# Impact of Express Toll Lanes on Traffic Congestion for Interstate Travel

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## Introduction:

1. Explanation of express lanes
    a. The Washington State Department of Transportation (WSDOT) utilizes special lanes on some major interstates known as express lanes [1]. These lanes are designed to improve traffic flow by allowing cars to bypass heavily trafficked areas of the interstate. The lanes change directions at scheduled times of day, determined by which direction would help relieve congestion the most. The express lanes on I-5 are free-to-all and not restricted to carpool-only.
2. Difference in express toll lanes [2]
    a. Express toll lanes are express lanes that have tolls. In order to utilize these lanes, cars can either pay a daily fee by mail for $2 extra, or through a Good-to-Go! account. Buses and some carpools are exempt from these fees; carpools must have a Good-to-Go! Account to use the express toll lanes for free. The WSDOT uses the Traffic Management Computer System to update the express toll lanes' fees based on real-time traffic conditions. The two factors that go into the calculation of the toll is the amount of cars in the express toll lanes and their speeds. As the amount of cars increases or as the average speed of the cars in these lanes decreases, the toll prices rise. This reduces the amount of cars in the express toll lanes and allows for reduction of congestion, but potentially a negative impact on non-express lane traffic.
3. Price elasticity and express lane traffic [3]
    a. The price of the toll lanes on I-405 currently changes on a supply-and-demand basis. With this form of pricing, it only allows cars who can afford/want to pay a high rate for a lane to be able to utilize them. This results in only partial traffic redirection, and potentially does not reduce traffic as much as it could. In this model, we want to analyze the effects on traffic of changing the price of these lanes. More specifically, if the price did not fluctuate on a real-time basis, but instead was at a constant rate, how would this price affect the number of cars utilizing the express lanes? In turn, how would the number of cars using the express lanes impact I-405 traffic?

b. Price Elasticity of Demand refers to the change in consumption of an object as the price of it increases. Express Toll Lanes (ETL) leverage this by increasing the price as demand increases in an attempt to create a more even flow. Price Elasticity breaks down when the price of goods is give a price floor or price ceiling, which is currently the case for the I-405 ETLs, with a price floor of $0.75 and a price ceiling of $10.00.

## Model Overview:

Assumptions Made:

- Income from each city will be assumed to be a normal distribution centered around the mean
- Weather will be dry, cloudy
- Accidents happen on a random basis, normal distribution centered around average value
- Roads are straight
- Assume people are trained, courteous drivers
- Model follows lane widths of I-405
- Can enter/exit lane freely
- Shoulder will never open up
- Roads are of uniform, fair quality
- Roads will never be maintained
- All buses are three cars long
- Vehicles maintain safe following distances
- Vehicles maintain constant speed unless stopped
- Vehicles exit off-ramp at 5/vehicles every five intervals

Constraints:

- We will use a flat-rate instead of the real-time changing rates that the lanes use. We will have one rate during rush hour, one rate for when it is not rush hour, and then free when it is free. We will change these values in our model, but these will be our three main pricing categories.
- Since we are going to be using a grid to model the freeway, the model will not be able to take into account the fact that cars are not evenly spaced on a freeway.
- We will only analyze a specific section of I-405.
- We will analyze I-405 on a typical Wednesday.

Data Collection:

- Daily Use Traffic Patterns will be collected from the Washington State DOT
    - https://www.wsdot.wa.gov/mapsdata/geodatacatalog/Maps/noscale/DOT_TDO/TrafficGeoportal/TrafficGeoportalSourceDataIDX.htm
- Income patterns will be collected from the US Census 2010 data for income based on city
    - "2010 US Census." *American Fact Finder*, 5 Oct. 2010, factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_5YR_DP03&prodType=table.
- Traffic incidents on I-405 will be collected from the DOT, provided that they respond to data access query. Else, will be assumed 3 per day, sd of 1
- We will need to research how traffic occurs so that our simulation will show realistic slowdowns and properly simulate congestion of traffic.

Model Utility:

- Determine the best price for the express lane toll fee
- Simulate the average amount of traffic using express lane each day.
- Simulate the peak hours of each day.
- Simulate the proportion of accidents may occur in a day.
- Simulate the amount of cars in traffic in every hour.
- Track number of cars in different areas at different times

Limitations of Model:

- Model will not be able to handle large numbers of vehicles (greater than uint_64)
- Model will not handle negative numbers of vehicles
- Model will predict outcomes based on current data, not future theoretical data
- Price will never increase above a certain amount
- Price will never decrease below zero

Overcome Use Limitations:

- The model will make sure the number of vehicles is a capped at a certain maximum and will never decrease under zero.

## Analysis:

Metrics and Quantities:

- Average speed of cars on the freeway as a float at each time period each day
- How many cars use I-405 in a given weekday
- How many cars utilize the toll lanes
- The difference in how many cars use the toll lanes based on the price and time of day

- The number of buses using the interstate at a given time

Questions Asked:

- Does this model accurately reflect the changes in traffic?
- Would more cars in the express lanes be worse for traffic in the long-run? (more congestion in the express lanes)
- At what price point is traffic the least congested?
- How does the number of express lanes affect traffic?
- How does exit placement/utilization affect traffic congestion?

Questions Answered:

- Our model will be able to show us how express lanes impact traffic
- Our model will be able to predict how traffic changes as express lane use increases/decreases
- Our model may be able to show us how express lane usage will be affected based on the price
- Our model may be able to show us what the best time to drive to avoid traffic.

Validation:

- We will validate our model by comparing it to historical data gathered by the Washington Department of Transportation.
- We will make sure the model accurately reflects the following assumptions:
    - As tolls rise, the number of cars in the express toll lane decreases
    - The number of cars on the freeway will increase when the model's time hits peak hour
- The model should not produce data that is impossible in the real-world such as negative vehicles or prices

# Testing:

Motion of Cars:

- If there is no vehicle two spaces in front (one-space gap), vehicle will move forward. Inputs: Location of the nearest car in front; Outputs: Bool as to whether the car can move
- If there is a vehicle two spaces in front, and there is no vehicle to the left, and car is not near the exit, and car is not next to express lane or car can enter express lane, car will shift left. Inputs: Location of the nearest car in front; Outputs: Bool as to whether the car can move
- If a vehicle is one space in front of car, car will follow that vehicle. Inputs: Location of the nearest car in front; Outputs: Bool as to whether the car can move

- cars attempting to exit are stopped. Inputs: Location of car on the grid; Outputs: Bool as to whether the car can move
- Cars start moving towards exit ___ spaces before exit. Inputs: Location of car on the grid; Outputs: Bool as to whether the car can move
- Cars in the ETL during peak hours move twice as fast as cars in the normal use lanes. Inputs: Location of car on the grid; Outputs: Int representing the speed of the car
- There is an average of two car accidents per day
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Motion of Buses:

- If there is no vehicle three spaces in front, bus will move forward. Inputs: Location of the nearest vehicle in front; Outputs: Bool as to whether the vehicle can move
- If there is a vehicle three spaces in front, and there is no vehicle to the left, and bus is not near the exit, and bus is not next to edge of road, bus will shift left. Inputs: Location of the nearest car in front; Outputs: Bool as to whether the car can move
- If a vehicle is three spaces in front of bus, bus will follow that vehicle. Inputs: Location of the nearest car in front; Outputs: Bool as to whether the car can move
- Buses attempting to exit are stopped. Inputs: Location of car on the grid; Outputs: Bool as to whether the car can move
- Buses start moving towards exit ___ spaces before the exit. Inputs: Location of car on the grid; Outputs: Bool as to whether the car can move
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Enter/Exit Highway:

- If the amount of vehicles on the highway exceed the highway carrying capacities, the vehicles entering will need to stop at the red light and wait for a particular time. (Metered Lane). Inputs: Number of vehicles on the highway; Outputs: bool representing if the car can enter
- If the number of vehicles in the off-ramp exceeds the on-ramp carrying capacity, vehicles will back up into the highway. Inputs: Number of vehicles on the off-ramp; Outputs: bool representing if a car can enter

Enter/Exit Toll Lane:

- The amount of card entering the express lanes as the price goes up would increase at a later determine rate. Inputs: Current rate for the express toll lane; Outputs: Percentage of total cars that are in the express toll lanes
- Buses have a 100% chance of using the ETL when available. Inputs: bus object; Outputs: bool returning if bus is in express lane

Sensitivity Analysis:

- Changes to number of cars
- Changes to number of lanes
- Changes to number of exits
- Changes to the rate at which cars switch lanes

## Personnel:

Adam Sirkis:

- Python
- Object-Oriented Programming (OOP)
- Git

Callie Bianco:

- Experienced in Python
- Proficient in math/statistics
- OOP
- Frequent bus-taker on I-405
- Knowledgeable about express lanes

Abdullahi Diriye:

- Experienced in Python
- General Knowledge of Git
- Public transit user
- Experience in creating testing suites
- OOP

Tung Dinh:

- Python
- OOP
- Math/statistics

Rough Task Allocation:

- Callie and Abdullahi will work on most of the research of the problem since they are the most familiar with I-405.
- Adam will oversee most of the coding as this is when his team manager role comes into play.
- Callie will oversee most of the reporting phase due to team manager role assignment.
- Everyone will have a mostly equal part in coding with Adam having the final say/overseeing of the work.
- Callie and Tung can oversee the sensitivity analysis due to their math abilities.

- Abdullahi can oversee testing due to familiarity with testing suites
- Adam and Abdullahi will manage version control and finding team contributions due to familiarity with Git.
- All of us have familiarity with OOP, so we can further determine who's going to work on which breakdown of classes when we work on our program design.

## Technologies:

Development Platform:

- Anaconda Platform: Development platform for python that provides distribution of python and R software and packages.
- Canopy: Development platform that has pre-installed scientific python packages and modules.

Project Sharing:

- GitHub: Open-Source platform that will help us to keep track of version control and track contributions from teammates in our coding phase.
- Discord: A real-time messaging platform that we can use for remote communication among team members. This will help us to plan meetings and collaborate when we can't meet in real-time.

Presentation and Report:

- Google Docs: Document sharing platform that we can use to collaborate on. We can use this for brainstorming as well as working on this development plan.
- Powerpoint: Software used for creating presentations. This will be used for our reporting phase when we report to the class.
- OneDrive:
  Another document sharing and real-time editing platform. Another option for remote work and the analysis/reporting phases.

## Benchmarks:

| **Benchmark** | **Date** |
|---|---|
| Overall Project Description and Development Plan | May 20, 2019 |

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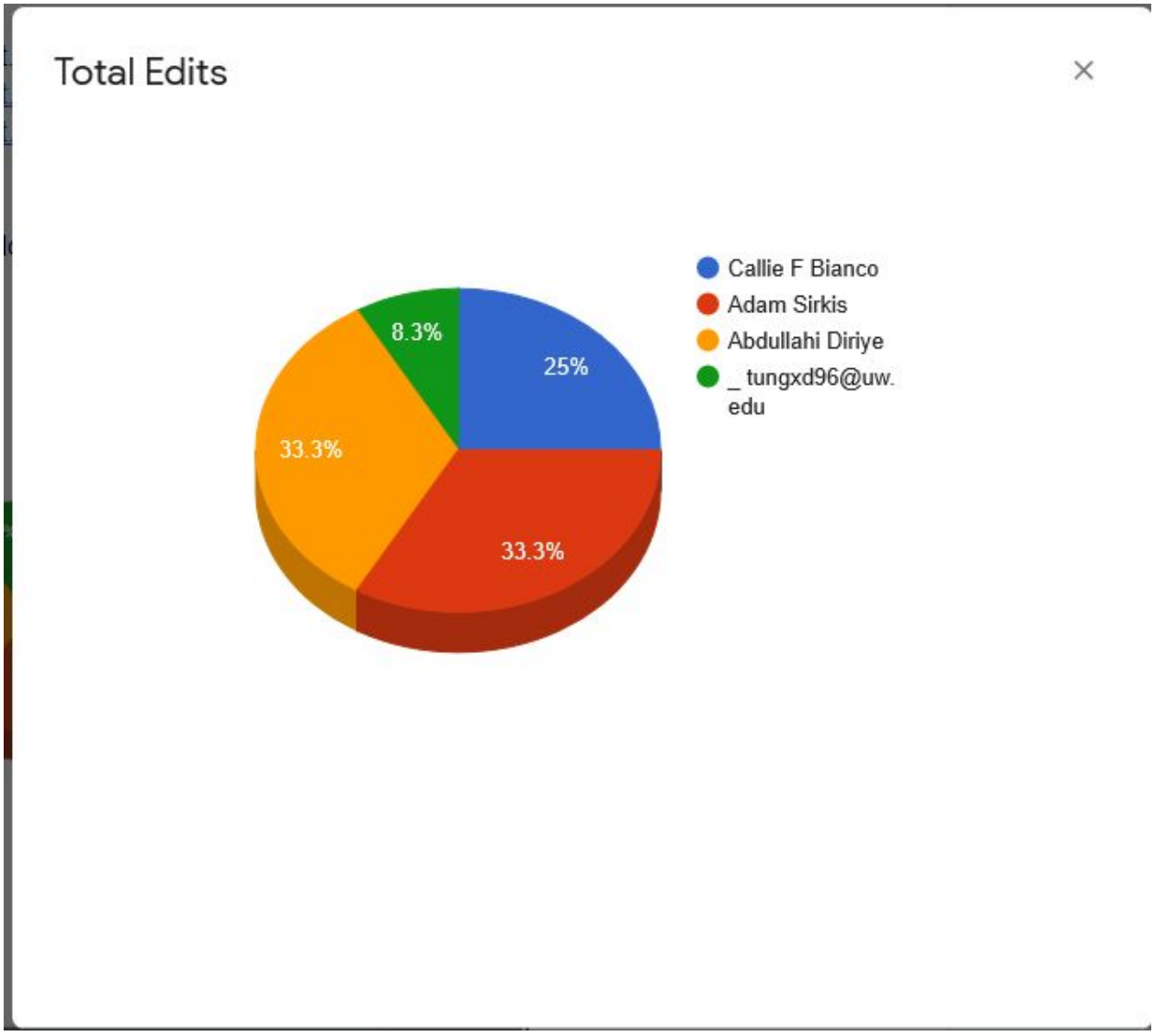
|---|---|
| Program Design | May 22, 2019 |
| Milestone | May 29, 2019 |
| First Draft of Program | May 31, 2019 |
| Final Program and Presentation | June 3, 2019 |

REFERENCES


1. https://www.wsdot.wa.gov/travel/operations-services/express-lanes/home
2. https://www.wsdot.wa.gov/Tolling/405/about.htm
3. https://www.wsdot.wa.gov/sites/default/files/2015/11/12/I-405_ETL_18MonthUpdate.pdf


Development Plan Development History:


Total Edits
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25%
33.3%
33.3%
8.3%