2025/2026 Congestion Mitigation and Air Quality Improvement Program (CMAQ) Application

COUNTY OF FRESNO

CHESTNUT AVE & NORTH AVENUE INTERSECTION IMPROVEMENTS

2 of 3

$2,917,874 | $4,290,992

$87.97/lb.

Applicant Information

Implementing Agency: This agency must enter into a Master Agreement with Caltrans and will be financially and contractually responsible for the delivery of the project within all pertinent Federal funding requirements, including being responsible and accountable for the use and expenditure of program funds. This agency is responsible for the accuracy of the technical information provided in the application and is required to sign the application.

IMPLEMENTING AGENCY'S NAME:

COUNTY OF FRESNO

IMPLEMENTING AGENCY'S ADDRESS:	CITY:	STATE:	ZIPCODE:
2220 TULARE STREET, 6TH FLOOR	FRESNO	CA	93721

IMPLEMENTING AGENCY'S CONTACT PERSON:	CONTACT PERSON'S TITLE:
Mohammad Alimi	Design Engineer

CONTACT PERSON'S PHONE NUMBER:	CONTACT PERSON'S EMAIL ADDRESS:
(559) 600-4505	malimi@fresnocountyca.gov

General Project Information

PROJECT NAME: (To be used in all program referenced project lists)

Chestnut Ave & North Ave Intersection Improvements

Project/Application Number: (Priority # - Max 10 per Agency) 2 of 3

FTIP Proposed Project Title: (Maximum 34 characters)

Chestnut Ave & North Ave Intersection Improvements

Project is being submitted in the following category:

- ☐ Transit
- ☐ Cleaner Fuel Technology
- ☒ Traffic Flow Improvements
- ☐ Bicycle/Pedestrian
- ☒ PM-2.5/10 Reduction
- ☐ Miscellaneous

Is the project Cost-Effective? ($88/lb. or less) **YES**☒ **NO**☐

Does the project deliver PM2.5 emission reductions? **YES**☒ **NO**☐

SUMMARY OF PROJECT SCOPE: Summary of the Existing Condition, Project Scope, and the Expected Benefits:

Existing Condition:

The intersection of Chestnut Avenue and North Avenue is a heavily congested intersection in a mostly industrially zoned, urban area of Fresno County. It is located approximately 1.25 mile to the north of State Route 99 on Chestnut Avenue and is about 1.25 mile to the east of State Route 99 on North Avenue. Golden State Boulevard, which runs parallel to the east, is about .75 mile from the intersection on both North Avenue and Chestnut Avenue. Golden State Boulevard is a heavily traveled Minor Arterial which is the former US Interstate 99. The Central Canal runs parallel to the west side of Chestnut Avenue and the Fresno Colony Canal intersects that canal and parallels the north side of North avenue to the west. The San Joaquin Valley Railroad has a branch that runs parallel to North Avenue and crosses North Avenue west of Chestnut Avenue and the Central Canal. The intersection is one half-mile north of the unincorporated community of Malaga, an underserved area where 92% of residents are Hispanic and 80% live below the poverty line. The location is within Census Tract 15, considered an Area of Persistent Poverty. The Census Tract for the project location scored in the 99th percentile on CalEnviroScreen (Attachment K), which means that the pollution in this tract is higher than 99% of other Census tracts in the state. The left-turn phasing on east-bound and west-bound North Avenue is not protected and has a large average percentage of trucks and commercial traffic. The left-turn delay typically allows for only one truck, bus, or 2-3 cars per cycle. The traffic on both SR 99 from and Golden State Boulevard to the west, as well as the railroad, add to the traffic congestion.

Project Scope:

Add signalized left turn lanes to the east and west bound lanes of North Avenue; add a right turn lane to the westbound lane on North Avenue and add a right turn lane to the northbound traffic on Chestnut Avenue; change the light phasing to accommodate the new left-turn lanes.

Expected Benefits:

The expected benefits of the project are to reduce congestion and carbon emissions by installing protected left turn phasing at the intersection. This measure will prevent left-turning vehicles in the existing unprotected left-turn lane from having to wait for a gap in oncoming traffic, which can lead to congestion and increased emissions. Carbon emissions and congestion can be reduced by protected left turn phasing in several ways:

- Reduced idling: Left-turning vehicles in a protected lane do not have to idle while waiting for a gap in oncoming traffic. This can save a significant amount of fuel and emissions, especially for heavy-duty vehicles. At this intersection, approximately 20% of the traffic is from commercial trucking; that is, one of every five vehicles is a heavy vehicle.

- Reduced acceleration and deceleration: Left-turning vehicles in a protected left-turn phase do not have to accelerate and decelerate as much as vehicles in the through lane. This is because they do not have to worry about oncoming traffic or conflicting pedestrians. Reduced acceleration and deceleration can also save fuel and reduce emissions.

- Reduced traffic congestion: Protected left turn lanes can help to reduce traffic congestion at intersections. Vehicles queuing in the left-turn lanes exceed the storage capacity of the lane, thereby accumulating into adjacent through-lanes, which can lead to increased emissions by obstructing through-traffic and causing delays. This also increases the possibility of rear-end crashes and congestion of the intersection. The improvements allow left-turning vehicles traveling east-bound or west-bound on Central Avenue to proceed more safely and efficiently because the left-turn movements would allow traffic to proceed through the intersection without the hazards of oncoming traffic or conflicting pedestrians, which will result in reduced emissions.

PROJECT PURPOSE: Describe the main purpose of the project:

The purpose of the project is to decrease traffic congestion and carbon emissions that result from on-road, highway sources by reducing idling time at the intersection. The protected left turn signals will also provide increased safety at the intersection.

FTIP PROJECT DESCRIPTION: (Max 156 characters) [(Location :) + (Limits) + (;) + (Improvement)]

Chestnut Ave and North Avenue Intersection Improvements – Install left turn signals on North Avenue; add left turn lanes on east and west legs of North Avenue; replace ADA curbs ramps on all four corners.

PROJECT LOCATION: (Include Route # or Name, Post Mile Limits/Length of Project and Project Limits)

Intersection of Chestnut Ave & North Avenue near the unincorporated community of Malaga in central Fresno County.

In addition to the Location Description provided, please **attach** a location map to the application as specified in "Attachment G" below. The location map needs to show the project boundaries in relation to the Implementing Agency's boundaries.

Functional Classification: Examples of local function include arterial, expressway, major collectors, etc., as designated within local circulation plan. Provide both local classification and federal classification if different. The federal classification takes precedence. CMAQ funds may be used on local roadways.

Chestnut Ave: Minor Arterial (north), Other Principal Arterial (south); North Ave: Minor Arterial (See Attachment M)

Project Details

Air Pollution Reduction in kg/day: (submit calculations as attachment)

2.910 kg/day

Cost-Effectiveness in dollars/pound: (refer to guidelines for methodology, submit calculations as attachment)

$87.97/lb.

Average Daily Traffic Volume (ADT): (also, please provide source of ADT data)

Chestnut Ave: 5,400 (Source: Fresno County Traffic Census 2019) North Ave: 5,100 (Source: Fresno County Traffic Census 2009)

Annual Auto Trips Reduced in trips/year: (if greater than zero, calculations should be included in emissions reduction sheet attachment)

0

Annual Auto Vehicle Miles Travelled (VMT) Reduced in miles/year: (if greater than zero, calculations should be included in emissions reduction sheet attachment)

0

Air Quality Screening Criteria Code(s): (refer to Appendix A for list of codes, list all applicable)

5.02 Intersection signalization projects at individual intersections

Length/Width (in miles/feet) of Any New Active Transportation Facility (Class I / II / III / IV):

N/A

Length/Width (in miles/feet) of New Sidewalk:	**Number/Type of New Crosswalks:**
0	0

Number of New ADA Ramps:	**Number/Type of New Pedestrian Signals:**
4	4

If ITS Project, Number of Signals Connected:	**Length of Connected Signals:**
0	N/A

Does this project have a warrant study? (submit calculations as attachment)

YES, See attachment ☐ **NO** ☒

Right of Way (ROW) Impacts: (Check all that apply)

☐ <u>**Agency has site control.**</u> Project is 100% within the Implementing Agency's ROW and/or is within their control at the time of this application submittal. (This includes temporary construction easements)

☒ **Private ROW and/or utility relocations required.** Project will likely require ROW in fee ownership, permanent easements, and/or temporary construction easements from private owners and/ or will require utility relocations from utility companies outside that implementing agency's governmental control.

The federal ROW process involving private property acquisitions and/or private utility relocations can often take 18 to 24 months after environmental document approval. The project schedule in the application for ROW needs to reflect the necessary time to complete the federal ROW process.

☐ **Public ROW required.** Project will likely require ROW, Easements, encroachment, and/or approval involving Governmental, Environmental, or Railroad owner's property.

What is the total number of months included in the project schedule to account for all ROW and/or utility impacts selected above? 24

Anticipated ROW Certification Date. Expected date project will receive ROW certification or RFA for certification will be submitted.

2030

Is this project listed on the Financial Constrained List of the 2022 RTP?

☒ Project is on the constrained project list in the 2022 RTP. **RTP Project ID: FRE504060**

☐ Project is NOT on the constrained project list in the 2022 RTP.

If not, does the project meet the goal and objectives of the RTP policies? **YES** ☐ **NO** ☐

Optional: Please explain why the project is not on the RTP. The CMAQ Scoring Committee may take extenuating circumstances into consideration. Project would still be reduced by 5 points at minimum.

N/A

Please provide any other pertinent subjective information that you would like evaluators to consider when scoring your project:

A study published May 16, 2023, conducted by an international team of scientists, found that protected left turn lanes reduced carbon emissions by up to 30% at intersections with mixed traffic and high left-turn volumes. A printout of this study, published in the online peer-reviewed journal Heliyon, is included as Attachment L.

While safety is not a main focus of the CMAQ program, it is a strong motivator to acquire funding to make the intersection improvements. The intersection has experienced 34 collisions between January 2020 and December 2024 (Attachment I). There were a total of 12 severe injury collisions during this period. This intersection also experienced 8 sideswipe collisions during the 5-year period with 14 broadside and 3 head-on crashes. Adding the left turn signals will

Project Delivery Schedule

Fund	Work Phase	2026/27	2027/28	2028/29	2029/30	Total
CMAQ Regional Bid Funds						
68%	Percent share of costs – maximum 88.53%					
PE		356,138				**356,138**
ROW				246,840		**246,840**
Construction					2,314,897	**2,917,874**
Sub-total		**356,138**		**246,840**	**2,314,897**	**2,917,874**

Local Matching Funds					
32%	Matching fund rate – minimum 11.47%				
PE	167,594				**167,594**
ROW			116,160		**116,160**
Construction				**283,754**	**283,754**
Sub-total	**167,594**		**116,160**	**283,754**	**1,373,117**

Project Total					
PE	523,732				**523,732**
ROW			363,000		**363,000**
Construction				3,404,260	**3,404,260**
Grand Total	**523,732**		**363,000**	**3,404,260**	**4,290,992**

- Please fill out the project delivery schedule according to the planned years of implementation for your project.
- Note that actual programming will depend on financial capacity.
- **Please note that the cost-effectiveness calculation is based on the amount of total CMAQ funding, including any local match.**
- Any non-participating costs (non-CMAQ eligible costs) of your project need to be clearly listed in the engineers estimate, on this project delivery schedule, and on the financial plan.

Is the project applying as a "construction-ready project"? Points will be awarded to projects requesting construction funding only and within the first two years of the FTIP. Please attach all available environmental and ROW certifications or documentation. Projects requesting points in this category will go through a Caltrans screening process.

☐ **Project is requesting funds for construction only in the first year (2026/27) of the FTIP and PE/ROW documentation is attached.**

☐ **Project is requesting funds for construction only in the second year (2027/28) of the FTIP and PE/ROW documentation is attached.**

☒ **Project does not qualify / applicant is opting out**

Is the project going to follow an expedited delivery schedule? **YES☐** **NO☒**

Please check "yes" if your project qualifies for the construction ready and/or expedited project delivery scoring criteria and you agree to the project delivery guidelines.

Is the project leveraging additional local funds? Points will be awarded to projects that leverage additional local funds (Measure C, TDA) in addition to the required local match.

☐ **Project includes a 20% local match**

☒ **Project includes a 30% local match**

☐ **Project is not leveraging additional local funds**

Project Funding and Scalability

Proposed Source of Local Match Funding:
Place a checkmark in the box signifying where local matching funds for this project will be coming from and specify dollar amount.

LOCAL	***Sales Tax***	
	☐City	
	☐ County	
	☐ Other (Transportation Development Act)	
	Sales Tax sub-total:	
	Gas Tax	
	☐ Gas Tax (Subventions to Cities)	
	☒ Gas Tax (Subventions to Counties)	$1,073,117
	Gas Tax sub-total:	**$1,073,117**
	Other Local Funds	
	☐ City General Funds	
	☒ Street Taxes and Developer Fees	$300,000
	☐ Local Transportation Funds	
	☐ Other	
	Other Local Funds sub-total:	**$300,000**
	Transit	
	☐ Transit Fares	
	☐ Other Transit (parcel/property taxes, parking revenue, etc.)	
	☐ Tolls (e.g., non-state-owned bridges)	
	☐Other (e.g., RTEP)	
	Transit sub-total:	
REGIONAL	☐ Tolls	
	☐ Bridge	
	☐ Corridor	
	☐ Regional Transit Fares/Measures	
	☐ Regional Sales Tax "Measure C" Local Pass Through	
	☐ Regional Bond Revenue	
	☐ Regional Gas Tax	
	☐ Vehicle Registration Fees (CARB Fees, SAFE)	
	☐ Other	
	Regional sub-total:	
	Grand Total:	**$1,373,117**

Is this project scalable? **YES☐** **NO☒**

If yes, specify the minimum funds required: $

Please provide an explanation of scalability with specific reference to budget line items on the Financial Plan (Attachment B).

Example: If a project is asking for funding to pave 10 alleyways, and applicant is willing to take funding for #X (less <10) alleyways, or a partial scope of any project, this project would be considered scalable.

Would your agency accept partial funding for this project? **YES☒** **NO☐**

If yes, please explain your contingency plan to fully fund and implement the project.

If full funding cannot be awarded, the County will accept partial funding for PE and/or ROW phases and apply to future cycles for construction funding.

Application Attachments

Application Checklist and Signature Page (Required for all applications)
Attachment A

Financial Plan (Required for all applications)
Attachment B

AB 1012 Resolution (Required for all applications)
Attachment C

Project Estimate (Required for all applications)
Attachment D

Cost-Effectiveness and Emissions Reductions Calculations (Required for all applications)
Attachment E

RTP Documentation (Required for all applications)
Attachment F

Project Location Map (Required for all applications)
Attachment G

Preliminary Engineering and Design, Environmental, and Right-of-Way Documentation or Certification (If needed)
Attachment H

Collision Report
Attachment I

Photos of Existing Conditions (*Strongly* recommended for all applications)
Attachment J

Additional Attachments

Additional attachments may be included. They should be organized in a way that allows application reviews easy identification and review of the information. All additional attachments must be scanned into one document. Please list the additional attachments:

ATTACHMENT K- CALENVIROSCREEN
ATTACHMENT L - RESEARCH ARTICLE
ATTACHMENT M - CRS_10N53

Attachment A: Project Submittal Checklist and Signature Page

Name of Project:

Chestnut Ave & North Ave Intersection Improvements

Submitted by:

Mohammad Alimi, Design Engineer

Agency/Organization:

County of Fresno, Department pf Public Works and Planning

Check All That Apply:

- ☒ Project meets CMAQ eligibility under federal guidelines.
- ☒ Sponsor will comply with California Environmental Quality Act, the National Environmental Policy Act, the Americans with Disabilities Act, AB1012 (Timely Use of Funds), Buy America, and/or any other applicable regulations.
- ☒ Project can be obligated within the identified timelines.
- ☒ Project scope will remain the same as detailed in application.
- ☒ Emissions calculations are attached and show positive reduction in air pollution.
- ☐ If needed, a warrant study is attached.
- ☐ If needed, PE&D, Environmental, and ROW documentation are attached.
- ☒ AB 1012 Resolution is attached.
- ☒ 10 hard copies of application for regional bid are attached, and an electronic copy has been provided via email or USB flash drive.
- ☒ An engineer's estimate/quote of probable costs for project is attached.
- ☒ All required attachments are included.
- ☒ I understand that incomplete or late submittals will be considered for scoring at the committee's discretion, as time allows, after scoring other projects.

I certify that the information contained in the application packet is accurate to the best of my knowledge and that I am authorized to submit the following project proposal for scoring and possible programming. The agency will provide the required non-federal matching funds, and deliver the project as proposed within the scope and schedule specified in the application should the project be awarded funding. Signature of full-time agency staff authorized to enter into a contract for federal funding if selected.

Signed: [signature]

Printed Name: **Mohammad Alimi, Design Engineer**

Date: **03/21/2025**

Attachment B: Financial Plan

Below, please discuss the project funding strategy, clearly indicating total cost, authorization amounts and dates for all funding sources committed or anticipated to fully fund the project and any contingency plan if anticipated funding does not materialize. Any contingency plan to provide a reduced scope, should partial funding be available, would need to take into consideration air quality benefits and demonstrate it is feasible to perform the project in deliverable segments, or with reduced scope.

The total project cost is estimated to be $4.3 million, with the Preliminary Engineering (PE) and Right-of-way (ROW) phases costing $887k. The project funding strategy is to use CMAQ funding for cost effectiveness and supplement the project costs and the local match with development fees, SB-1 funds, and possibly HSIP funds. If full funding cannot be awarded, the County will accept partial funding for PE and/or ROW phases and apply to future cycles for construction funding.

I certify that the information contained in the financial plan is accurate to the best of my knowledge and that I am authorized to submit the following project proposal for scoring and possible programming. The agency will provide the required non-federal matching funds, and deliver the project as proposed within the scope and schedule specified in the application should the project be awarded funding.

Signed: [signature]

Printed Name: Mohammad Alimi, Design Engineer

Date: 03/21/2025

23-1184

ATTACHMENT C

Resolution No. 23-370

BEFORE THE BOARD OF SUPERVISORS
OF THE COUNTY OF FRESNO
STATE OF CALIFORNIA

A RESOLUTION OF THE BOARD OF SUPERVISORS OF FRESNO COUNTY REGARDING PROJECT DELIVERY SCHEDULES FOR FEDERAL TRANSPORTATION PROJECT SELECTION UNDER ASSEMBLY BILL 1012	RESOLUTION

WHEREAS, AB 1012 was enacted into State law, in part to provide for the "timely use" of State and Federal funding; and

WHEREAS, the County of Fresno (County) is able to apply for and receive Federal and State funding under the Congestion Mitigation and Air Quality (CMAQ) Program, the Carbon Reduction Program (CRP), and the Surface Transportation Block Grant (STBG) Program; and

WHEREAS, the County desires to ensure that its projects are delivered in a timely manner to preclude the Fresno Region from losing those funds for non-delivery; and

WHEREAS, it is understood by the County that failure for not meeting project delivery dates for any phase of a project may jeopardize Federal or State funding to the Region; and

WHEREAS, the County must demonstrate dedicated and available matching funds.

NOW THEREFORE BE IT RESOLVED that the Fresno County Board of Supervisors (Board) hereby agrees to ensure that all project delivery deadlines for all project phases will be met or exceeded.

BE IT FURTHER RESOLVED, that failure to meet project delivery deadlines may be deemed as sufficient cause for the Fresno Council of Governments Policy Board to terminate an agency's project and reprogram Federal/State funds as deemed necessary.

BE IT FURTHER RESOLVED, that the Board hereby directs its management and engineering staffs to ensure all projects are carried out in a timely manner as per the requirements of AB 1012 in accordance herewith.

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ATTACHMENT C

THE FOREGOING, was passed and adopted by the following vote of the Board of Supervisors of the County of Fresno this 28th day of November, 2023, to wit:

AYES: Supervisors Brandau, Magsig, Mendes, Pacheco, Quintero
NOES: None
ABSENT: None
ABSTAINED: None

Sal Quintero, Chairman of the Board
of Supervisors of the County of Fresno

ATTEST:
Bernice E. Seidel
Clerk of the Board of Supervisors
County of Fresno, State of California

By ____________________
Deputy

ATTACHMENT D

COUNTY OF FRESNO
DEPARTMENT OF PUBLIC WORKS AND PLANNING
PRELIMINARY ENGINEER'S ESTIMATE
FRESNO, CA
March 20, 2025

PROJECT:
CHESTNUT AVE & NORTH AVE INTERSECTION IMPROVEMENTS

Item No.	Item Description	Estimated Quantity	Unit	Unit Price	Amount
1	Mobilization	1	LS	$ 140,000	$140,000
2	Construction Funding Sign	2	EA	$ 2,000	$4,000
3	Traffic Control	1	LS	$ 172,500	$172,500
4	Job Site Management	1	LS	$ 5,000.00	$5,000
5	Prepare & Implement SWPPP	1	LS	$ 5,000	$5,000
6	Dust Control	1	LS	$ 23,000	$23,000
7	Clearing and Grubbing	1	LS	$ 60,000	$60,000
8	Detectable Warning Devices	48	SF	$ 35.00	$1,680
9	Roadway Excavation	500	CY	$ 70.00	$35,000
10	Finishing Roadway	1	LS	$ 15,000	$15,000
11	Class II Aggregate Base	500	CY	$ 100	$50,000
12	Hot Mix Asphalt	979	TON	$ 115	$112,556
13	Cold Plane Asphalt	550	SY	$ 3.50	$1,925
14	Tack Coat	1	TON	$ 1,500	$1,500
15	Minor Concrete Curb Ramps and Returns	4	EA	$ 8,000	$32,000
16	Adjust Water Valve Box Covers to Finished Grade	1	EA	$ 1,000	$1,000
17	Adjust Electrical Vaults to Finished Grade	1	LS	$ 5,000	$5,000
18	Adjust Manholes to Finished Grade	1	EA	$ 1,500	$1,500
20	Signage, Striping, Pavement Markings	1	LS	$ 40,000	$40,000
21	Signal and Lighting System	1	LS	$ 600,000.00	$600,000
31	Miscellaneous Facilities and Operations	1	LS	$ 12,000.00	$12,000
22	Culvert Extension	1	LS	$ 300,000.00	$300,000
23	Railroad Crossing Improvements	1	LS	$ 1,000,000.00	$1,000,000
	Street Improvements Subtotal				**$2,618,661**

Contingency (15%)		**$392,799**
Construction Items Subtotal		**$3,011,460**
Construction Engineering (15%)		**$392,799**
	CON SUBTOTAL	**$3,404,260**
Preliminary Engineering (20%)		**$523,732**
RIGHT OF WAY ACQUISTION		**$363,000**
	PE & ROW SUBTOTAL	**$886,732**
	PROJECT TOTAL:	**$4,290,992**

ATTACHMENT E

Fresno County **CMAQ Emission Calculations**

Project Description
Chestnut Ave & North Ave Intersection Improvements

Inputs to Calculate Cost-Effectiveness:

Total Project Cost	4,290,883	
CMAQ Dollars	2,917,874	
Effectiveness Period (Life):	30 yrs	
Days of Use/year (D):	365 days	
Roadway Length (L):	1 mile(s)	
Congested Traffic Volume	7600 trips per day	
Before Speed	8 mph	
After Speed	20 mph	*See Page 26 of 2005 ARB Methodology.*

Emissions Factors (From Table 4, for a 5 year Service Life):

	Before Speed Factor (grams/mile) *8 mph*	*After Speed Factor (grams/mile)* *20 mph*
ROG Factor	0.67	0.3
NOx Factor	1.3	0.95
PM10 Factor	0.08	0.040
PM2.5 Factor	0.012	0.007

Calculations:

Annual Project VMT = (D) x (L) x (Congested Traffic)
= 2,774,000 miles/year

Annual Emission Reductions (ROG, Nox and PM10) in pounds/year)

0.5 x [(VMT) x (Before Speed Factor - After Speed Factor)]/454

ROG = 1130
NOx = 1069
PM10 = 122
PM2.5 = 15

Annual Emission Reductions = ROG + NOx + PM10 + PM2.5
= 2337.1 (lbs/yr)

Once emissions reductions have been calculated, add them together and convert pounds of emissions reductions per year to kg/day:

$$\frac{\text{Annual Emission Reductions (lbs/yr)}}{2.2\ \text{lbs/kg} \times 365\ \text{days/yr}}$$

Thus,
Calculated Emissions Reductions = **2.910** **kg/day**

		Kg/Day
ROG	=	1.408
NOx	=	1.332
PM10	=	0.152
PM2.5	=	0.019

Capital Recovery Factor (CRF)

$$= \frac{(1+i)^n \times i}{(1+i)^n - 1}$$ where i = Discount Rate (3%) and n = Project Life (20 years)

So, the capital recovery factor = 0.07

Cost-Effectiveness of CMAQ Dollars

= (CRF x CMAQ Funding) / (ROG + NOx + PM10)
= 87.97

Thus,
Calculated Cost - Effectiveness = **$87.97** **(dollars/lb.)**

MAIN MENU LOGOUT | FCOG

Fresno Council of Governments

Metropolitan Planning Organization and Regional Transportation Planning Agency

VIEW PREVIOUS VERSIONS OF THIS PROJECT UPLOAD PROJECT DOCUMENTS

PROJECT ID: FRE504060 VERSION: 2 EST TOTAL COST: $2,600,000.00 STATUS: In Progress - Programmed RANK SCORE:

LAST MODIFIED BY: Estefany Villafan (1/17/2025) APPROVED BY: N/A HISTORY (+) EDIT OBLIGATION

ADMINISTRATIVE EDIT - READ-ONLY

CALL FOR PROJECTS: 26-00 - RTP

FRESNO MODELING #

INTERNAL NOTES

ADMINISTRATIVE NOTES

AMENDMENT NOTES

PROJECT INFORMATION

IMPLEMENTING AGENCY: Fresno County

MODE - GUIDELINES: Streets & Roads-Operations

[EDIT SCORE]

CAPACITY INC: N

BIKE PED: N

PROJECT TITLE: Chestnut and North

PROJECT DESCRIPTION - GUIDELINES: Traffic signal improvement to improve LOS

SYSTEM	ROUTE	SUFFIX	INTERSECTION	LOCAL STREET NAME	CROSSSTREET	CROSSSTREET	DISTANCE (MI)
Local			Y	N/A	Chestnut Ave	North Ave	N/A

PROGRAMMING INFORMATION ($0)

PDF DRILLDOWN REPORT [HISTORICAL REVENUES] [GRAPH REVENUES]

EST TOTAL PROJECT COST	ESTIMATED OPEN TO TRAFFIC DATE
$2,600,000.00	2040

HISTORICAL COMMENTS

- ○ COMPLETE PROJECT
- ○ DELETE PROJECT
- ● CARRY OVER FROM 22-01

Add funding to new phase
Add new funding source
Delete fund source
Increase funding
None
Project Closure - Final Report
Reduce funding
Revise funding between fiscal years

OTHER CHANGE REASON

JUSTIFICATION - LAST UPDATED: 12/16/2024 -

Carry over; increased estimate

SUMMARY OF CHANGES (AUTOMATE)
Changed Project Completion Date:
- from "2025" to "2040"
Changed Change Reason:
- from "New Project" to "Increase funding"

No change in project funding

Total project cost remains the same at $0

CONTACT FCOG   3.03s   EMAIL FRESNOTRAKHELP@ECOINTERACTIVE.COM

	DATE:	SCALE IN FEET	DEPARTMENT OF PUBLIC WORKS & PLANNING
DESIGNED: D.N.	03/12/2025	Feet 0 100 200	ATTACHMENT G
REVISED D.N.	03/12/2025		NORTH AVE AND CHESTNUT AVE TRAFFIC SIGNAL IMPROVEMENTS
STATE BRIDGE NO. N/A			

ATTACHMENT H

County of Fresno
Traffic Engineering

From 1/1/2020 to 12/31/2024

Collision Summary Report 3/12/25

Total Collisions: 34
Injury Collisions: 12 Total Injured: 21
Fatal Collisions: 0 Total Killed: 0

CHESTNUT & NORTH

9435202000084 **1/9/2020** **17:30** Thursday NORTH - CHESTNUT 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:1
Sideswipe Other Motor Vehicle Auto R/W Violation 21801A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver East Making Left Turn Age: No Injury
Veh Type: Sobriety: Assoc Factor:
Party 2 Driver West Proceeding Straight Age: No Injury
Veh Type: Sobriety: Assoc Factor:

9435202001412 **5/2/2020** **13:20** Saturday CHESTNUT - NORTH 30' Direction: South Daylight Clear Pty at Fault:1
Rear-End Other Motor Vehicle Unsafe Speed 22350 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Proceeding Straight Age: Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver North Stopped In Road Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:
Party 3 Driver North Stopped In Road Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:
Party 4 Driver North Stopped In Road Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:

9435202001568 **5/15/2020** **14:00** Friday CHESTNUT - NORTH 0' Direction: Not Stated Daylight Clear Pty at Fault:1
Rear-End Other Motor Vehicle Unsafe Speed 22350 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Making U Turn Age: No Injury
Veh Type: Sobriety: Assoc Factor:
Party 2 Driver North Proceeding Straight Age: No Injury
Veh Type: Sobriety: Assoc Factor:

9435202002702 **8/7/2020** **12:00** Friday NORTH - CHESTNUT 0' Direction: Not Stated Daylight Clear Pty at Fault:1
Sideswipe Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver South Proceeding Straight Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver West Stopped In Road Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:

9435202003387 **9/11/2020** **06:35** Friday CHESTNUT - NORTH 20' Direction: South Daylight Other Pty at Fault:1
Rear-End Other Motor Vehicle Unsafe Starting or Backing 22106 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Proceeding Straight Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver North Stopped In Road Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:

ATTACHMENT I

County of Fresno
Traffic Engineering

From 1/1/2020 to 12/31/2024

Total Collisions: 34

Collision Summary Report

3/12/25

Injury Collisions: 12 Total Injured: 21

Fatal Collisions: 0 Total Killed: 0

CHESTNUT & NORTH

9435202000084 **1/9/2020** **17:30** Thursday NORTH - CHESTNUT 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:1
Sideswipe Other Motor Vehicle Auto R/W Violation 21801A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver East Making Left Turn Age: No Injury
Veh Type: Sobriety: Assoc Factor:
Party 2 Driver West Proceeding Straight Age: No Injury
Veh Type: Sobriety: Assoc Factor:

9435202001412 **5/2/2020** **13:20** Saturday CHESTNUT - NORTH 30' Direction: South Daylight Clear Pty at Fault:1
Rear-End Other Motor Vehicle Unsafe Speed 22350 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Proceeding Straight Age: Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver North Stopped In Road Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:
Party 3 Driver North Stopped In Road Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:
Party 4 Driver North Stopped In Road Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:

9435202001568 **5/15/2020** **14:00** Friday CHESTNUT - NORTH 0' Direction: Not Stated Daylight Clear Pty at Fault:1
Rear-End Other Motor Vehicle Unsafe Speed 22350 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Making U Turn Age: No Injury
Veh Type: Sobriety: Assoc Factor:
Party 2 Driver North Proceeding Straight Age: No Injury
Veh Type: Sobriety: Assoc Factor:

9435202002702 **8/7/2020** **12:00** Friday NORTH - CHESTNUT 0' Direction: Not Stated Daylight Clear Pty at Fault:1
Sideswipe Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver South Proceeding Straight Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver West Stopped In Road Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:

9435202003387 **9/11/2020** **06:35** Friday CHESTNUT - NORTH 20' Direction: South Daylight Other Pty at Fault:1
Rear-End Other Motor Vehicle Unsafe Starting or Backing 22106 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Proceeding Straight Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver North Stopped In Road Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:

CHESTNUT & NORTH

9435202004038 **11/5/2020** **18:35** Thursday NORTH - CHESTNUT 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:1
Broadside Other Motor Vehicle Auto R/W Violation 21801A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver East Making Left Turn Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver West Proceeding Straight Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:

9435202004148 **11/11/2020** **22:55** Wednesday NORTH - CHESTNUT 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:1
Sideswipe Other Motor Vehicle Improper Passing 21755 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver East Passing Other Vehicle Age: Truck Tractor No Injury
Veh Type: Truck Sobriety: Assoc Factor:
Party 2 Driver East Making Left Turn Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:

9435202101292 **4/7/2021** **00:01** Wednesday NORTH - CHESTNUT 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:1
Head-On Other Motor Vehicle Auto R/W Violation 21801A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver East Making Left Turn Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver West Proceeding Straight Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:

9435202101338 **4/9/2021** **18:30** Friday CHESTNUT - NORTH 0' Direction: Not Stated Daylight Clear Pty at Fault:1
Broadside Other Motor Vehicle Improper Turning 22107 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Other Unsafe Turning Age: Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: Assoc Factor:
Party 2 Driver North Proceeding Straight Age: Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: Assoc Factor:

91585823 **9/28/2021** **23:00** Tuesday NORTH - CHESTNUT 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:1
Head-On Other Motor Vehicle Auto R/W Violation 21801A Hit & Run: No Complaint of Pain # Inj: 1 # Killed: 0

Party 1 Driver East Making Left Turn Male Age: 19 2007 NISS Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 2 Driver West Proceeding Straight Female Age: 20 2011 NISS Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated

91596178 **10/4/2021** **00:30** Monday NORTH - CHESTNUT 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:1
Broadside Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver West Proceeding Straight Male Age: 46 2001 GMC Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
Party 2 Driver North Proceeding Straight Female Age: 32 2004 PONT Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated

91684968 **1/15/2022** **14:35** Saturday NORTH - CHESTNUT 0' Direction: Not Stated Daylight Cloudy Pty at Fault:1
Broadside Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Complaint of Pain # Inj: 1 # Killed: 0

Party 1 Driver North Proceeding Straight Female Age: 50 2004 CADI Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated

Party 2 Driver East Proceeding Straight Male Age: 61 2008 TOYT Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
91713496 **2/17/2022** **12:20** Thursday NORTH - CHESTNUT 0' Direction: Not Stated Daylight Clear Pty at Fault:1
Broadside Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Other Visible Injury # Inj: 2 # Killed: 0

Party 1 Driver East Proceeding Straight Male Age: 35 2007 HOND Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 2 Driver South Proceeding Straight Male Age: 28 1999 TOYT Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
91733969 **3/15/2022** **12:28** Tuesday CHESTNUT - NORTH 0' Direction: Not Stated Daylight Clear Pty at Fault:1
Head-On Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Severe Injury # Inj: 4 # Killed: 0

Party 1 Driver South Proceeding Straight Female Age: 22 2015 NISS Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 2 Driver West Making Left Turn Male Age: 23 2016 FORD Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
91743661 **3/31/2022** **11:25** Thursday NORTH - CHESTNUT 25' Direction: East Daylight Clear Pty at Fault:1
Rear-End Other Motor Vehicle Unsafe Speed 22350 Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver West Proceeding Straight Male Age: 57 2015 DODG Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
Party 2 Driver West Stopped in Road Female Age: 21 2021 NISS Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
91829859 **7/24/2022** **12:25** Sunday NORTH - CHESTNUT 0' Direction: Not Stated Daylight Clear Pty at Fault:1
Broadside Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Complaint of Pain # Inj: 2 # Killed: 0

Party 1 Driver North Proceeding Straight Female Age: 51 2006 FORD Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 2 Driver East Proceeding Straight Male Age: 45 2011 HOND Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 3 Driver West Proceeding Straight Female Age: 24 2013 KIA Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
91907584 **10/28/2022** **10:12** Friday NORTH - CHESTNUT 100' Direction: East Daylight Clear Pty at Fault:
Rear-End Other Motor Vehicle Unsafe Starting or Backing 22106 Hit & Run: Misde Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver West Proceeding Straight Male Age: 20 2009 MITS Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
Party 2 Driver West Stopped in Road Male Age: 45 2022 TOYT Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
Party 3 Driver West Stopped in Road Not Sta Age: 0 CHEV Unknown Hit and Run Vehicle Involvem No Injury
Veh Type: Not Stated Sobriety: Impairment Not Kno Assoc Factor: Not Stated Not Stated Not Stated
92064128 **5/7/2023** **16:15** Sunday CHESTNUT - NORTH 0' Direction: Not Stated Daylight Clear Pty at Fault:
Broadside Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Complaint of Pain # Inj: 2 # Killed: 0

Party 1 Driver South Proceeding Straight Female Age: 36 2017 HYUN Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 2 Driver East Making Right Turn Female Age: 64 2015 CHEV Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated

CHESTNUT & NORTH

92133460 **7/28/2023** **12:51** Friday NORTH - CHESTNUT 0' Direction: Not Stated Daylight Clear Pty at Fault:
Sideswipe Other Motor Vehicle Unknown Hit & Run: Misde Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver East Making Right Turn Male Age: 72 2002 CHEV Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
Party 2 Driver South Proceeding Straight Male Age: 29 2015 TOYT Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated

92191205 **9/23/2023** **22:20** Saturday CHESTNUT - NORTH 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:
Sideswipe Other Motor Vehicle Unsafe Lane Change 21658A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Changing Lanes Female Age: 23 2018 HYUN Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 2 Driver North Proceeding Straight Female Age: 31 2016 JEEP Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated

92194381 **9/30/2023** **20:00** Saturday CHESTNUT - NORTH 0' Direction: Not Stated Dark - Street Ligh Clear Pty at Fault:
Broadside Other Motor Vehicle Auto R/W Violation 21801A Hit & Run: Misde Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver North Proceeding Straight Female Age: 40 2014 DODG Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
Party 2 Driver South Making Left Turn Not Sta Age: 0 - Unknown Hit and Run Vehicle Involvem No Injury
Veh Type: Not Stated Sobriety: Impairment Not Kno Assoc Factor: Not Stated Unknown Not Stated

92261073 **12/7/2023** **14:20** Thursday NORTH - CHESTNUT 0' Direction: Not Stated Daylight Cloudy Pty at Fault:
Broadside Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver East Proceeding Straight Male Age: 60 2007 CHRY Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 2 Driver North Proceeding Straight Male Age: 48 2017 FRHT Truck Tractor No Injury
Veh Type: Truck with Trailer Sobriety: HNBD Assoc Factor: Not Stated Not Required Not Stated

92279451 **12/30/2023** **17:10** Saturday NORTH - CHESTNUT 0' Direction: Not Stated Dark - Street Ligh Cloudy Pty at Fault:
Broadside Other Motor Vehicle Traffic Signals and Signs 21453A Hit & Run: No Complaint of Pain # Inj: 1 # Killed: 0

Party 1 Driver South Proceeding Straight Female Age: 35 2015 MERZ Sport Utility Vehicle No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated
Party 2 Driver East Proceeding Straight Male Age: 20 2016 HOND Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HNBD Assoc Factor: Not Stated Air Bag Deployed Not Stated

92292086 **1/2/2024** **22:07** Tuesday CHESTNUT - NORTH 45' Direction: North Dark - Street Ligh Raining Pty at Fault:
Rear-End Other Motor Vehicle Driving Under Influence 23152A Hit & Run: No Complaint of Pain # Inj: 1 # Killed: 0

Party 1 Driver South Proceeding Straight Male Age: 33 2009 FORD Passenger Car, Station Wagon, Jeep No Injury
Veh Type: Passenger Car Sobriety: HBD Under Influence Assoc Factor: Not Stated Air Bag Deployed Not Stated
Party 2 Driver South Stopped in Road Male Age: 21 2023 CHEV Pickups & Panels No Injury
Veh Type: Pickup Truck Sobriety: HNBD Assoc Factor: Not Stated Air Bag Not Deployed Not Stated

92362488 **4/7/2024** **10:13** Sunday CHESTNUT - NORTH 30' Direction: South Daylight Clear Pty at Fault:
Hit Object Fixed Object Other Equipment 29006A Hit & Run: Misde Property Damage Only # Inj: 0 # Killed: 0

Party 1 Driver West Other Unsafe Turning Not Sta Age: 0 - Unknown Hit and Run Vehicle Involvem No Injury
Veh Type: Not Stated Sobriety: Impairment Not Kno Assoc Factor: Not Stated Unknown Not Stated

CHESTNUT & NORTH

92363286	**4/8/2024**	**12:30**	Monday	NORTH - CHESTNUT	15'	Direction: West	Daylight	Clear	Pty at Fault:
	Sideswipe		Other Motor Vehicle	Improper Turning	22107	Hit & Run: No	Property Damage Only	# Inj: 0	# Killed: 0
Party 1 Driver	East	Other Unsafe Turning	Male	Age: 27	2019 NISS		Passenger Car, Station Wagon, Jeep	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		
Party 2 Driver	East	Proceeding Straight	Male	Age: 24	2018 FORD		Pickups & Panels	No Injury	
Veh Type: Pickup Truck		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		
92364405	**4/8/2024**	**20:10**	Monday	NORTH - CHESTNUT	0'	Direction: Not Stated	Dark - No Street	Clear	Pty at Fault:
	Broadside		Other Motor Vehicle	Traffic Signals and Signs	21453A	Hit & Run: No	Other Visible Injury	# Inj: 1	# Killed: 0
Party 1 Driver	West	Proceeding Straight	Male	Age: 33	2021 FRHT		Truck Tractor	No Injury	
Veh Type: Truck with Trailer		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		
Party 2 Driver	North	Proceeding Straight	Male	Age: 43	2018 NISS		Sport Utility Vehicle	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Deployed		Not Stated		
92369106	**4/18/2024**	**08:05**	Thursday	CHESTNUT - NORTH	0'	Direction: Not Stated	Daylight	Clear	Pty at Fault:
	Rear-End		Other Motor Vehicle	Improper Turning	22107	Hit & Run: No	Property Damage Only	# Inj: 0	# Killed: 0
Party 1 Driver	South	Other Unsafe Turning	Male	Age: 56	2000 JEEP		Sport Utility Vehicle	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		
Party 2 Driver	South	Proceeding Straight	Female	Age: 19	2019 HYUN		Passenger Car, Station Wagon, Jeep	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Deployed		Not Stated		
92399968	**5/18/2024**	**17:50**	Saturday	CHESTNUT - NORTH	0'	Direction: North	Daylight	Clear	Pty at Fault:
	Hit Object		Fixed Object	Driving Under Influence	23152A	Hit & Run: No	Severe Injury	# Inj: 1	# Killed: 0
Party 1 Driver	North	Other Unsafe Turning	Male	Age: 18	1992 TOYT		Pickups & Panels	No Injury	
Veh Type: Pickup Truck		Sobriety: HBD Under Influence	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		
92432106	**6/28/2024**	**18:42**	Friday	NORTH - CHESTNUT	0'	Direction: Not Stated	Daylight	Clear	Pty at Fault:
	Broadside		Other Motor Vehicle	Traffic Signals and Signs	21453A	Hit & Run: No	Complaint of Pain	# Inj: 4	# Killed: 0
Party 1 Driver	East	Proceeding Straight	Male	Age: 29	2015 VOLK		Sport Utility Vehicle	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Deployed		Not Stated		
Party 2 Driver	North	Proceeding Straight	Female	Age: 21	2009 FORD		Passenger Car, Station Wagon, Jeep	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Deployed		Not Stated		
Party 3 Driver	West	Stopped in Road	Male	Age: 35	2020 JEEP		Sport Utility Vehicle	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		
92433152	**7/7/2024**	**12:45**	Sunday	NORTH - CHESTNUT	0'	Direction: Not Stated	Daylight	Clear	Pty at Fault:
	Broadside		Other Motor Vehicle	Traffic Signals and Signs	21453A	Hit & Run: No	Property Damage Only	# Inj: 0	# Killed: 0
Party 1 Driver	East	Proceeding Straight	Male	Age: 38	2016 HOND		Passenger Car, Station Wagon, Jeep	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		
Party 2 Driver	North	Proceeding Straight	Male	Age: 40	2010 TOYT		Passenger Car, Station Wagon, Jeep	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		
92464667	**7/17/2024**	**09:27**	Wednesday	NORTH - CHESTNUT	7'	Direction: West	Daylight	Clear	Pty at Fault:
	Sideswipe		Other Motor Vehicle	Unknown		Hit & Run: No	Property Damage Only	# Inj: 0	# Killed: 0
Party 1 Driver	East	Making Right Turn	Female	Age: 37	2018 NISS		Passenger Car, Station Wagon, Jeep	No Injury	
Veh Type: Passenger Car		Sobriety: HNBD	Assoc Factor: Not Stated		Air Bag Not Deployed		Not Stated		

ATTACHMENT J

PHOTOS OF EXISTING CONDITIONS
CHESTNUT AVE & NORTH AVE TRAFFFIC SIGNAL IMPROVEMENTS

Figure 1: Chestnut Avenue facing north.

Figure 2: Chestnut Avenue facing south.

PHOTOS OF EXISTING CONDITIONS
CHESTNUT AVE & NORTH AVE TRAFFFIC SIGNAL IMPROVEMENTS

Figure 3: North Avenue facing east.

Figure 4: North Avenue facing west.

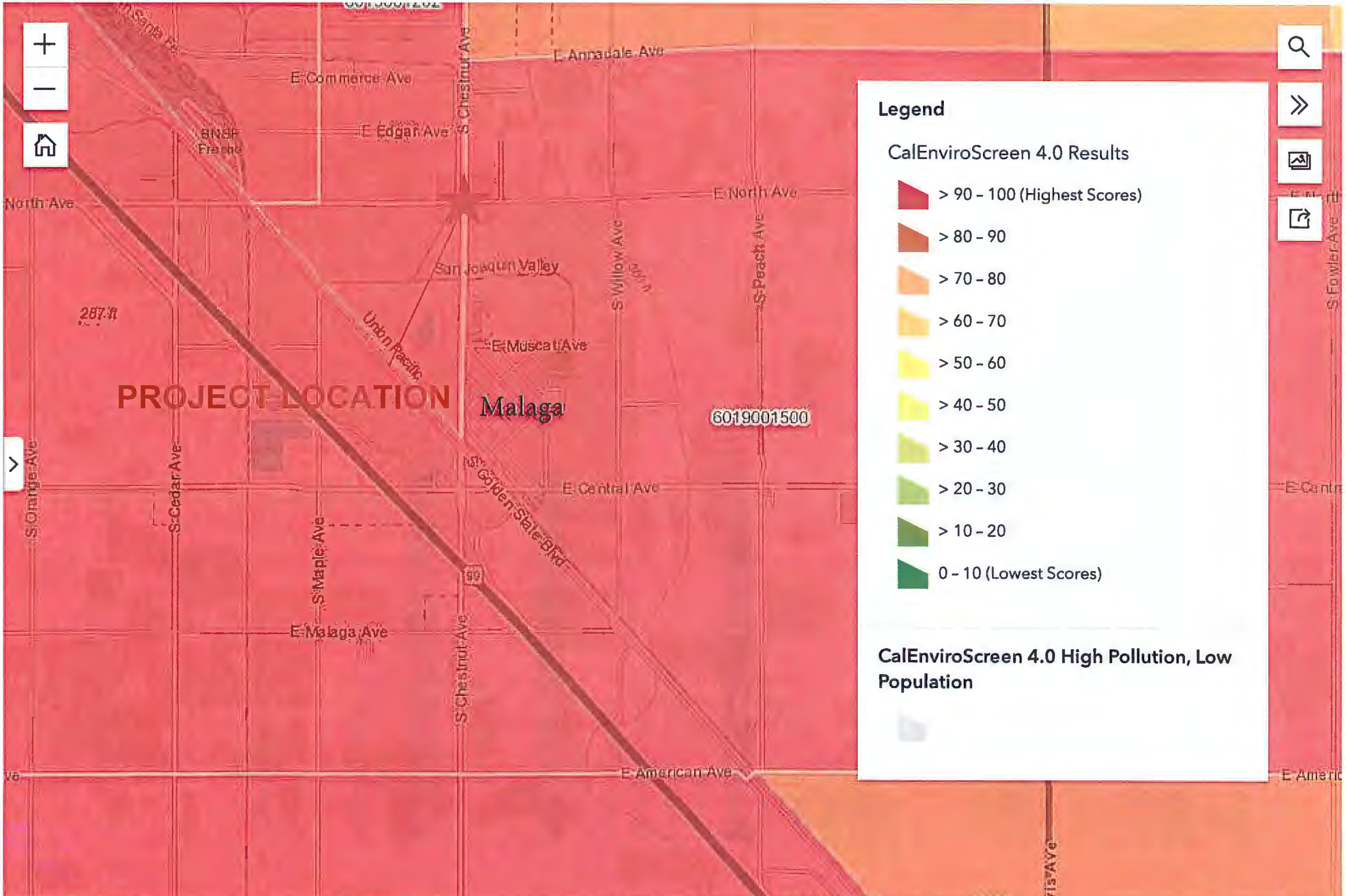
PHOTOS OF EXISTING CONDITIONS
CHESTNUT AVE & NORTH AVE TRAFFFIC SIGNAL IMPROVEMENTS

Figure 3: North Avenue facing east from railraod crossing.

Figure 4: North Avenue facing west from canal toward railroad crossing.

ATTACHMENT K

CalEnviroScreen 4.0   from O…   SB 535 Disadvantaged Commu…   CalEnviroScreen W…   Indicator Maps   About



Esri, HERE, Garmin, FAO, NOAA, USGS, EPA | Header, P1, P2, P3, P4, H1, and P5 Tables from U.S. Census Bureau's 2020 Public Law 94-171 files.   Powered by Esri

ATTACHMENT K

Census Tract: 6019001500 (Population: 2,407)

The results for each indicator range from 0-100 and represent the percentile ranking of census tract 6019001500 relative to other census tracts.

Overall Percentiles	
CalEnviroScreen 4.0 Percentile	99
Pollution Burden Percentile	100
Population Characteristics Percentile	79
Exposures	
Ozone	85
Particulate Matter 2.5	96
Diesel Particulate Matter	65
Toxic Releases	95
Traffic	25
Pesticides	95
Drinking Water	100
Lead from Housing	82
Environmental Effects	
Cleanup Sites	98
Groundwater Threats	94
Hazardous Waste	99
Impaired Waters	0
Solid Waste	100
Sensitive Populations	
Asthma	93
Low Birth Weight	34
Cardiovascular Disease	71
Socioeconomic Factors	
Education	95
Linguistic Isolation	70
Poverty	94
Unemployment	88
Housing Burden	14

Heliyon 9 (2023) e16260

Contents lists available at ScienceDirect

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Research article

Emission impacts of left-turn lane on light-heavy-duty mixed traffic in signalized intersections: Optimization and empirical analysis

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ARTICLE INFO

Keywords:
Traffic emission
Instantaneous emission model
Left-turn lane
Traffic efficiency and simulation

ABSTRACT

Reducing emissions from the transport sector is one of the crucial countermeasures for climate action. This study focuses on the optimization and emission analysis regarding the impacts of left-turn lanes on the emissions of mixed traffic flow (CO, HC, and NO_x) with both heavy-duty vehicles (HDV) and light-duty vehicles (LDV) at urban intersections, combining high-resolution field emission data and simulation tools. Based on high-precision field emission data collected by Portable OBEAS-3000, this study first develops instantaneous emission models for HDV and LDV under various operating conditions. Then, a tailored model is formulated to determine the optimal left-lane length for mixed traffic. Afterward, we empirically validate the model and analyze the effect of the left-turn lane (before and after optimization) on the emissions at the intersections using the established emission models and VISSIM simulations. The proposed method can reduce CO, HC, and NO_x emissions crossing intersections by around 30% compared to the original scenario. The proposed method significantly reduces average traffic delays after optimization by 16.67% (North), 21.09% (South), 14.61% (West), and 2.68% (East) in different entrance directions. The maximum queue lengths decrease by 79.42%, 39.09%, and 37.02% in different directions. Even though HDVs account for only a minor traffic volume, they contribute the most to CO, HC, and NO_x emissions at the intersection. The optimality of the proposed method is validated through an enumeration process. Overall, the method provides useful guidance and design methods for traffic designers to alleviate traffic congestion and emissions at urban intersections by strengthening left-turn lanes and improving traffic efficiency.

1. Introduction

The transport sector takes up around a quarter of greenhouse gas (GHG) emissions globally and plays a crucial role in realizing the ultimate goal of net-zero emissions in the era of climate change [1,2]. Meanwhile, transport-related air pollution contributes to a large part of global air pollution [3,4]. Although air quality standards have been improved by government and agencies such as the US

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https://doi.org/10.1016/j.heliyon.2023.e16260
Received 23 March 2023; Received in revised form 26 April 2023; Accepted 11 May 2023
Available online 16 May 2023

Environmental Protection Agency and the World Health Organization (WHO) to guide and facilitate air quality improvements, more than 90% of the world's population lives in areas where pollutant levels are higher than WHO air quality standards [5]. Excessive emissions in terms of GHG emissions and pollutants in the transport sector have been resulting in profound negative impacts on air quality, climate, and public health that influence almost every piece of daily life [6,7]. Especially, traffic congestion due to large traffic volume reduces driving speed and thus leads to significantly higher energy consumption and emissions during operations [8,9]. Therefore, it is crucial to reduce emissions in the transport sector by improving infrastructure, vehicles, and the operation of the systems from different aspects. Urban transport managers and policymakers worldwide are pressing to reduce transport emissions to fulfill the national target of reducing emissions.

One of the focuses of reducing transport emissions in urban areas is to reduce traffic congestion in typical bottlenecks (e.g., intersection and freeway merging areas) and corresponding traffic emissions, taking advantage of effective infrastructure and traffic management. In traffic congestion situations, internal combustion engine (ICE) vehicles emit 5–10 times more pollutants than in normal driving conditions [10]. One essential component for establishing effective infrastructure and traffic management to reduce traffic emissions is the use of vehicle emission models. These models quantify the emission patterns of vehicles under different driving conditions, providing important insights for reducing emissions and improving air quality. (e.g., speed and acceleration). Vehicle emission models are essential for evaluating and optimizing the actual performances of traffic management. The necessity of vehicle emission models has motivated researchers to develop various modeling approaches based on different data sources [11]. used a portable emission test system to test and examine the on-road fuel consumption and carbon dioxide (CO_2) emissions of 60 light passenger vehicles. Their results indicated that the on-road fuel consumption and emissions under the average driving patterns were 10 $\pm$ 2% higher than type-approval values and were highly influenced by speeds. Their results highlighted the necessity of measuring emissions in the type approval test based on real-world driving features [12]. studied traffic emissions in the work zone using the Comprehensive Modal Emissions Model (CMEM) to generate second-by-second emissions. They reported that fuel consumption rates and emission rates of hydrocarbons (HC), carbon monoxide (CO), nitrogen oxide (NO_x), and CO_2 were highly related to traffic conditions. Meanwhile, the emission patterns of light-duty and heavy-duty vehicles in different traffic conditions presented different principles. Meanwhile [13], developed a method for assessing the representativeness of fuel-specific vehicle-based emission factors. The method was validated based on actual emission data for 23 selected light gasoline vehicles. Results indicated that route average emission factors varied by approximately 20% for NO_x or CO, and site-specific emission factors varied by 20% for NO_x and 30% for CO between sites, respectively. However, fuel-based HC emission rates varied little with engine load, between routes, or between sites. This showed that estimating vehicle operational emissions was a complex process, especially in traffic flow with much complexity and randomness [14]. confirmed the importance of accurate emission modeling for different vehicle types (e.g., hybrid electric vehicles) in the Vehicle Specific Power model and improved the emission models tailored for hybrid electric vehicles. They also made significant improvements to the emissions detection tool in terms of temporal resolution, simultaneous data recording capability and data accuracy.

One of the most critical infrastructure and traffic management for reducing traffic emissions is optimizing the design of intersections [15–17], which are the most critical bottlenecks of urban transportation systems. To name a few [16], investigated the design of multiple target signal cycle lengths to minimize vehicle delays and traffic emissions. The simulation software INTEGRATION was used to simulate traffic demand distribution, traffic demand levels, signal timing loss times, and signal cycle lengths and to estimate intersection delays and emissions (CO_2, HC, CO, and NO_x) [18]. pointed out that emissions of road pollutants were related to many infrastructure parameters as well as to the intensity and type of traffic. They investigated the performances and the pollutant emissions of turbo roundabouts (CO, CO_2, CH_4, NO_x, PM2.5, and PM10), assessed by COPERT software (European emission calculation tool) [19]. studied road geometries that continuously guide drivers from the entrance to the exit while eliminating weaving and queue jumping, and investigated the impact of conventional single-lane and two-lane roundabouts on traffic emissions, traffic capacity, and safety. Their results showed that the implementation of turbo-roundabouts has no benefit in terms of reducing emissions.

In urban intersections, the lane functions are generally set to left-turn (or turnaround), through, and right-turn. The left-turn lane generates the most conflict points among vehicles from different directions and thus has the most significant impact on traffic efficiency and emissions [16,20,21]. When the left-turn traffic volume reaches a certain threshold, a dedicated left-turn lane is required to reduce the impact of left-turn vehicles in the opposite road lanes to improve traffic efficiency at the intersections [22]. Therefore, rationalizing the design of left-turn lanes is one of the most effective measures to improve traffic efficiency and reduce traffic emissions at intersections [15]. In the relevant studies of optimizing left-turn lanes, the main design objectives are generally to reduce conflict points and improve capacity and efficiency. For instance Ref. [23], developed a method to determine the length of left-turn lanes at signalized intersections that can prevent spillover. The study considered intersection capacity, arrival rates, different signal schemes, and sequences of left-turn and through traffic to obtain the probabilities of lane blockage and lane overflow to calculate the recommended length of left-turn lanes. Yao and Zhang (2013) proposed three models to optimally allocate lane space and green divisions for isolated signalized intersections with short left-turn lanes. Two performance metrics were proposed to compare the performance of the three models and to investigate their sensitivity to the model parameters. Afterward, Bing et al. (2014) investigated the impact of lane configurations on traffic emissions based on the traffic simulation tools VISSIM and VSP emission models. Traffic emissions under different lane configurations were analyzed in different scenarios in terms of five indicators, including average delay per vehicle, the average number of stops per vehicle, and total emissions of CO, HC, and NO_x. Results showed that the presence of dedicated left-turn lanes (with or without widening) had a significant impact on the traffic flow and emission characteristics of the intersection [24]. focused on improving the operation of urban intersections, which are often congested and a key bottleneck of the road network. The study proposes a model that integrates an improved optimal velocity model and a multi-intersection signal state function to analyze traffic flow, including vehicles turning left accurately. The model also considers pollutant emissions and has been tested through simulation analysis to show its effectiveness in describing actual traffic flow [25]. proposed an optimization model for minimizing delay in traffic for left-turns at signalized intersections using exit-lanes for a left-turn (EFL) traffic organization. The model considered the relationship between the pre-signal start node of the EFL and the queuing dissipation time of left-turn vehicles. The validation of the model showed that a well-designed pre-signal control scheme can improve capacity and reduce emissions while minimizing average vehicle delays compared to conventional left-turn lanes.

There is extensive literature on the effects of left-turn lanes on traffic flow characteristics (e.g., travel time and speed) [26,27]. However, there is much less research about the impact of dedicated left-turn lane settings on different exhaust emissions. In particular, most existing studies ignored the complexity of mixed traffic flow with different vehicle types and mainly focused on single traffic flow with merely light-duty passenger vehicles. Few studies have investigated the left-turn lane optimization specific for mixed traffic flows, even though heavy-duty vehicles (HDVs) and light-duty vehicles (LDVs) have significantly distinct emission patterns, vehicular sizes, and kinetic characteristics [12–14]. Therefore, the left-turn lanes at the intersections for mixed traffic are anticipated to have different design principles and should be tailored based on new methods for mixed traffic rather than existing methods for LDVs.

To address the gap, this study focuses on the optimization and emission analysis regarding the impacts of left-turn lanes on the emissions (CO, HC, and NO_x) of mixed traffic flow with HDVs and LDVs, combining high-resolution field emission data and simulation tools. We utilize portable OBEAS-3000 to collect high-precision emission data for LDVs and HDVs in various traffic scenarios. Based on the field data, we first develop separate instantaneous emission models for HDVs and LDVs under various operating conditions. Then, we formulate a tailored optimization model to determine the optimal left-lane length considering the penetration rate of HDV and traffic volumes from different directions at the intersection. Finally, we empirically validate the proposed model and analyze the effect of the length of the left-turn lane (before and after optimization) on the emissions of mixed traffic flows based on the established emission model and microscopic traffic simulations using VISSIM.

The remaining sections of the paper are structured as follows. Section 2 provides a description of the emission data collection process and emission modeling. In Section 3, we elaborate on the model to determine the length of the left-turn lane for mixed traffic flow. Section 4 describes the simulation method and empirical case study, followed by concluding remarks in Section 5.

2. Emission data collection and emission model establishment

This study uses the portable emission monitoring device OBEAS-3000 to collect vehicle emission data regarding CO, HC, and NO_x in real traffic scenarios, considering the complexity of road conditions and the contingent nature of vehicle operating conditions. The instantaneous emission rate of CO, HC, and NO_x operating in different traffic conditions for LDV and HDV are collected to establish vehicle-type specific emission models.

2.1. Emission data collection equipment

The OBEAS-3000 portable emission monitor in Fig. 1 was used to continuously collect the instantaneous emission of CO, HC, NO_x, and corresponding vehicle operating dynamics, including positions (coordinates), speed, and accelerations. The data acquisition frequency is 10 Hz, namely, ten times in a second. The data reflect the quantitative relationship between instantaneous emissions and vehicle dynamics in a high resolution [28]. The experimental vehicles include both LDVs and HDVs. LDVs refer to M1, M2, and N1 vehicles with a total mass not exceeding 3.5 tonnes, while HDVs refer to vehicles with a total mass exceeding 8 tonnes [29]. The LDVs in this study were the Volkswagen Lavida and Harvard SUV, which were typical and popular household passenger cars in China. For HDVs, we used the vehicle of FAW Liberty. The petrol emission standards for the experimental vehicles were Chinese National IV, with engine displacements of 1.6 L (Volkswagen Lavida), 2.0 L (Harvard SUV), and 6.6 L for the HDV. The detailed parameters of the experimental LDVs and HDV are summarized in Table 1. The vehicles were driven in the urban contexts of Shanghai, China in the daytime to collect the emission data under real traffic conditions. After experiments, a total of 170972, 66804 and 52251 valid records were finally collected for Volkswagen Lavida, Harvard SUV, and the heavy-duty vehicle, respectively.

Fig. 1. OBEAS-3000 portable emission monitor.

Table 1
Technical details of the experimental vehicles.

Model/Parameters	Light vehicles		Heavy vehicles
Brands	Volkswagen Lavida	Harvard SUV	FAW Liberty
Mass (kg)	1285	1725	15790
Engine Displacement (L)	1.6	2.0	6.6
Fuel type	Petrol	Petrol	Diesel
Emission standards	State IV Standard	State IV Standard	State IV Standard
Year of manufacture	2010	2014	2012

2.2. *Instantaneous vehicle emission models for light- and heavy-duty vehicles*

The VSP calculation model can effectively describe the instantaneous emission characteristics of vehicles, and it has a higher time and driving state resolution than other macroscopic emission models, which can effectively express the time-varying characteristics of traffic emissions. Vehicle emission patterns depend highly on vehicle dynamics during operations, which is a complex process. In this study, we adopt the well-known Vehicle Specific Power (VSP) model to establish the relationship between vehicle dynamics and instantaneous emissions of different exhausts. Utilizing field data we have collected in Shanghai of China, we develop instantaneous emission models for both LDVs and HDVs in terms of CO, HC and NO_x for quantifying vehicle emissions. VSP is the instantaneous power per unit mass of a vehicle (kW/t), and the transient emissions of a vehicle are closely related to the VSP values [30]. It should be noted that the VSP models for vehicles in different countries may be different due to different vehicle emission standards. Herein, we use the field emission data in Shanghai for empirical analysis. The formula of VSP [31] can be seen in Eq. (1).

$$VSP = v \times (a + g \times grade + g \cdot C_R) + \frac{1}{2} \cdot \rho_a \cdot \frac{C_D}{m} \cdot A \cdot v^3 \tag{1}$$

where v is the instantaneous speed, m/s. a is the instantaneous acceleration, m/s^2. g is the acceleration of gravity and is set to be 9.81 m/s^2. *grade* is the road gradient, %. C_R is the rolling resistance coefficient. ρ_a is the air ambient density. C_D is the air resistance coefficient. A_i is the area of the vehicle cross-section, m^2. m is the total vehicle mass, kg [32]. provided model parameters of VSP model for LDVs based on empirical data, and the VSP value of LDVs can be expressed by Eq. (2).

$$VSP = v \times (1.1a + g \times grade + 0.132) + 0.000302v^3 \tag{2}$$

In this study, the effect of the slope is not considered because the experimental areas (i.e., Shanghai, China) are plain without much variation in altitude, so *grade* is set to be 0 [28]. The VSP formula for HDVs is not the same as that for LDVs due to the considerable distinctions in vehicular characteristics [33]. Referring to Ref. [33]; this study uses the following VSP calculation formula for HDVs considering vehicle weight, front-end cross-section, and other parameters regarding HDVs.

$$VSP = v \times (a + g \times grade + 0.09199) + 0.000169v^3 \tag{3}$$

Based on second-by-second speed and acceleration data, the corresponding VSP is calculated and then grouped into discrete bins, which will link to the emissions of different exhausts. Please note that even though the device can record emission and vehicle dynamic data in a high resolution (0.1s), we aggerated the data into 1s on account of variation and monitoring accuracy to obtain more reliable results. In terms of determining the number of VSP bins, two basic rules of thumb are generally adopted: (1) the emission rates in different VSP bins should be statistically different; and (2) the resolution of bins should be high enough to avoid minor VSP bins that dominate the estimate of emissions [34]. To make full use of fine-grained vehicle operating and emission data, we divide the VSP values by a step of 1 kW/t to generate the BIN partition, which can well satisfy the aforenoted two rules.

$$\forall VSP \in VSP_{BI.N_i} = \begin{cases} (-\infty, -30] \\ [n-1, n), n = (-29, 29], n \in Z \\ [30, +\infty) \end{cases} \tag{4}$$

in our field data, we have collected the instantaneous vehicle dynamics, including speed and accelerations, and corresponding instantaneous emissions of exhausts (CO, HC and NO_x) detected by the OBEAS-3000 system. Using Eqs (2) and (3), the VSP at a certain time slot can be calculated based on speed and acceleration. To establish the relationship between VSP values and instantaneous exhaust emissions, we group the instantaneous emission rates (CO, HC and NO_x) by the VSP interval (every 1 kW/t) and then calculate the instantaneous emission rates in the same VSP interval to obtain representative emission rates within each VSP interval. Especially, the processes are separately conducted for LDVs and HDVs. The final results for the instantaneous emissions within different VSP intervals for LDVs and HDVs are summarized in Table 2. These results construct a relationship between the vehicle operating conditions (speed and acceleration), VSP values, and the corresponding emission rates for the different exhausts, which can be utilized for the following analysis. Particularly, there are remarkable differences in the emission rates of different exhausts in the same VSP interval, which corroborates the necessity to develop separate emission models for HDVs and LDVs.

Table 2
Instantaneous emission data for VSP at 1 kW/t partition for LDV and HDV.

VSP	LDV			HDV		
	Instantaneous emissions (mg/s)			Instantaneous emissions (mg/s)		
	CO	HC	NO_x	CO	HC	NO_x
(-∞ , -30)	4.27	0.77	0.15	111.84	13.71	18.59
[-30 , -29)	4.28	0.42	0.08	68.45	10.99	14.89
[-29 , -28)	4.62	0.59	0.15	92.02	11.37	12.18
[-28 , -27)	2.92	0.74	0.23	87.14	11.88	14.90
[-27 , -26)	2.16	0.34	0.03	101.90	13.81	17.80
[-26 , -25)	7.95	0.57	0.24	116.41	15.56	21.67
[-25 , -24)	5.72	0.60	0.27	103.48	9.40	14.62
[-24 , -23)	4.80	0.57	0.20	151.47	14.57	11.74
[-23 , -22)	2.30	0.47	0.03	150.56	14.54	22.91
[-22 , -21)	3.06	0.50	0.45	96.43	12.78	18.73
[-21 , -20)	5.05	0.72	0.26	94.08	10.62	8.31
[-20 , -19)	4.49	0.51	0.10	131.80	12.39	26.63
[-19 , -18)	5.50	0.57	0.19	70.33	9.79	14.96
[-18 , -17)	3.06	0.62	0.16	82.79	11.78	10.88
[-17 , -16)	3.78	0.55	0.15	65.97	8.61	10.20
[-16 , -15)	4.25	0.62	0.36	108.66	13.05	15.14
[-15 , -14)	5.59	0.51	0.18	83.90	13.32	22.83
[-14 , -13)	5.21	0.65	0.07	71.29	9.00	10.73
[-13 , -12)	5.19	0.72	0.13	97.78	10.85	16.90
[-12 , -11)	5.54	0.54	0.07	72.69	11.87	14.59
[-11 , -10)	4.45	0.88	0.17	78.75	9.81	17.12
[-10 , -9)	5.67	0.59	0.20	68.22	10.15	14.64
[-9 , -8)	5.45	0.57	0.18	72.19	10.51	12.09
[-8 , -7)	4.56	0.85	0.14	86.53	10.18	15.16
[-7 , -6)	5.14	0.46	0.16	63.44	11.11	15.15
[-6 , -5)	4.23	0.53	0.05	65.69	11.54	13.29
[-5 , -4)	6.22	0.95	0.24	63.83	9.04	12.25
[-4 , -3)	3.74	0.49	0.10	70.91	9.54	12.91
[-3 , -2)	3.94	0.69	0.06	64.36	8.84	10.11
[-2 , -1)	3.13	0.53	0.12	75.58	11.72	17.61
[-1 , 0)	3.31	0.59	0.08	100.49	11.19	14.50
[0 , 1)	2.24	0.42	0.02	46.95	7.29	7.44
[1 , 2)	3.56	0.65	0.07	66.88	9.38	11.09
[2 , 3)	4.09	0.60	0.16	60.13	9.35	13.09
[3 , 4)	4.67	0.71	0.09	69.81	10.73	14.52
[4 , 5)	7.24	0.80	0.22	103.63	9.79	15.63
[5 , 6)	3.90	0.56	0.14	73.96	11.21	16.24
[6 , 7)	6.92	0.81	0.21	87.71	9.40	11.86
[7 , 8)	7.82	0.84	0.10	97.53	10.64	13.26
[8 , 9)	5.62	0.69	0.22	91.18	10.45	14.83
[9 , 10)	8.96	0.82	0.41	73.50	10.37	16.70
[10 , 11)	7.27	0.67	0.16	84.97	10.50	13.36
[11 , 12)	7.68	0.75	0.30	100.07	11.69	15.73
[12 , 13)	6.60	0.77	0.18	81.80	11.77	16.48
[13 , 14)	9.29	0.85	0.38	92.66	11.56	14.74
[14 , 15)	8.99	0.89	0.23	103.44	11.97	18.88
[15 , 16)	7.95	0.72	0.14	100.01	12.36	17.27
[16 , 17)	8.22	0.95	0.18	82.90	12.08	16.32
[17 , 18)	6.14	1.19	0.26	107.68	14.08	20.35
[18 , 19)	6.66	0.86	0.23	159.31	14.13	12.92
[19 , 20)	7.74	0.80	0.32	93.99	11.32	20.34
[20 , 21)	11.87	0.94	0.32	94.69	11.43	14.51
[21 , 22)	7.01	0.79	0.22	102.21	11.87	21.39
[22 , 23)	8.85	0.86	0.28	86.06	12.50	19.13
[23 , 24)	8.89	1.05	0.26	76.94	11.99	16.88
[24 , 25)	12.19	0.93	0.23	72.89	11.73	16.74
[25 , 26)	5.82	1.00	0.26	96.07	12.32	19.84
[26 , 27)	6.91	0.81	0.20	90.50	10.95	17.97
[27 , 28)	11.08	1.01	0.33	111.83	13.61	18.04
[28 , 29)	5.73	1.82	0.55	102.11	12.49	16.47
[29 , 30)	16.03	0.97	0.32	117.23	11.97	22.59
[30 , +∞)	6.77	1.51	0.27	110.06	13.62	23.34

3. Determining the left-turn lane for mixed traffic flow

The left-turn lane at an intersection generally includes a deceleration section (traverse section) and a storage section (see Fig. 2 (a)). Vehicles complete the traverse from through to left-turn in the deceleration section and then turn left or queue to wait for the next green-light phase. Inadequate lengths of the storage section will result in two consequences, as shown in Fig. 2 (b) and (c). A large number of left-turn vehicles will cause the left-turn queue to block the adjacent straight lane, making it impassable for the through traffic, as shown in Fig. 2(b). A long queue of through traffic will block the left-turn lane, preventing left-turn vehicles from passing into the storage section, as shown in Fig. 2(c). Short left-turn lane length can cause increased conflict between left-turning and straight-

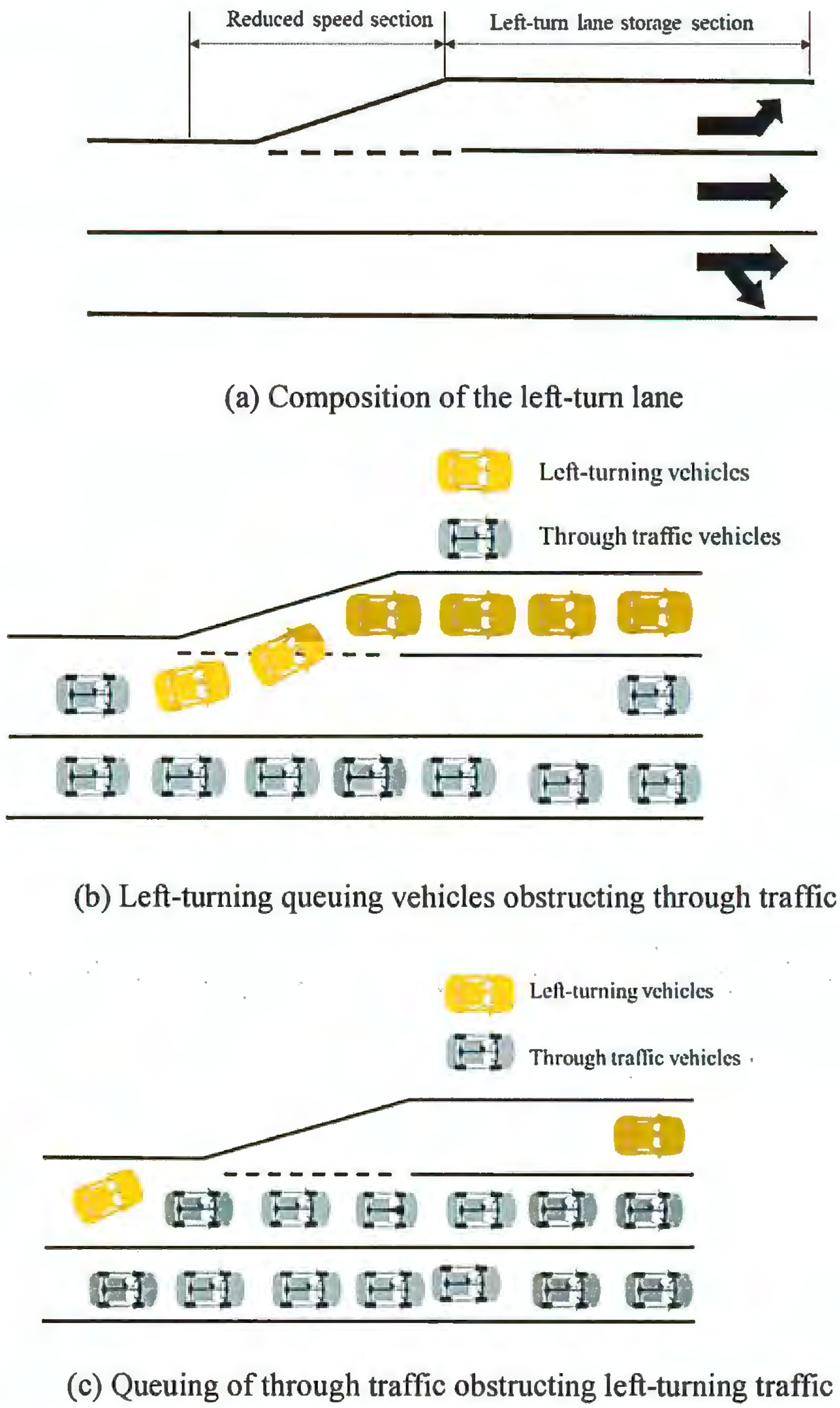

Fig. 2. Diagram showing the impact of insufficient left-turn lane storage length on traffic flow.

through vehicles, so the length of the left-turn storage section is, therefore, crucial to the operational efficiency of the intersection. Our design aim is to determine the optimal storage length of the left-turn lane for mixed traffic with different penetration rates of HDVs for reducing conflict points, traffic delays, and thus traffic emissions at the intersection. Due to the large difference in the length of HDVs and LDVs, the left-turn lane storage length for mixed traffic flow must consider not only the number of vehicles in the traffic flow but also the proportion of HDVs in the traffic flow. It is worth noting that it is implausible to directly formulate an optimization in which left-turn lane length is the decision variable and the overall traffic emission at the intersection is the objective function [15,26,27]. The reason is that the quantitative relationships between left-turn lane length and traffic emission cannot be mathematically modeled directly or indirectly. However, leveraging the validated relations between traffic delays and emissions, it is plausible to formulate an optimization model minimizing traffic delays and minimizing traffic emissions indirectly. This strategy has been adopted and validated by several relevant studies [15,16,20,26,27] and is utilized herein.

Assuming that the traffic flow on the road section consists of n different types of vehicles and the length of the vehicle type i is L_i with $L_1 < L_2 < \cdots < L_i < \cdots < L_n$. The proportion of vehicle type i is P_i and $P_1 + P_2 + \cdots + P_i + \cdots + P_n = 1$. Because the combination of two adjacent vehicles in the traffic flow is random, the probability of the combination that the preceding vehicle is the type i and the following vehicle is the type j, is P_iP_j. Then, it is easy to verify, as shown in Eq. (5).

$$\sum_{i=1}^{r}\sum_{j=1}^{r} p_i p_j = (p_1 + p_2 + \cdots + p_r)^2 = 1 \tag{5}$$

Assume t_{ij} is the time headway between vehicle type i and vehicle type j when the traffic volume reaches the capacities of a lane. We can estimate the average time headway in the mixed traffic of various vehicle types, as shown in Eq. (6).

$$H_t = \sum_{i=1}^{n}\sum_{j=1}^{n} p_i p_j t_{ij} \tag{6}$$

Based on the average time headway, the theoretical capacity of one lane for mixed traffic is

$$CP = \frac{3600}{H_t} = \frac{3600}{\sum_{i=1}^{n}\sum_{j=1}^{n} p_i p_j t_{ij}} \quad i,j = 1,2,3,\cdots,n \tag{7}$$

The above equations are genera for mixed traffic flows with several vehicle types. However, this study mainly investigates the case of two types of vehicles on account of the available emission models, namely $n = 2$. Let us assume the proportion of LDVs and HDVs are p and $1 - p$. We use subscripts l and h to denote light- and heavy-duty vehicles, respectively. It can be deduced that the capacity of a lane for mixed traffic flow is

$$CP = \frac{3600}{\sum_{i=1}^{2}\sum_{j=1}^{2} p_i p_j t_{ij}} = \frac{3600}{t_{ll}p^2 + (t_{lh} + t_{hl})p(1-p) + t_{hh}(1-p)^2} \tag{8}$$

In a mixed traffic flow, the arrival rate of left-turn vehicles at the intersection is λ (veh/h), and the maximum number of vehicles per hour that can pass the intersection at the left-turn green light phase is μ. λ is set to be less than μ. Otherwise, it will be undissipated traffic congestion. We assume that vehicle arrivals follow a Poisson distribution and time headway follows a negative exponential distribution, as most traffic flow studies did [8,9]. In this regard, this is a typical M/M/1 queuing model. As per the queueing theory, the probability that there is a queue of n_l LDVs waiting in the left-turn lane at a given time is

$$P_{nl} = p\left(1 - \frac{\lambda}{\mu}\right)\left(\frac{\lambda}{\mu}\right)^{n_l} \tag{9}$$

The probability of having n_h HDVs waiting in the left-turn lane is

$$P_{nh} = (1-p)\left(1 - \frac{\lambda}{\mu}\right)\left(\frac{\lambda}{\mu}\right)^{n_h} \tag{10}$$

The probability of fewer than N vehicles queuing in the left-turn lane is

$$P(x \le N) = 1 - \left(\frac{\lambda}{\mu}\right)^{N+1} \tag{11}$$

$$N = \left[\frac{ln(1 - P(x \le N))}{ln\left(\frac{\lambda}{\mu}\right)} - 1\right] \tag{12}$$

In the N vehicles, the number of LDVs queuing in the left-turn lane N_l is

$$N_l = Np = p \times \left[\frac{ln(1 - P(x \leq N))}{ln\left(\frac{\lambda}{\mu}\right)} - 1 \right] \tag{13}$$

and the number of HDVs queuing in the left-turn lane N_h is

$$N_h = (1 - p) \times \left[\frac{ln(1 - P(x \leq N))}{ln\left(\frac{\lambda}{\mu}\right)} - 1 \right] \tag{14}$$

The maximum number of vehicles per hour that can pass the intersection at the left-turn green light phase μ.

$$\mu = \frac{S_L G_L}{C} \tag{15}$$

where S_L is the hourly maximum traffic throughput of a single left-turn lane (veh/h), namely the capacity, which can be calibrated based on Eq. (8). G_L is the effective green time of the left-turn protection phase (in seconds), and C is the signal cycle length in seconds. Then, we can get Eq. (16).

$$\frac{\lambda}{\mu} = \frac{\lambda C}{S_L G_L} \tag{16}$$

In mixed traffic flows, the average length occupied by an LDV while parking is approximately 1.5 times its length, with a default value of 7.6 m. Referring to relevant literature [35], the average length occupied by an HDV L_h is related to the percentage of HDV in mixed traffic and can be approximated by Eq. (17).

$$L_h = 7.6(1 + M) = 7.6(2 - p) \tag{17}$$

To accommodate the N vehicles with N_l LDVs and N_h HDVs, the length of the stored section of the left-turn lane should be followed Eq. (18).

$$L_S = 7.6N_l + L_h N_h \tag{18}$$

Combining Eqs. (13), (14) and (18), the length of the stored section of the left-turn lane that wants to ensure no spillover in Fig. 2 (a) at the probability of P is

$$L_S = 7.6p\left[\frac{ln(1 - P)}{ln(\lambda C) - ln(S_L G_L)} - 1\right] + 7.6(2 - p)(1 - p)\left[\frac{ln(1 - P)}{ln(\lambda C) - ln(S_L G_L)} - 1\right] \tag{19}$$

The value of P denotes the probability of ensuring no spillover in the left-turn storage lane and is the empirical value that considers the tradeoff between construction costs and service levels. If the value of P is too large, the length of the left-turn storage lane will be very long, which can ensure service levels but be a waste of the lane in most periods. If the value of P is too small, there will be a high risk or probability of left-turn lane spillover. Based on the arrival rate of left-turn traffic, the signal phases and cycles in an intersection, lane capacity of left turning, and penetration rate of HDVs in the traffic flow, we can design the corresponding left-turn lane length as per Eq. (19), which is tailored for mixed traffic.

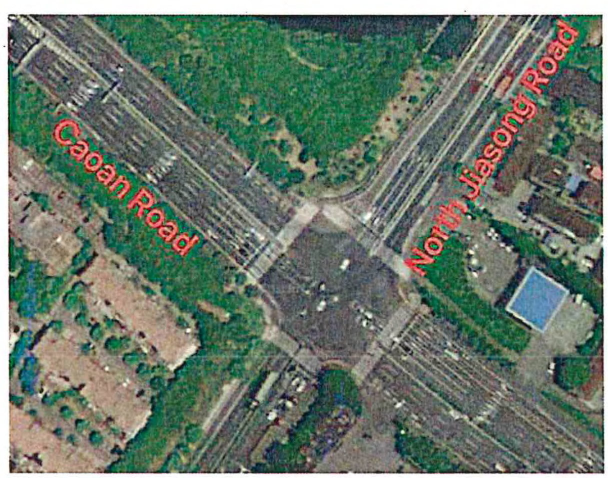

Fig. 3. Cao'an road – Jiasong north road intersection.

4. Empirical analyses based on field scenarios

To validate the effects of the proposed method on the traffic emissions of mixed traffic at intersections, we conduct an empirical analysis regarding a typical intersection with mixed traffic in Shanghai, China. We use the VISSIM simulator to simulate the traffic and obtain high-resolution vehicle trajectories before and after optimizing the left-turn lane. In the simulation, we consider motor vehicles including LDVs and HDVs, but do not consider micro-mobility such as bicycles and scooters, which are out of the scope of this study. The intersection of Cao'an Road and North Jiasong Road (see Fig. 3) was chosen for the case study. The reasons for selecting the intersection are 1) the intersection has a high traffic flow with congestion in the morning and especially has high left-turn traffic flow; 2) all inlet lanes from four directions of the intersection have left-turn lanes; 3) the traffic flow at the intersection has many HDVs and is a typical mixed traffic flow. At this intersection, Cao'an Road is a two-way 12-lane urban road, with each inlet lane comprising two left-turn-only lanes, three through lanes, and one right-turn lane. North Jiasong Road is a six-lane urban road in both directions, which includes one left-turn lane, one straight-through lane, and one right-turn lane. A bird's view of the intersection is shown in Fig. 3. To reflect the real traffic flow characteristics in the intersection appropriately, we have conducted field surveys in the morning peak hours at the intersection for one week (from Monday to Friday, 7:30 a.m.-8:30 a.m.). Drones were used to record video above the intersection. Details about traffic flow in terms of traffic volumes and penetration rate of HDVs were extracted manually from the recorded videos. We did not apply computer vision techniques as manual counting is more accurate even though time-consuming. The details of the traffic flow are summarized in Table 3. Please note that we average the data from five consecutive days to get the representative values.

The traffic volumes in VISSIM are inputted according to the traffic volumes at the intersections of the field survey, and the road network is built according to the actual construction of the intersections in the original scenario of the simulation. Based on the field research, the VISSIM simulation platform is built with the intersections taken in the field as the base map (see Fig. 4).

The total number of LDVs in the morning peak hour was 4062, representing 85.91% of the total traffic, while HDVs were 666, representing 14.09% of the total traffic. For different directions, the proportion of LDVs ranged from 76.43% to 95.18%, while the proportion of HDVs ranged from 4.82% to 23.57%. It can be observed that the penetration rate of HDVs in different directions is distinct. Meanwhile, the traffic volumes from and to different directions have considerable variation as well. As indicated by the results of the field survey, there are considerable delays in different import lanes. We compare the traffic emissions and efficiency at the intersections in original and optimized scenarios. In the original scenario, we use the real and current settings about the length of left-turn lanes in different directions at the intersections. In the optimized scenario, we use our proposed method to determine the length of left-turn lanes in different directions according to the traffic volume, the penetration rate of HDVs, and signal timing. The lengths of left-turn lanes in different directions in two scenarios are summarized in Table 4. We simulate the case of morning peak hours as per our field survey data. In the VISSIM simulation, the velocity and acceleration of each vehicle are recorded and outputted at the frequency of 1 s. We record the vehicles' information during the period from the time frame when they arrive 200 m away from the stop line of the entrance lane to the time frame when they leave 200 m away from the stop line of the exit lane. Based on these data, we use the developed instantaneous emission models for LDV and HDV in Section 2.2 to estimate the emissions of CO, HC, and NO_x of each vehicle crossing the intersections. In this manner, the emissions of all vehicles crossing the intersection in the two scenarios can be directly quantified and compared. We repeat the simulation five times to eliminate the potential biases due to randomness. The mean values of emissions in the five simulations are used for representatives.

The results of the emissions in the two comparative scenarios are summarized in Table 4. The results show that the CO, HC, and NO_x emissions of all traffic, including LDVs and HDVs at the intersections, are substantially reduced at the intersection in the optimized scenario. More specifically, the CO emission in the optimized scenario decreases by 34.43% as compared to the original scenario, which is a significant improvement. The same goes for HC and NO_x emissions, which reduce by 29.77% and 30.42% in the optimized scenario, respectively. The results indicate that the proposed method for improving left-turn lane settings can cut down traffic emissions considerably in terms of CO, HC, and NO_x.

More importantly, the emission patterns of LDV and HDV show divergences. It can be observed in Table 5 that the percentage of HDV in the mixed traffic flow is much smaller than that of LDV. The proportion of LDV in the traffic flow from different directions

Table 3
Morning peak-hour Traffic volume at the investigated intersection.

Entrance	Turning	LDV	HDV	Percentage of LDV	Percentage of HDV	Average delay(s)	Max. delay(s)	Max. Queue length(m)
West Entrance	Left	45	21	95.18%	4.82%	81.5	197.8	103.2
	Right turn	59	7	89.39%	10.61%	11.2	29.1	0
	Straight	737	137	84.32%	15.68%	72.6	174.2	106.2
East Entrance	Left	313	31	90.99%	9.01%	62.9	190.1	57.6
	Right turn	231	61	79.11%	20.89%	1.5	7.4	0
	Straight	563	72	88.66%	11.34%	83.7	183.5	154.5
North Entrance	Left	253	45	84.90%	15.10%	57.7	146.5	124.4
	Right turn	160	27	85.56%	14.44%	3.5	16.9	13.2
	Straight	597	85	87.54%	12.46%	66.7	164.0	53.9
South Entrance	Left	207	58	78.11%	21.89%	88.9	191.1	169.2
	Right turn	120	37	76.43%	23.57%	28.5	83.0	90.2
	Straight	407	85	82.72%	17.28%	75.3	186.8	172.7
Total number vehicles		4062	666	85.91%	14.09%			

Fig. 4. Simulation scenario in VISSIM.

Table 4
Storage length of the left-turn lane.

Directions	Length of the left-turn lane in original scenario (m)	Length of the left-turn lane in optimized scenario (m)
West Entrance t	70	120
East Entrance	70	93
North Entrance	50	122
South Entrance	50	63

varies from 76.43% to 95.18%, with an average value of 85.91%. The percent of HDV from different directions varies from 4.82% to 23.57%, with a mean of 14.09%. However, the emission results in Table 4 show that in the original scenario, the LDVs merely contribute 27.86% of CO, 31.61% of HC, and 5.67% of NO_x, which is not proportional to the percentage of LDV in traffic volumes. In contrast, HDVs produce 72.14% of CO, 68.39% of HC, and 94.33% of NO_x in the studied intersection, even though they merely take up 14.09% of traffic flows. The same phenomenon is observed in the optimized scenario. HDVs contribute the most emissions of CO, HC, and NO_x, although the percentage of HDVs is not large. These results imply the necessity of specific measures for reducing the traffic emissions of traffic flow with only LDVs, and mixed traffic flow with HDVs, as well as the merits of the proposed method for mixed traffic. For LDV, the CO emissions reduce by 33.74% in the optimized scenario as compared to the original scenario. A similar reduction in CO emissions (34.7%) for HDVs is also found. The HC emissions of LDVs decrease by 17.78%, but the reduction in the HC emissions for HDVs is more notable (35.31%). The NO_x emissions for LDVs reduce by 27.93% in the optimized scenario, similar to the reduction of NO_x emissions for HDVs (30.57%). The results demonstrate that the optimization of the left-turn lane has similar impacts on the reduction of CO and NO_x emissions for LDVs and HDVs, but has a more remarkable influence on the HC emissions for HDVs compared to LDVs.

To further validate the reliability of the proposed method to determine the storage length of left-turn lanes properly, we have enumerated the relationship between the storage length of the left-turn lane and corresponding traffic emission in the north import directions at an increment of 25 m. The results are summarized in Table 5. It can be seen that the emissions of CO, HC, and NO_x from LDVs decrease with the increase of left-turn lane length firstly, reach a swale at the length of 125 m, and then increases with a longer left-turn lane. The same pattern can be observed for HDV with differences in absolute values. Interestingly, the emissions, to some extent, increase with a longer left turn, which seems counterintuitive but rational. The reason found from observing the trajectories of vehicles is that straight-through traffic would use the left-turn lane to take over preceding vehicles and cut into the straight-through lanes when the left-turn lane is rather long, as demonstrated in Fig. 5. These behaviors will increase the conflicting points in the traffic and result in traffic oscillations (deceleration and acceleration behavior) due to cut-in behaviors, which will lead to higher vehicle emissions. More importantly, the best length for the left-turn lane is around 125 m in the enumeration, which is highly aligned with the theoretically derived value of 122 m based on our proposed method in Table 6. These corroborate the validity and ability of the proposed method to determine the optimized left-turn storage length for mixed traffic properly.

The setting of the left-turn lane storage not only affects emissions but also traffic efficiency at the intersection in terms of travel time and delays. Therefore, we compare the changes in the traffic efficiency before and after optimizing the left-turn lane in terms of average travel delay, maximum delay, and maximum queue length in different directions. The results are summarized in Table 7. The average traffic delays in different entrance directions after optimization reduces by 14.61% (West), 2.68% (East), 16.67% (North), and 21.09% (South). The maximum delays of vehicles from different directions reduce by 4.73%–9.05%. The maximum queue lengths in different directions decrease significantly by 37.02%, 79.42%, and 39.09%. The improvements are mainly attributed to avoiding the

ATTACHMENT L

Table 5
Comparison of emissions before and after optimization.

		Original scenario		Optimized scenario		Emission reduction
		Overall emission (g/h)	The proportion of different vehicle types	Overall emission (g/h)	The proportion of different vehicle types	
All vehicles	CO	26031.94		17068.5		34.43%
	HC	3731.64		2620.74		29.77%
	NO_x	3453.18		2402.58		30.42%
LDV	CO	7252.14	27.86%	4804.98	28.15%	33.74%
	HC	1179.72	31.61%	970.02	37.01%	17.78%
	NO_x	195.90	5.67%	141.18	5.88%	27.9%
HDV	CO	18779.80	72.14%	12263.52	71.85%	34.70%
	HC	2551.92	68.39%	1650.72	62.99%	35.31%
	NO_x	3257.28	94.33%	2261.40	94.12%	30.57%

Note: The proportion of different vehicle types is calculated by the emissions of one exhaust from a vehicle type (e.g., LDS) divided by the emission of one exhaust from all vehicles.

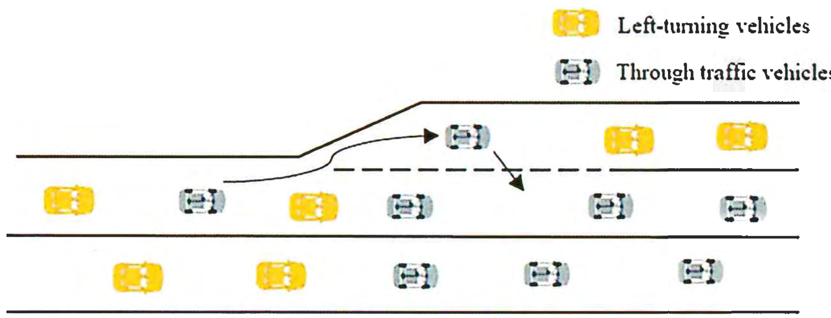

Fig. 5. Through traffic uses left-turn storage lane to take over.

Table 6
The effects of left-turn lane storage length on traffic emission in the north import.

	LDV			HDV		
Length of left-turn lane	CO (g/h)	HC (g/h)	NO_x (g/h)	CO (g/h)	HC (g/h)	NO_x (g/h)
Original scenario (50 m)	1802.9	293.3	48.7	4426.4	601.5	767.7
75 m	1514.0	297.8	42.2	3863.1	523.6	702.1
100 m	1437.6	286.7	41.0	3794.3	513.3	695.6
125 m	1194.5	241.1	35.1	2890.5	389.1	533.0
150 m	1536.8	305.2	44.9	4125.5	553.5	757.0
175 m	1486.9	296.9	43.4	3714.8	496.5	687.4
200 m	1539.1	306.6	45.3	3683.3	492.2	681.7

Note: We use the north import direction as the representative and repeating the validation process in other directions can find similar conclusions, which are not elaborated in case of redundancy.

Table 7
Comparison of emissions under emission optimization and delay optimization.

	West import	East Import	North Import	South Import
ORS -Average delay(s)	69.16	59.19	54.27	71.2
OPS -Average delay(s)	59.05	57.6	45.23	56.19
Reduction percentage	14.61%	2.68%	16.67%	21.09%
ORS-Maximum delay(s)	197.8	190.1	164	186.8
OPS-Maximum delay(s)	181.9	181.1	155.9	169.9
Reduction percentage	8.04%	4.73%	4.94%	9.05%
ORS-Maximum queue length(m)	106.2	154.5	124.4	172.7
OPS-Maximum queue length(m)	57.8	97.3	25.6	105.2
Reduction percentage	45.57%	37.02%	79.42%	39.09%

Note: ORS and OPS denote the original scenario and optimized scenario, respectively.

harmful scenarios demonstrated in Fig. 2 by providing appropriate storage lanes for left-turn vehicles. The results demonstrate that the proposed method can reduce travel delays and queues considerably and generate benefits in traffic efficiency. Although heavy vehicles only account for 13–18% of the vehicle count in the intersection, they generate more than 70% of CO emissions, over 65% of HC emissions, and more than 90% of NOx emissions from all heavy vehicles.

5. Conclusions

This study investigates the optimization and emission analysis regarding the effects of left-turn lanes on the emissions (CO, HC and NO_X) of mixed traffic flow with both LDVs and HDVs at urban intersections. High-resolution field emission and vehicle operating data of LDVs and HDVs in real urban contexts are collected and used to establish instantaneous emission models for HDVs and LDVs regarding CO, HC and NO_X. Meanwhile, a tailored model is formulated to determine the optimal left-turn lane length based on queueing theories and the penetration rate of HDVs. The proposed method is validated using an empirical case study combining established emission models and VISSIM simulation tools and based on field data in a typical intersection.

The results show that the proposed method can reduce the CO, HC and NO_X emissions at the intersection by around 30% as compared to the original scenario. An enumeration process is conducted to validate further the ability of the proposed method to determine the proper length of left-turn lanes. The optimization of the left-turn lane has similar impacts on the reduction of CO and NO_X emissions for LDVs and HDVs but has a more remarkable influence on the HC emissions for HDVs as compared to LDVs. It is found that HDVs contribute to most of CO, HC, and NO_x emissions at the intersection whilst they take up a small percentage of the traffic flow. The proposed method can also improve traffic efficiency at the intersection by reducing travel delays and queuing, as evidenced by empirical analysis results. This study establishes the instantaneous emission model for mixed traffic flow and provides a model basis for calculating traffic emissions from mixed traffic flows. Moreover, the results provide useful guidance and design methods for transportation designers to optimize and improve the left-turn lane configuration to alleviate traffic congestion and reduce traffic emissions at urban intersections.

Compared to former studies, this study offers several unique contributions regarding the impact of left-turn lanes on traffic emissions. Firstly, we collected high-resolution field emission and vehicle operating data for both LDVs and HDVs, providing a comprehensive understanding and modelling of the emissions of LDVs and HDVs in different operation conditions, which are essential for analyzing emissions of mixed traffic flow. Secondly, we formulated a tailored model to determine the optimal left-turn lane length, which takes into account queueing theories and the penetration rate of HDVs. Finally, the proposed method was validated using an empirical case study, providing evidence of its effectiveness in reducing emissions and improving traffic efficiency.

Nevertheless, there are several limitations that can be further investigated in future work. Firstly, it is tough to directly formulate quantitative models about emissions at the traffic flow level in the optimization model of left-turn lanes, as the change of left-turn lane design will influence several aspects and a lot of vehicles rather than a certain vehicle. It will be interesting work to develop a quantitative method for reflecting the relationship between changes in traffic flow characteristics and corresponding emissions. In this regard, the objective function of the optimization will be more straightforward. Moreover, this study focuses on the left-turn lane design and takes the signal timing setting at the intersection as the default input. However, the signal timing can be optimized and controlled to facilitate traffic efficiency as well, which a load of literature has been doing. It is an interesting future work to jointly optimize lane configuration design and signal timing at the intersection, which is expected to have more remarked benefits. Last but not least, our emission models are established based on the field emission data of three representative vehicles due to data limitations and the high expense of collecting data from various LDVs and HDVs. Collecting more field emission data will always be beneficial for improving the instantaneous emission models and analysis accuracy in relevant studies.

Author contribution statement

Jieyu Fan: Kun Gao: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper. Aoyong Li: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Anugrah Ilahi: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Data availability statement

The authors do not have permission to share data.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors are grateful to the Area of Advance Transport and AI Center (CHAIR) at the Chalmers University of Technology for funding this research.

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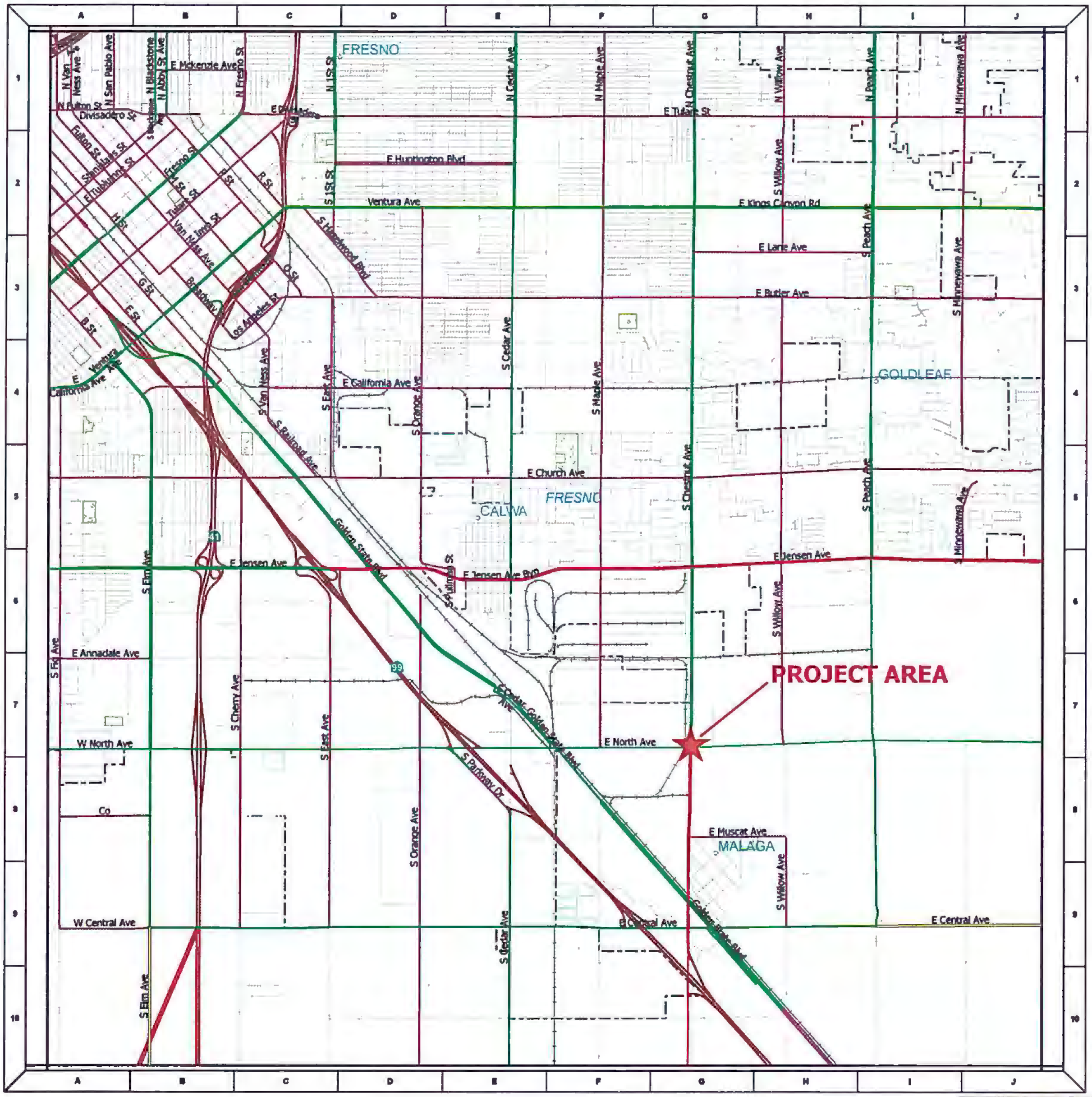
ATTACHMENT M

SEE MAP 10N43

SEE MAP 10N52

SEE MAP 10N54



SEE MAP 10P13

APPROVED Date: 02/07/2023
FEDERAL HIGHWAY ADMINISTRATION

FOR: VINCENT P. MAMMANO
DIVISION ADMINISTRATOR

0 0.25 0.5 0.75 1 Mile

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
In Cooperation With The
FEDERAL HIGHWAY ADMINISTRATION
AND LOCAL AGENCIES

Caltrans

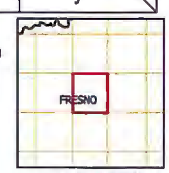
COUNTY BOUNDARY	
CITY BOUNDARY	
RAILROAD	

SIGN ROUTES

5	INTERSTATE
3	U.S.
1	STATE

FUNCTIONAL CLASSIFICATION SYSTEM

INTERSTATE	1
OTHER FWY OR EXPWY	2
OTHER PRINCIPAL ARTERIAL	3
MINOR ARTERIAL	4
MAJOR COLLECTOR	5
MINOR COLLECTOR	6
LOCAL	7



Fresno County

MAP 10N53
CALIFORNIA ROAD SYSTEM