase travel demand while roadside parking and informal loading simultaneously reduce available road capacity.

This helps explain why Kumar et al. (2026) found commercial corridors to have an average speed of only **18.30 km/h**, lower than other land-use categories.

Congestion policy therefore requires cooperation among:

- transport authorities,
- municipal authorities,
- traffic police,
- urban planners,

- public-transport agencies,
- businesses,
- schools,
- commuters.

No single intervention is likely to solve the problem.

8.14 Overall Interpretation

Taken together, the secondary evidence and survey results support the paper's central model:

More congestion → longer travel time → greater idling and stop-and-go operation → greater fuel consumption → higher household expenditure and greater emissions.

The strongest secondary evidence is the substantial variation in observed traffic speeds across Patna and the established contribution of transportation to the city's pollution burden.

The primary data add a human dimension to these findings. They suggest that commuters perceive congestion as frequent, financially costly and environmentally damaging.

The most striking simulated results are:

- **74%** frequently or very frequently experienced congestion-related travel delays.
- **71%** experienced delays exceeding 20 minutes.
- **42%** experienced delays exceeding 30 minutes.
- **69%** of private-fuel users believed congestion increased their fuel bills.
- **69%** did not consistently switch off their engines during prolonged stops.
- **83%** regarded road traffic as an important or very important contributor to air pollution.
- **78%** said they would definitely or probably use improved public transportation more frequently.

Together, these results suggest that Patna's congestion problem creates both measurable transport inefficiency and a substantial perceived burden on residents.

The policy implication is therefore not simply that Patna must make cars move faster. The larger objective should be to make **urban mobility more efficient**.

A successful transport system should minimise the amount of time, fuel, road space and pollution required to allow residents to reach schools, workplaces, markets, hospitals and other destinations.

From this perspective, the central question changes from:

"How can Patna accommodate more vehicles?" to:

"How can Patna move more people with less time, fuel and pollution?"

That is ultimately the more economically and environmentally sustainable approach.

The primary and secondary findings collectively support the central proposition that congestion creates intertwined economic and environmental costs.

The 2026 Patna corridor study provides direct evidence that road performance varies substantially by time and land use. Evening peak speeds averaged only 15.85 km/h compared with 28.30 km/h in the afternoon non-peak period (Kumar et al., 2026).

Consider a simplified hypothetical journey of 10 kilometres. At 28.3 km/h, the theoretical travel time would be approximately 21.2 minutes. At 15.85 km/h, it would be approximately 37.9 minutes. The difference is approximately 16.7 additional minutes.

This simplified calculation does not represent an actual door-to-door Patna journey because observed spot speeds are not identical to route-average journey speeds. Nevertheless, it illustrates the scale of the effect created when average traffic speeds decline.

For a commuter making two similar journeys each working day, the extra time would be approximately 33.4 minutes per day. Over 250 working days, that equals about 8,350 minutes, or approximately 139 hours per year. This time represents a substantial opportunity cost.

The Fuel-Cost Mechanism

The relationship between congestion and fuel expenditure is not simply that longer time automatically means proportionately more petrol. The mechanism is more complex.

Idling: Fuel is consumed while distance travelled is zero.

Repeated acceleration: Each time a vehicle accelerates after stopping, the engine must provide energy to restore momentum.

Inefficient operating speeds: Engines generally achieve better fuel economy within particular operating ranges. Extremely low-speed stop-and-go operation may produce poor fuel economy per kilometre.

Consequently, the relevant measurement is not fuel per minute but fuel per completed journey or fuel per kilometre under different traffic conditions.

A Household Cost Illustration

Consider a hypothetical petrol car that would normally consume 0.65 litres on a particular journey in relatively free-flowing traffic.

If repeated idling and acceleration increase consumption to 0.80 litres, congestion adds 0.15 litres per journey.

If the commuter makes two such journeys per working day, the additional use becomes 0.30 litres per day.

Over 250 working days, this equals 75 litres per year.

If petrol costs approximately ₹100–₹115 per litre, the resulting expenditure would be in the broad range of ₹7,500–₹8,625 annually for this commuter.

This is not a measured Patna statistic. It is a scenario calculation demonstrating how small daily inefficiencies can accumulate into meaningful annual household costs. For thousands of commuters, the aggregate amount becomes much larger.

ECONOMIC INTERPRETATION: CONGESTION AS MARKET FAILURE

Traffic congestion is a classic example of a negative externality.

When a driver enters a congested road, the driver considers personal benefits and costs such as convenience, travel time, petrol and parking. However, each additional vehicle slightly slows down other road users. The driver therefore imposes an external cost in the form of additional delay on everyone else.

The driver may also impose additional local pollution, greenhouse-gas emissions, noise, collision risk and demand for road and parking infrastructure.

Because these costs are not fully reflected in the price paid by the motorist, road space can become overused.

From an economic perspective, this explains why simply widening roads may not permanently solve congestion. Additional capacity can encourage additional vehicle trips, eventually placing renewed pressure on the road network. A sustainable solution must therefore improve both supply and demand management.

ENVIRONMENTAL INTERPRETATION

The pollution consequence of congestion operates at two levels. The first is global: burning additional petrol or diesel produces additional carbon dioxide, contributing to climate change. The second is local: residents near congested roads may experience exposure to pollutants released by dense traffic.

TERI's estimate that transport contributes approximately 19% of Patna's ambient PM2.5 demonstrates that transportation policy is directly relevant to air-quality management.

However, it is equally important not to exaggerate the result. If transport contributes around one-fifth of ambient PM2.5 in the relevant modelling exercise, approximately four-fifths comes from other sources. Therefore, cleaner traffic is necessary but insufficient.

- Domestic fuel use
- Road dust
- Construction
- Industrial emissions
- Brick kilns
- Open waste burning
- Generator sets

EQUITY AND CONGESTION

Congestion is also an equity issue. A wealthy household and a low-income household may both lose twenty minutes in traffic, but the financial implications differ.

Fuel expenditure represents a larger proportion of disposable income for lower- and middle-income households. At the same time, people who do not own cars may still suffer from the pollution and delays caused by private motor vehicles.

Bus passengers can be trapped in the same congestion as cars despite occupying much less road space per passenger. Pedestrians and cyclists may inhale roadside pollution without producing tailpipe emissions themselves.

This produces a distributional question: Who creates congestion, who pays for it, and who suffers its consequences? A sustainable mobility policy should therefore evaluate not merely average travel speeds but accessibility and fairness.

IX. POLICY RECOMMENDATIONS

9.1 Strengthen High-Quality Public Transport

The most important long-term solution is to provide attractive alternatives to private motor vehicles. The survey indicates that 78% of respondents would definitely or probably use public transport more frequently if it were reliable, comfortable and time-efficient. Improved buses can move substantially more passengers using less road space per person than private cars.

- Higher service frequency
- Predictable timetables
- Clean and safe vehicles
- Digital arrival information
- Integrated tickets
- Convenient interchanges
- Appropriate bus stops
- Efficient last-mile connectivity

9.2 Integrate Metro, Bus and Last-Mile Transport

Metro infrastructure can carry large passenger volumes, but its effectiveness depends on access. A commuter who lives several kilometres from a station still needs reliable first- and last-mile connectivity. Metro stations should therefore connect smoothly with buses, e-rickshaws, walking routes, cycling routes and organised pick-up zones. Public transport must operate as a network rather than a collection of unrelated modes.

9.3 Improve Traffic Signals

Poorly coordinated signals can create unnecessary queues. Signal timings should be based on traffic volume, turning movements, pedestrian demand and time of day. Adaptive or coordinated signal systems can potentially reduce unnecessary stopping. This is particularly relevant because

idling research shows that delays at intersections create measurable fuel and emissions losses (Sharma et al., 2019).

9.4 Manage Parking and Roadside Encroachment

Road capacity is determined not only by the physical width of a road but by how much of that width remains available for movement. A lane partially blocked by parked vehicles, delivery vehicles, vendors, informal auto stands or construction material has lower effective capacity.

Kumar et al. (2026) specifically identified on-street parking, pedestrian spill-over and roadside friction as important characteristics of Patna traffic environments. Enforcement should therefore be combined with properly designed alternatives. Simply removing informal activities without providing loading areas, vending zones or passenger pick-up points may shift problems elsewhere.

9.5 Reduce Unnecessary Engine Idling

Public information campaigns could encourage motorists to switch off engines during sufficiently long stationary periods when safe and appropriate. Modern automatic start-stop systems already perform this function in many vehicles. The objective is simple: if the vehicle is not moving for an extended period, avoid burning fuel unnecessarily. Such behaviour will not solve congestion, but it can reduce the economic and environmental cost generated while congestion persists.

9.6 Encourage Walking and Cycling for Short Journeys

Some urban motor-vehicle trips are sufficiently short to be replaced by walking or cycling. However, telling people to cycle is unrealistic if the street environment feels unsafe. Infrastructure must precede behavioural expectations.

- Usable footpaths
- Safer pedestrian crossings
- Continuous walking networks
- Protected cycle infrastructure where feasible
- Shade and lighting

Active travel produces almost no operational emissions and reduces demand for road space.

9.7 Cleaner Vehicles

Electric vehicles can substantially reduce direct tailpipe emissions. Electrification is particularly valuable for high-utilisation vehicles such as buses, taxis, auto-rickshaws and delivery fleets. However, electric vehicles must not be mistaken for a complete congestion solution. An electric car occupies approximately the same road space as a petrol car. One hundred electric cars can still create a traffic jam. Therefore, electrification addresses the emissions problem more directly than it addresses the congestion problem. Patna needs both cleaner vehicles and more efficient mobility.

9.8 School and Office Travel Management

Travel demand is concentrated during morning and evening peak periods. Institutions can help distribute this demand.

- School-bus systems
- Employee shuttles
- Carpool programmes
- Staggered office timings
- Hybrid working where appropriate
- Coordinated school arrival zones

The 2026 Patna findings showing major differences between afternoon and evening speeds demonstrate why time-of-day demand management matters.

Congestion Pricing: A Long-Term Possibility

Economists frequently propose congestion pricing as a method of making drivers account for some of the delay they impose on others. Vehicles entering the most congested districts during peak periods pay a charge.

The objective is not primarily to raise revenue. It is to encourage some travellers to travel at another time, take public transport, carpool or avoid unnecessary trips.

However, congestion pricing would be difficult to introduce fairly in Patna unless high-quality public transport alternatives existed first. Without alternatives, such charges could disproportionately burden commuters who have no practical choice but to drive. Therefore,

congestion pricing should be considered only as a longer-term policy following major improvements in public transportation.

EVALUATION OF THE HYPOTHESES

Hypothesis 1

Longer congestion-related travel times are associated with higher fuel consumption for private motor-vehicle users. Supported conceptually and by existing literature. Research demonstrates that idling and interrupted traffic consume fuel, while the survey suggests that commuters experiencing longer delays also report higher fuel bills. However, direct Patna fuel-flow measurements would be required to quantify the causal magnitude.

Hypothesis 2

Commuters who experience greater traffic delays report higher monthly expenditure on petrol or diesel. Supported within the dataset, but not established empirically. The simulated results show progressively greater average fuel expenditure across higher delay categories. A real survey must control for journey distance before reaching a strong conclusion.

Hypothesis 3

A majority of Patna commuters perceive congestion as an important contributor to air pollution. Supported within the survey model. Eighty-three percent described road traffic as important or very important.

Hypothesis 4

Reducing congestion can generate both private economic benefits and wider environmental benefits. Supported. Reducing idling and unnecessary stop-and-go operation can reduce fuel expenditure while also reducing emissions generated per journey.

LIMITATIONS

- The primary dataset currently presented is simulated and must be replaced with real survey results before the work is submitted as original empirical research.

- Even a real survey of 100 people would be relatively small compared with Patna's population.
- Convenience sampling may produce demographic bias.
- Reported travel time and fuel spending depend on respondent memory and may contain estimation errors.
- Monthly fuel expenditure does not depend only on congestion; it also varies by trip distance, vehicle type, mileage, engine size, driving style, number of trips and fuel prices.
- Pollution cannot be inferred directly from travel-time surveys because atmospheric pollution is affected by meteorology, background concentrations and multiple emission sources.
- Some city-level secondary datasets are older than the traffic observations used in this paper.

Future research should therefore combine GPS journey tracking, measured fuel consumption, traffic-camera counts, vehicle type, route distance and portable air-quality measurements.

OPPORTUNITIES FOR FURTHER RESEARCH

A more advanced follow-up study could equip 20–30 vehicles with GPS tracking or use smartphone journey data. Each participant could travel the same routes during peak and non-peak periods.

- Journey distance
- Journey duration
- Average speed
- Stationary time
- Fuel consumption
- Number of stops

This would allow calculation of fuel consumption per kilometre and a congestion fuel penalty, defined as the difference between peak-period and free-flow fuel consumption for the same route. The monetary cost could then be calculated by multiplying additional fuel consumption by the prevailing fuel price. Such a design would provide considerably stronger causal evidence.

CONCLUSION

Traffic congestion is often described in terms of irritation: horns, queues, missed appointments and slow journeys. This paper demonstrates that congestion should instead be understood as an economic and environmental problem.

When a vehicle takes longer to complete the same journey, the additional minutes are not free. They may produce a time cost because commuters lose productive or leisure hours. They may produce a financial cost because engines continue consuming petrol or diesel while vehicles idle, accelerate repeatedly or operate inefficiently in stop-and-go conditions. They may produce an environmental cost because additional fuel combustion generates additional emissions.

Patna demonstrates why this relationship deserves attention. A 2026 study of nine city corridors found average traffic speeds of only 21.16 km/h overall and 15.85 km/h during the evening peak. Commercial corridors experienced particularly high traffic flows and low speeds (Kumar et al., 2026).

At the same time, Patna's pollution source-apportionment evidence identifies transport as a significant contributor to particulate and gaseous pollution. Transport accounted for approximately 19% of ambient PM2.5 in the relevant modelling assessment, alongside substantial contributions to carbon monoxide and volatile organic compounds (TERI, 2021).

Government fuel data further demonstrate the scale of petroleum consumption in the Patna district, with approximately 99.8 thousand metric tonnes of petrol and 263.5 thousand metric tonnes of diesel recorded in 2018–19.

The survey reinforces the everyday dimension of these statistics. In the simulated 100-person sample, 74% of respondents frequently or very frequently experienced congestion-related delay, 69% of private-fuel users believed congestion increased their fuel expenditure, and 83% believed road traffic was an important contributor to air pollution.

The most important policy lesson is that these problems should not be addressed separately. A policy that makes traffic flow more efficiently may reduce travel time, fuel wastage and emissions simultaneously. A high-quality public-transport system can move more people while requiring less road space per passenger. Better traffic signals can reduce unnecessary idling. Parking management can restore effective road capacity. Walking and cycling infrastructure can remove short motorised trips entirely. Cleaner vehicles can reduce emissions generated by journeys that continue to require motorised transport.

Yet technology alone cannot eliminate congestion. An electric car remains a car in terms of road space. Building more roads may provide temporary relief but can also attract additional traffic. Patna therefore requires a broader shift from asking, "How can the city move more vehicles?" to asking, "How can the city move more people efficiently?" This distinction is fundamental.

The ultimate cost of congestion is not merely measured by the time displayed on a navigation app. It appears in household petrol bills, business delays, lost hours, polluted air and inefficient use of urban space. Reducing that cost can therefore improve household finances, economic productivity, public health and environmental sustainability simultaneously.

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Appendix A: Google Form

Section A: Respondent Information

1. Age group: Below 18; 18–25; 26–40; 41–60; Above 60.
2. Main mode of travel: Car; Two-wheeler; Auto/e-rickshaw; Bus; Cab; Bicycle/walking; Other.

Section B: Travel Time

1. Approximately how much time do you spend travelling on a normal weekday? Below 30 minutes; 30–60 minutes; 1–2 hours; More than 2 hours.

2. How often does traffic congestion significantly increase your travel time? Very frequently; Frequently; Sometimes; Rarely; Never.
3. On a congested day, approximately how much additional time does traffic add to a normal journey? Below 10 minutes; 10–20 minutes; 21–30 minutes; 31–45 minutes; More than 45 minutes.

Section C: Fuel Expenditure

1. If you regularly use a petrol or diesel vehicle, approximately how much does your household spend on fuel per month for your regular journeys? Below ₹2,000; ₹2,000–₹3,999; ₹4,000–₹5,999; ₹6,000–₹7,999; ₹8,000 or more; Not applicable.
2. Do you believe congestion increases your monthly fuel expenditure? Yes, significantly; Yes, somewhat; Very little; Not at all; Not sure.
3. When stationary for a long period, do you normally switch off your engine? Usually; Sometimes; Rarely; Never; Not applicable.

Section D: Pollution

1. How important do you think road traffic is as a contributor to air pollution in Patna? Very important; Important; Moderately important; Minor contributor; Not a contributor.
2. Have you personally noticed smoke, dust or poor air quality while travelling on congested roads? Frequently; Sometimes; Rarely; Never.

Section E: Solutions

1. Would you use public transport more frequently if it were reliable, comfortable and reduced your journey time? Definitely; Probably; Unsure; Probably not; Definitely not.
2. Which measure do you think would most effectively reduce congestion in Patna? Better buses/public transport; Improved traffic signals; Stricter parking and encroachment control; Better road/intersection design; Metro expansion/integration; Walking and cycling infrastructure; Restrictions or congestion charges on private vehicles.

Appendix B: Figures for the Final Paper

1. Conceptual pathway: congestion → time → fuel → expenditure → emissions.
2. Average traffic speed in Patna by time period: morning peak, afternoon non-peak and evening peak.
3. Patna PM2.5 source-apportionment pie chart.
4. Survey respondents by mode of transport.
5. Frequency of congestion-related travel delay.
6. Additional minutes caused by congestion.
7. Monthly fuel expenditure of private-vehicle respondents.
8. Perceived effect of congestion on fuel bills.
9. Travel delay versus average reported monthly fuel expenditure.
10. Public willingness to shift to improved public transportation.