ISYE 6644 SIMULATION: MODELING A LOCAL INTERSECTION TO DETERMINE SUGGESTIONS FOR SAFETY IMPROVEMENTS

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ABSTRACT

Motor vehicle incidents are responsible for more than 40,000 deaths of Americans every year. Unfortunately, the rate of injury and death related to motor vehicles is rising at rates not seen since before the mandate of seatbelts in every vehicle [1]. Motor vehicle crash has long been the leading cause of death of American children, and is now second only to guns. This change is not due to a decrease in death from cars, but rather to a dramatic increase in death from guns [2]. The exact cause of this increase is a matter of debate [3]. Known reasons for this increase include rises in speeding and distracted driving due to mobile phones and infotainment systems in new cars, vehicle design that prioritizes larger fronts over high-visibility fronts, and increased sales of SUVS and trucks along with a decrease in sedan sales. While new driver assist technologies show promise for combatting the rise in traffic deaths, a growing school of thought focuses on street design as the most important strategy for reducing avoidable traffic death. By observing behavior at local intersections and modeling different street design interventions, suggestions can be made to improve safety on neighborhood streets.

Index Terms- street design, simulation, traffic, street safety

BACKGROUND

As someone who frequently walks, runs, and bikes around their neighborhood, I have personally observed an increase in aggressive driving behavior over the last several years. After nearly being hit by a driver while running through a particular intersection that is on a route commonly used for people on foot and bike to get to a local park, I engaged with my local police department to see what could be done to improve the safety of the intersection. The police response was to post an officer to surveil the intersection for a set period of time to deter drivers from failing to stop properly or yield to pedestrians and to cite traffic violations. After 7 half hour shifts at this intersection the traffic safety officer reported back to me that not a single driver had committed a violation. Finding this difficult to believe, I set out to observe the intersection myself and model the likelihood of this result. I will model this scenario with a large number of repetitions both as I observed the traffic and with theoretical alterations.

QUESTION TO ANSWER

- What is the likelihood that every single driver over a 3.5 hour time period operated their motor vehicle in full compliance with the law

LIMITATIONS & ASSUMPTIONS

There are of course a number of factors to consider when attempting to answer these questions. Considerations and how they are handled are listed below:

An obvious consideration is that I made my observations at a different time than the police officers who reported no traffic violations. They made their observations during the evening rush hours in October of 2021. I observed the same intersection in March and April 2023 during the evening rush hours. For the sake of this study, it is presumed that behavior is comparable at the times observed.

The presence of a police car at the intersection undoubtedly had an effect on driver behavior. We will attempt to model this effect by adjusting the rates of compliance in different runs of the simulation.

The presence of a person holding a clipboard and watching the intersection likely affected driver behavior. In an attempt to control for this effect, the observer stood to the side and out of the direct line of sight while observing the different traffic directions. For this study, it is assumed that the observer does not have an outsize effect on driver behavior.

The observer does not have unlimited time and thus the intersections used in this study were only observed for a limited time period. Intersection 1, the main intersection in question was observed with behavior recorded for a total of one hour and thirty minutes. Intersection 2 was observed for a total of 30 minutes. It is assumed that the times observed are representative of the intersection at any other similar time.

Distinctions between what counts as full compliance with the law and near compliance is subjective and at the discretion of the observer. Best attempts were made to be consistent in judging driver compliance with stop locations.

DATA DESCRIPTION

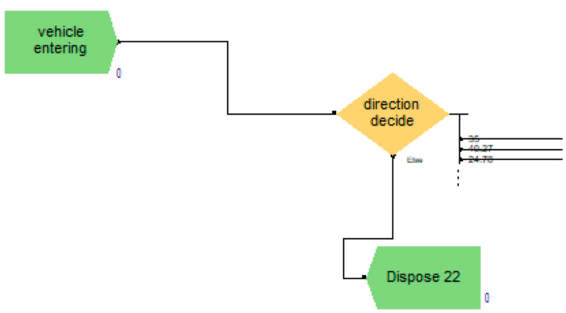
The dataset used as the basis for the simulations to follow is a collection of 226 observations, each corresponding to a motor vehicle that passed through the intersection. The full dataset is available as a csv in the zipped files. A list of the fields collected and a short description is below.

* *direction* - the cardinal direction the vehicle was heading
* *type* - closest approximate of the type of vehicle
* *stop* - whether the vehicle came to a complete stop before a marked crosswalk or stop line. A value of true corresponds to a stop
* *turn* - direction the vehicle turned or a value of straight for no turn
* *indicate* - only recorded for turning vehicles. A value of true means the driver did indicate their turn.
* *other_car* - whether there was another car in the intersection. A value of true indicates another car was at the intersection.

field	**values**	**# observations**
direction	east, west, north	226
type	truck, sedan, suv, DPW	226
stop	true, false	226
turn	left, right, straight	226
indicate	true, false	109
other_car	true, false	226
pedestrian	true, false	226

DATA PREPARATION

With the ultimate goal of using the observations from time spent at the intersection in a simulation, the 226 observations needed to be converted into a usable format for Arena. To most accurately represent the conditions of the intersection, I needed multiple levels of probability for the various levels of the decision tree to be built in Arena. The first stop of my Arena simulation is determining the direction from which a motor vehicle came, meaning I would need a breakdown of the probabilities of a vehicle going east, west or northbound. I calculated these probabilities by summing all vehicles moving in the chosen direction and dividing by the total number of vehicles that entered the intersection. The eastbound direction, for instance, had 79 motor vehicles out of 226 total for 35% of the total traffic.



Close up of the first decide module for direction

The simulation is a series of ever more specific decisions, first for direction, then type of car and then whether the car stopped. Each decision necessitated another calculation of probability. For instance, one final decision in the tree was whether an eastbound sedan would stop. 10 out of 28 eastbound sedans stopped for a probability of 35% stopped.

In total, 30 probabilities were calculated for the different levels of decision and input into the decision modules of the Arena simulation.

ARENA MODEL DESCRIPTION

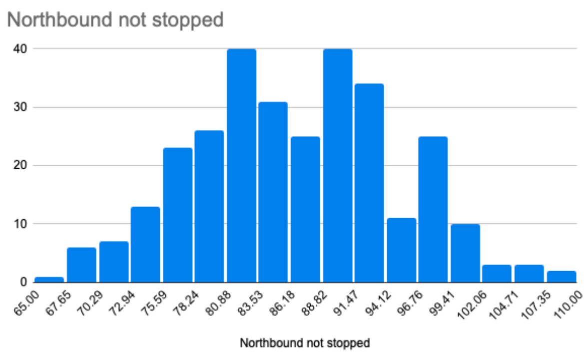
The Arena model for this simulation was built with create, decide, process and dispose modules. A snapshot of the entire model is included in the zip files, but the overall flow of the model is as follows:
A vehicle enters the intersection via the create module, a decide module determines the direction of travel, 3 more decide modules for each direction determines the type of car, and 9 more decide modules determine whether the vehicle stops or not. The final 9 decide modules feed into process modules to record the final stop/no stop designation, which all feed into dispose modules to end the simulation.

The simulation ends when 520 vehicles have run through the system. This value approximates the number of vehicles that would be predicted to enter the intersection in 3.5 hours based on the 226 vehicles observed in 1.5 hours. The simulation was run for 300 repetitions. This is about the limit that Arena seemed capable of handling while outputting to Excel.

SIMULATION RESULTS

Although I modeled three different directions, it would be difficult for an officer in a parked car to truly observe every direction of the intersection. One direction of the intersection has a bike lane, one direction has no parking, one side is the one-way driveway of a private business, meaning there is likely only one spot an officer would park to observe the intersection. This is on the western side, facing eastbound, meaning the direction that could truly be observed is the northbound direction. Because of this I will look at the modeled cars that did not stop in the northbound direction.

To get the total number of cars that did not stop for each run of the simulation I added the values for sedan, SUV and pickup. The histogram below shows the distribution of that sum.



The distribution of not stopping vehicles resembles a normal distribution. The mean is 86.6 with a standard deviation of 8.46. To achieve the likelihood of zero non-stopping vehicles, we can look at the z-score for 0. That z-score is -10.24, indicating that it is statistically impossible to have achieved this result.

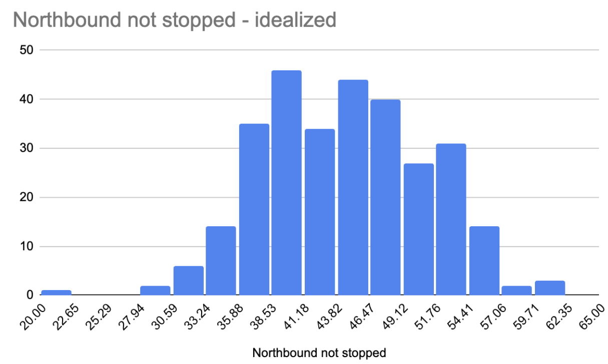
SIMULATING POLICE PRESENCE

It is undeniably true that a driver who believes they are in imminent danger of receiving a ticket will alter their behavior somewhat. While stationing a police officer at an intersection is not an efficient traffic control measure, it is likely quite effective. To simulate the effect that a visible police presence would have on this particular intersection, I have increased the stop rate for each category of vehicle. For conditions with a lower than 50% stop rate I doubled the probability of stopping. For conditions with a higher than 50% stop rate I increased the probability of stopping to 90%. While I could not effectively determine if every driver I saw while observing was distracted by a phone or other device, I saw enough to confidently say that 1 out of 10 drivers failing to see a police car at an intersection is likely a generous overstatement of driver competence.

I reran the same simulation with the changed probabilities of stopping to measure the likelihood of the traffic police's claims of 100% compliance.

IDEALIZED SIMULATION RESULTS

Following the same procedure as the reality-based model, the average number of vehicles simulated to not stop was 44.52 with a standard deviation of 6.59. The z-score for a value of 0 is -6.76. Again, this indicates that it is statistically impossible that not a single driver failed to stop properly at the intersection.



INTERPRETING RESULTS

There are many reasons why traffic officers may report a result that was judged to be statistically impossible by my study.

* Distraction - police officers have many demands on their attention while out on patrol. They are frequently responding to hails from dispatchers, watching monitors, and running license plates of passing vehicles.

*Standards - I will admit that I am highly sensitive to improper stopping on the streets near my house. I cannot begin to count the number of times a driver has nearly hit me in a crosswalk, in a bike lane, or at a stop sign because they failed to make a proper stop. Based on my high standards and my observations of the way local police drive, it is likely that a watching traffic officer would be a kinder judge of improper stops.

*Policy - I live in a small city, both in area and population. The local police have expressed to me on many occasions their desire to remain on friendly terms with residents. As a result, they have a policy to not enforce every traffic infraction they see.

*Paperwork - Every warning or citation given to a driver requires paperwork on the part of the officer giving the ticket and others in the department. It is understandable that an officer with many other responsibilities would not choose to take on a lot of paperwork.

FUTURE PROJECTS

I would love to be able to view the intersection at the same time as an officer to get a full understanding of the effect of a marked police car on driver behavior. Even more, I would be very interested to view the effects of different street designs on this intersection. For instance, what is the effect of a raised crosswalk, the word STOP written on the road, concrete barriers on the bike lanes, bumpouts to narrow the road, a speedbump, an additional stop sign on the couple blocks before the intersection or more pedestrians. I originally attempted to observe similar intersections at other places in the city, but was not able to narrow down the exact factors that caused the difference in behavior between intersections. For instance, at an intersection with greater stop compliance, was the difference the addition of a stop line, a newly painted crosswalk, better sightlines, less distance between stops, or another factor entirely. Perhaps some of these measures could be implemented on a trial basis and I could re-observe the intersection to see if behavior was significantly affected.

Additionally, there is more that can be studied from the observations I have already made such as differences in stopping behavior between different vehicle types and direction of travel, turning/not turning, and presence of other vehicles at the intersection.

EXHIBITS

The truck in this photo was judged as a stop

The SUV in this photo was judged as not a stop

Additional photos of the intersection are included with the zipped files.

REFERENCES

[1] National Safety Council (n.d.). *Car Crash Deaths and Rates*. NSC Injury Facts. Retrieved April 3, 2023, from https://injuryfacts.nsc.org/motor-vehicle/historical-fatality-trends/deaths-and-rates/

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