Solving Traffic Problems Using Machine Learning

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***Abstract*—The world (and *Lebanon* in particular) suffers from traffic, leading to waste of time and lower productivity rates where traffic densities are high. Machine learning can help us optimize traffic features, such as road conditions, non-efficient road connections, and unorganized traffic lights which is our main focus.**

I. Introduction

A. Problem

In a United Nations project report regarding transportation, the editor Alberto Bull stated "Synchronizing traffic lights is one of the most efficient ways to cut delays …" .Statically defined traffic lights are a missed opportunity for resolving congestion.

B. Stakeholders

Everyone who traverses the road using a vehicle. Less wasted time and fuel consumption would lead to a better economy. As well as the public transportation sector can benefit from having less traffic congestion to be more efficient in their work. The people we surveyed were generally "sad" and "frustrated" about the situation. They thought the causes were bad infrastructure, high population, law isn't being enforced, bad road planning, bad drivers and traffic lights.

II. Project Description

Traffic lights in Lebanon have predefined timing which causes unnecessary congestion, causing citizens to be late to work and spend most of their time commuting, spending money on fuel; hindering the development of the country's economy. In Fig.1, our model takes input several conditions, and the output is appropriate traffic light durations for an entire area, then gives feedback about performance.

III. Interviews

We met 2 AUB students and a random bystander that works in law. The students said they love to drive while the bystander preferred to ride a bike.

Interviewers	1. Abdallah & Eddy	2. Ali & Bashar	3. Hussein & Amer
Duration	10mins	10mins	10mins

1. Our interviewee reported daily high congestion feelings of frustration and sadness, blaming road conditions and no law enforcement. We wonder if this means people don't abide by the law since traffic management is faulty.
2. The interviews we conducted gave us an idea of how people felt limited and frustrated by traffic. There was an emphasis on how the time wasted on traffic had a negative influence on the interviewees' productivity and daily activities.
3. The person we interviewed, wasn't satisfied at all by the conditions of the streets in Lebanon, saying that traffic makes him angry all day especially if he was late to his work or any other appointment. He even had some fights on the street because of people that don't abide by street laws.

IV. Challenges

Traffic has a complex pattern that can be hard to detect, thus our main challenge would be gathering sufficient training data for our model to predict correctly the pattern and its reasons. As well as other traffic reasons might interfere with our results and assessment. Another challenge is using surveillance cameras to detect events and give them as input to our model.

Benefits include better economy, less noise pollution, less fuel consumption and greater public satisfaction(political benefit).

V. Workload Division Among Members

Abdallah and Edmond will be responsible for programming the traffic light model. Hussein and Amer will provide necessary training data. Bashar and Ali. will find a suitable model for the camera to detect events.

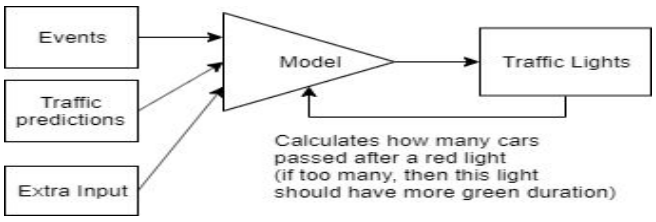
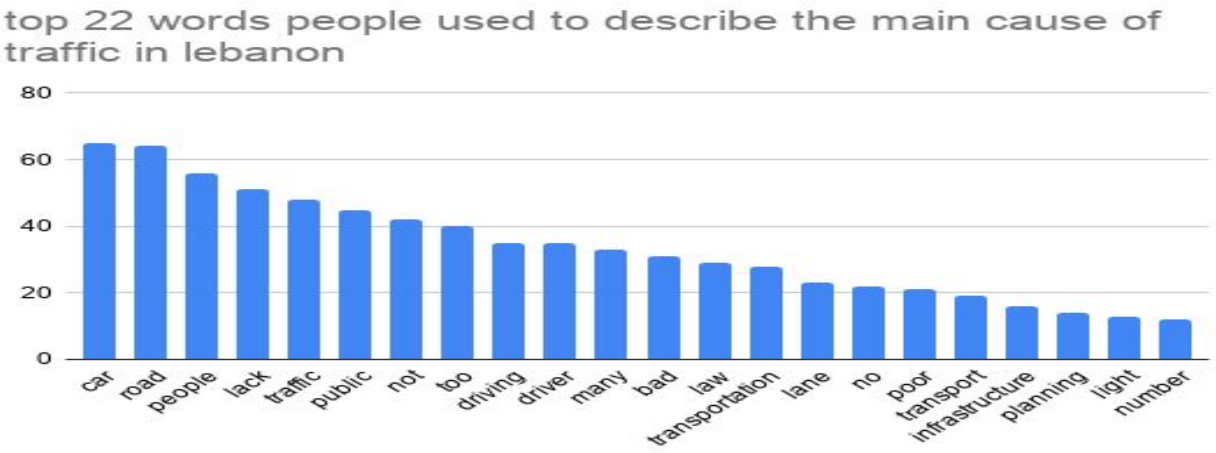


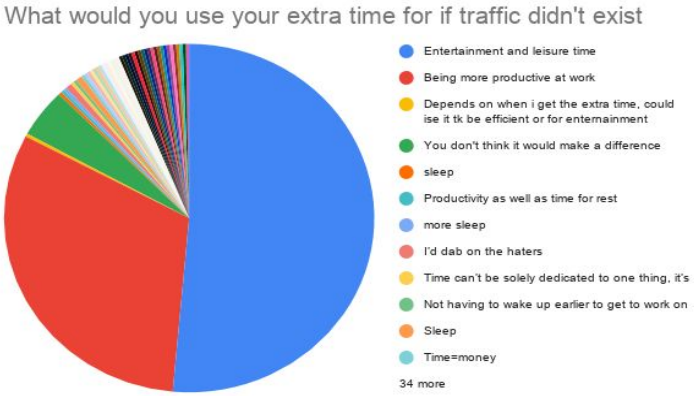
Fig.1 Machine learning model black box

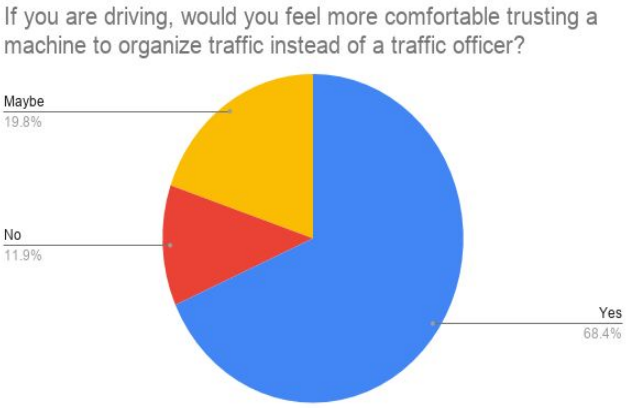
I. Brainstorming:

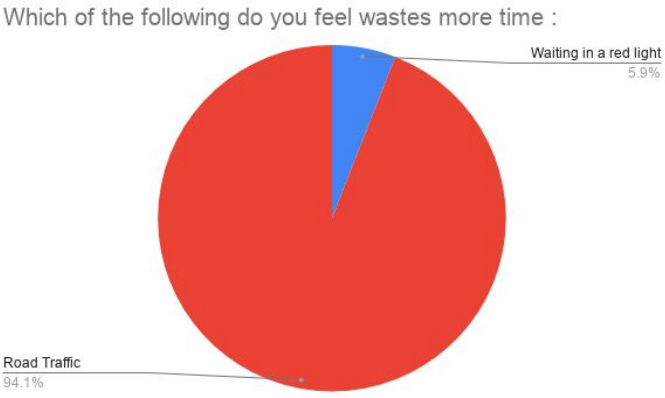
Accomodation for parking spaces	App that changes the light when you choose
Skipping class	Smart cars that take advantage of google maps
Job allocation for person to nearby jobs	Traffic light based on nearby events / jam prediction
Go by bike	Stop parking on the sides of roads
Better infrastructure for roads	Encouraging people to ride bikes & motorcycles
Online courses	Better law enforcement
increase the fine on driving rules	Re-organised job schedules / jobs end on different times
Car pooling	Sensors to control traffic lights
Road signs	Flying cars
Learning country	Using the sea / extra space
Smart lane organization	Red light no more
A better driving test for the license	Work from home
More traffic light colors	Portals
Enforce the driving rules more	Floating buildings
Schools causing jam	Increasing taxes on buying cars
Navigation for available parking slots	Long range bridges
Emulate a police like traffic light behavior	Rooftop parking
Trains	Park meter renewal online by app
Tunnels	Public transportation

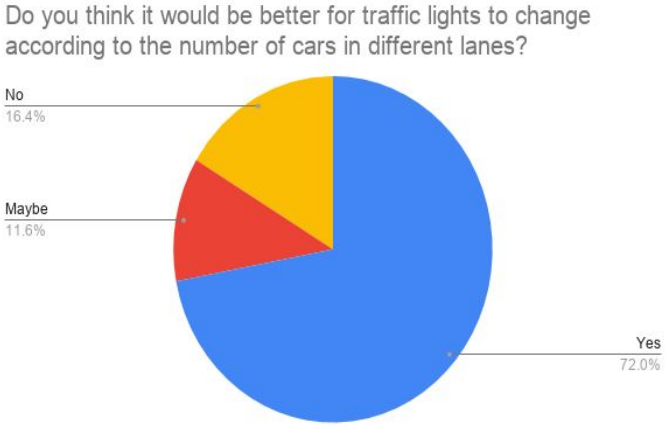
I. Survey Feedback: (355 Responses)











II. a. Survey Feedback Analysis:

The interesting words used the most by people we surveyed hint at several problems that cause road traffic. It would seem that people think the road's traffic are correlated with driver's behavior and the way they drive were many people reported that many drivers are bad at driving and don't obey the law. People also indicated that another reason is the poorly maintained infrastructure and mentioned often that the public transportation sector is inefficient and needs to be upgraded. Finally they frequently blamed bad road planning and traffic light coordination as the reason of traffic.

Asking people what would they do if they weren't wasting time on the road, we gave them 2 general options and the freedom to state any other option. About 80% reported using that time for leisure or for work, while about 5% stated that it wouldn't make much of a difference for them and the rest stated other options. Overall, this indicates that the lebanese are collectively feel they are wasting their time on the road and that this is indeed a major problem and solving it could be very beneficial.

11.9% reported that they wouldn't trust a machine to organize traffic, while 68.4% said they would and 19.8% said maybe (aren't sure). ~20% Saying no is fairly low but still big enough to pay attention to, thus this should incentivize us to add a human factor to our model. This might also mean that people would take time to adjust to any prototype we implement and could produce side effects socially.

People generally over ruled that they felt the main reason they are wasting time is because of road traffic rather than waiting on a red light, this helps us better understand the problem at hand. Realizing that there are other important factors we should address in our model besides red lights

Most people agreed that traffic lights should be adjusted according to the number of cars waiting on a lane, the 10% indicate that there should be more depth to this solution and that it requires further development to cover any scenario that might render our model inefficient.

II. Output Ideation: (raw)

1. Lack of parking spaces causing people to drive slowly or double park, increasing congestion.
    - Create more spaces by advanced technologies of making buildings float
    - Skipping work or classes, better alternative is working from home or taking online classes
    - Application that navigates the user to available park spaces
    - Use the sea for more parking spaces
    - Parking on rooftops
2. Large part of the population having activities far from their homes and necessitating the need for transportation, leading to high densities of vehicles
    - Working and attending schools that are nearby
    - Re-organising when jobs and schools end by territory
    - Smart lane organisation
    - Car pooling
    - Enhance public transportation
    - Tunnels and long bridges
3. Traffic lights are static and don't match the current situation's needs to facilitate traffic
    - Traffic lights change their duration based on nearby events that cause traffic
    - Use sensors (.ie cameras) to control traffic lights
    - Emulating a police like traffic behaviour
4. Cities with high density suffer from traffic even if people had their jobs nearby
    - Encourage people to go by bike through increasing taxes on buying cars
    - Linking buildings to each other
5. Citizens not abiding by street rules
    - Increasing fine on people who break street rules
    - Making the original lawful street paths a better path than the unlawful ones (because people usually use illegal paths thinking they get them faster to their location)
    - Usage of camera sensors to detect illegal activity and fine them
6. People move slowly because the road's infrastructure isn't maintained well
    - Fix road infrastructure
    - Use flying cars so that we don't need to use any infrastructure
7. People are bad at driving causing accidents and inefficient flow of cars
    - Create a better driving test to get a license to drive
    - Awareness campaigns about street rules and basic driving knowledge
    - Repeating driving test after a duration (10 years for example)

V. Interviews:

Four interviews were conducted with 4 different people asking them about their opinions on some solutions to solve the traffic problem and if implementing one of them would benefit them.

The first prototype was installing cameras and sensors on traffic lights that make them adjust to the traffic situation and turn on the green lights more for the roads with more cars.

The second prototype was using google maps to make the traffic lights adjust to traffic situations without using sensors or cameras.

The third was an application that makes buses go to the people instead of people waiting in certain destinations and be limited to a certain path taken usually by this bus.

The fourth was to reverse some roads' directions if it's found that it's better to decrease traffic and to prevent people from driving against the legal direction to arrive to their destination faster.

Disclosure: The interviews done were recorded in arabic language and translated to english in the report below.

Summary:

Prototypes 1 & 2 were received well with our interviewees, whilst prototypes 3 & 4 were clearly a miss. The interviewees who are also the stakeholders, think that prototypes 3 & 4 aren't dealing with the main problem of traffic, while adding that these prototypes require conditions that can't be met in Lebanon. For prototype 3 there was a general consensus that people should change their mentality to use public transportation and there should be bus stops rather than giving buses the best path. For prototype 4, they reflected the need for new roads which isn't possible in lebanon; plus the lebanese won't adjust fast to these changes, not to mention that it will help the majority of the citizens but not all of them.

Prototype 2 was less received than 1 where they thought that solving traffic in one location will just move that traffic to somewhere else since lebanese roads tend to be linear in design and obstruct spreading the traffic.

Finally prototype 1 satisfied all of them, where they said that if we are able to balance different lanes through changing traffic light durations accordingly, then we can stop cars from accumulating on a lane.

First Interview:

- Do you think the first prototype would work ? Why ? What are your concerns ?
- Yes, but might create traffic on the other road that the red light takes more time at.
- How would you benefit from it ?
- More time to study, less stress from spending time on roads.
- What about the second prototype ?
- Yes, but I don't know whether google maps update the traffic situation frequently and fast enough to help adjust the traffic lights faster.
- What do you think about the third prototype ?
- I guess it wouldn't work. It may confuse people at the beginning, and knowing lebanese people, even if you change a road's direction they will still drive in the opposite if they feel they would arrive faster.
- Okay, what do you think of the fourth then ?
- I think this wouldn't work at all, people should go to where buses pass by not the opposite, there is already uber for this. And I believe Lebanese people like to drive, so even if you provide them with buses to all destinations, they'll still use their cars.

Second Interview:

- Do you think the first prototype would work ? Why ? What are your concerns ?
- Yes, this would absolutely decrease traffic since by this we'll be waiting at red lights when in traffic for less time (kel ma tfadde bkon ahsan), but this depends on people actually following the laws and not crossing red lights and cause conflicts.
- How would you benefit from it ?
- This would increase productivity,less stress, more relaxation and energy.
- What about the second prototype ?
- Maybe, but why not use both google maps and cameras this would be even more efficient and I think that google maps are accurate enough for this.
- What do you think about the third prototype ?
- I don't think the problem is with the roads' directions, the problem is within the people themselves, they don't follow rules and they always take the wrong direction of some roads to arrive faster. People should be taught how to follow rules.
- Okay, what do you think of the fourth then ?
- No, I think this would work better if a scheduled plan was made for buses so people could know when a bus pass by instead of waiting randomly for one.

Third Interview:

- Do you think the first prototype would work ? Why ? What are your concerns ?
- Yes, accumulation of cars is the cause, and I think passing more people from digested lanes would balance the lanes.
- How would you benefit from it ?
- It would lessen my overall stress levels during the day and make me less sad about the country's condition
- What about the second prototype ?
- I think that google maps is accurate and this might work, although i prefer the 1st prototype. This model might create digestion problems somewhere else if you focus on solving the digestion problem road by road.
- What do you think about the third prototype ?
- I think this is more of an optimization model that won't really have a big impact on the roads since buses and taxis aren't the main cause of traffic
- Okay, what do you think of the fourth then ?
- I think some people will benefit from this approach but people won't adjust fast to the changes, I don't think it is worth it to do so.

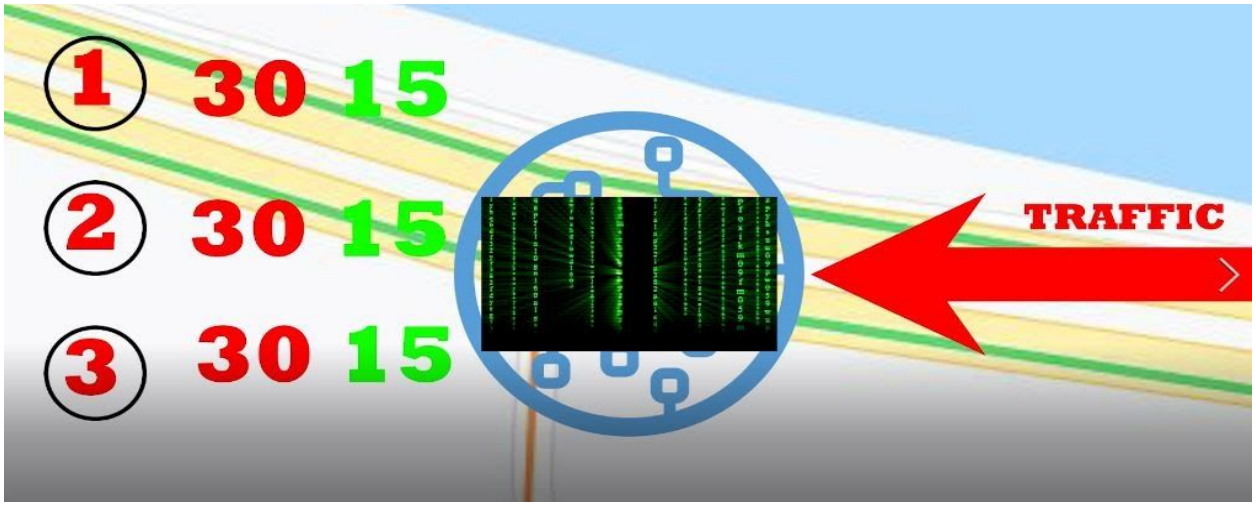
Fourth Interview:

- Do you think the first prototype would work ? Why ? What are your concerns ?
- Yes, i think this will clear the roads faster and the accumulation of traffic won't be drastic
- How would you benefit from it ?
- I'll get more time for myself, i read somewhere that lebanese people spend 720 hours a year driving, it's just psychologically demanding
- What about the second prototype ?
- No, solving it this way will only change the place of traffic, the real problem is that traffic is always pinpointed at one place rather than spreading.
- What do you think about the third prototype ?
- Yes, a bus takes as much people as 15 cars which would decrease the amount of cars on the road, however the lebanese always prefer driving their cars than taking public transportation, I would suggest telling people to go to one place rather than telling the buses.
- Okay, what do you think of the fourth then ?
- No, if you change one road, another road is bound to get affected and some roads only have 1 possible and reasonable direction.

IV. Low Resolution Prototype: (https://youtu.be/nqgbFa8vLdE)

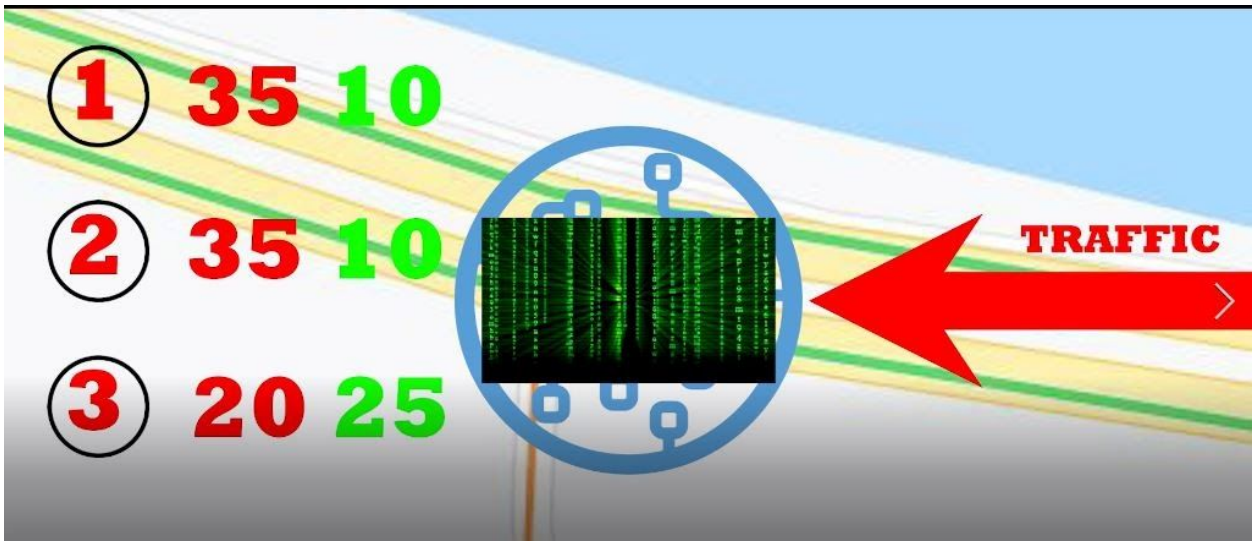
There is a traffic congestion in the street marked in red.

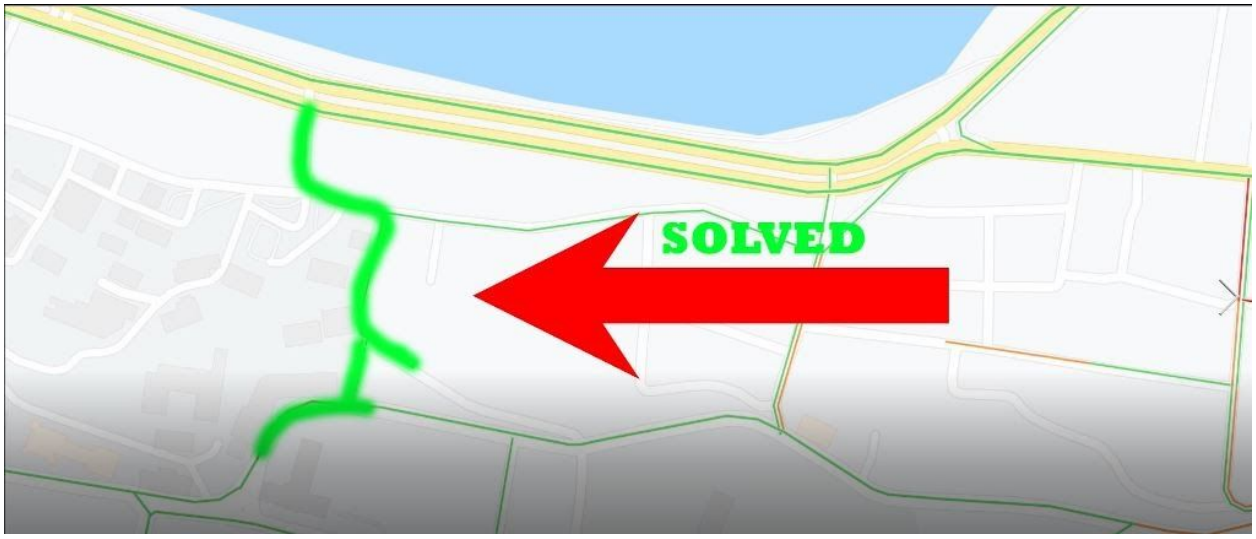
This symbol represents traffic light locations.



30 Numbers in red represent the duration of red light in seconds

10 Numbers in green represent the duration of green light in seconds





After our model adjusted the timing of the 3 lights at their respective locations, the congestion in this street was reduced.

Whilst creating the prototype, we encountered several issues that hindered our progress, namely, deciding if it was efficient to work on each intersection at a time, or working on a set of intersections at the same time in order to avoid a case where diminishing the congestion in one street would cause an increase in congestion in another. Finally, we decided as a start to work on each intersection at a time then loop through them all till we reach the best outcome, however we limit the number of iterations so that if the perfect outcome is not possible, it would stop at some point.

When we presented this prototype to the stakeholders -mainly drivers- they were welcoming to the idea, and found our prototype comprehensible and easy to follow. In addition, they asserted that such a solution would be convenient and time-saving. However, they added that they would have preferred if the idea was tested in real life to see its actual impact on traffic, since reality doesn't always comply with theory.

VI. M3 Feedback:

We simulated our low-res prototype in a room with 5 people which formed a fun little game, and then interviewed the participants. The whole process took around 14 min.

1. Interview by Edmond Samaha (10mins)

One participant said that he had a good experience and he believed that this idea could revolutionize commuting if implemented correctly. However we had issues synchronizing multiple simulated intersections and the participants said that an issue like that could cause more delay instead of saving road time, and even lead to accidents if at least one of the sensors malfunctioned. Another comment from a participant was that people don't always respect traffic lights and was concerned that such actions would lead to miscalculations by the sensor for future calculations. These statements made us think that, at least for a testing period, human intervention (traffic officers) are needed, after all, for our solution.

2. Interview by Abdallah Dandashli (10mins)

Another participant realized some improvement after our test (The group of people we interviewed after the test were not told what our model did). He thought that we were managing the traffic light based on congestion. He mentioned that if one lane keeps having more cars than the other lane, then the light will never open to the next lane, and after telling him what was our fix, he said that this will need to be very well maintained to work well. He also added another factor we weren't thinking of, that a lane's speed limit is used to calculate traffic light phase durations. This could eventually be added as a feature to our model.

3. Interview by Bashar Baajour (10 mins)

A participant pointed out a very significant flaw while being interviewed. He had a good guess of the model's design and functionality, and he realized that it depended on gathering data from the streets. He argued that accidents and unexpected occurrences may cause a hindrance to the functionality of our model. We concluded that in such cases, we would have to resort to human intervention. Even though he pointed out the flaws of what he thought the model was, he was impressed by it, and believed it would be a feasible solution to congestion.

Testing:

This is the video of the simulation taken and edited by Hussein Daoud that shows the advantage of adjusting the timing of traffic lights in real time to eliminate traffic and decrease the duration of waiting on red lights. Without the cameras, 3 people waited for around 7 seconds for the green light while the second traffic light had no cars passing by it, but when the cameras were added, lights turned green for the road with more people and then when they all passed the other lights turned green for the other road with less people.
https://www.youtube.com/watch?v=kzfJkewtjZE

VII. M4:

A-Output Ideation:

a-Summary of all steps and brainstorming:

First, ideas and solutions were proposed by the whole team members while brainstorming to solve the problem of traffic congestion in Lebanon and we chose the following four prototypes mentioned in M3:
1- Installing cameras and sensors on traffic lights that make them adjust to the traffic situation and turn on the green lights more for the roads with more cars.
2- Using google maps to make the traffic lights adjust to traffic situations without using sensors or cameras.
3- Application that makes buses go to the people instead of people waiting in certain destinations and be limited to a certain path taken usually by this bus.
4- Reversing some roads' directions if it's found that it's better to decrease traffic and to prevent people from driving against the legal direction to arrive to their destination faster.

After that, we conducted interviews asking people about their opinions on each prototype, if they find any of them helpful and if yes how would they benefit from each one.

Then, after evaluating all the interviews and prototypes we found out that the most positive feedbacks were on the first solution, so we built a low resolution prototype of it and we then took a video testing this prototype on people and the link is included above.

The solution we decided on can be implemented using CCTV and sensors that help traffic managers adjust traffic lights as needed or by varying the timing of traffic lights to match demand in *real time* without the need for human interference.
However, we knew that CCTVs are already installed in several junctions in Beirut and that didn't help reduce the problem, so we decided to go with the latter choice.

b-Summary of Literature on existing solutions:

Traffic congestion is a worldwide problem that governments are trying to solve. Several solutions are now available but the big deal is implementing them successfully.
The existing solutions are several and can be categorized into two types: The modern, sophisticated initiatives or The one-hit solution.

I- The modern, sophisticated initiatives

1- One of the sophisticated solutions is the use of closed-circuit TV(CCTV) at junctions to make traffic managers see breakdowns, collisions and other causes of traffic, combined with a good communication systems with the policemen and major road users (such as airport, universities, schools...), this can ensure traffic managers receive advance warning of issues that will impact their network.

2- Inbound Flow Control (our term for 'gating' or 'queue relocation') is a powerful technique for managing morning peak traffic flows efficiently, and for providing bus priority without the need to build bus lanes right into a city. The idea is that some of the traffic that would normally sit in a queue somewhere in the city is held back temporarily at the edge. Here there is typically land of relatively low environmental or heritage value that may be used to widen the road to queue traffic and provide a bypass lane for buses (and emergency services and potentially other authorised vehicles). Clear signage in advance of the queuing area should inform drivers of expected queuing times and direct them to the nearest park-and-ride. Vehicles are released from the 'gate' at a rate that matches the road's outflow rate, i.e. the rate at which vehicles are able to disperse. This ensures that all traffic flows freely beyond the gate. This obviates the need for bus lanes, and improves journey times for all road users.

3- Road pricing is an efficient solution and there is no doubt that it can work, since in Singapore, for instance, a network of ‘gates’ that charge a toll that varies in relation to demand successfully keeps a lid on congestion. But there is a complex debate to be had around designing and implementing road pricing: the social, political and technical challenges are huge and will take years to resolve.

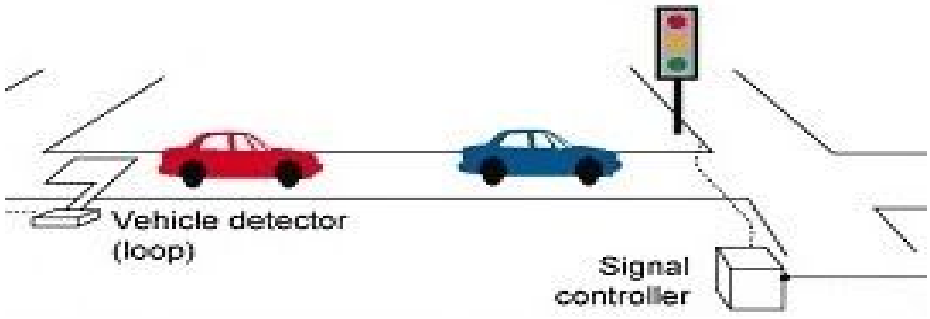
4- Requiring bus drivers to collect fares, verify tickets and passes, account for all money taken, and spot fare dodgers adds considerable stress to their job, and increases the dwell time at stops. Instead, operators should employ specialist revenue protection officers with powers to impose on-the-spot fines. CCTV on board buses provides a means to spot and target repeat offenders.

II- The one-hit Solutions:

- Widen roads
- Add bus lanes
- Remove bus lanes
- Build tunnels
- Build a new ring road
- Build a light rail network
- Ban cars from city centres
- Close through-routes to private vehicles
- Build more car parks
- Make buses free

All these solutions are called one-hit because none of them can deliver a complete solution, and most of them provide only temporary relief until induced demand fills up the road space once more. In addition, heavy-engineering measures, such as bus lanes and tunnelling can attract support from politicians, mindful of their legacy or for stealing money like most of the politicians do in Lebanon. But such projects typically require years of highly disruptive work, destroy fragile streetscapes, and undermine the viability of other public transport options.

B- Concept Product:



After collecting our data and analyzing it, we decided that this device is worth implementing even with its small downsides. It functions by using a sensor which can be a camera (in which case we would need a script to differentiate cars from other objects), or a simple motion detector. We believe that the camera is the better option since it minimizes errors. The camera would detect a car passing by and pass its speed (or even just the car count) to the signal controller which calculates the best sequence of lights to be displayed. The signal controller would also detect major irregularities in the case of an accident occurring, and it would revert the traffic controller to a non-dynamic traffic light switch.

C- Feasible Component with ML potential:

→ a & b are lanes
→ R(a) sets the light of lane "a" to red
→ G(a) sets the light of lane "a" to Green

```
Check_Lane(a,b)  (Prototype)
{
        If (a.cars > b.cars)
        {
                Set G(a);
        }

        If (time(G(a)) < min_limit)
                {Return NULL;}
        Else
        {
                If (a.cars < b.cars)
                {
                        Return R(a);
                }
                Else
                {
                        If (time(G(a) > max_limit)
                        {
                                Return R(a);
                        }
                        Else{return NULL;}
                }
        }
```

```
Set_Time_Limit(a1,b1) (Prototype)
{
        Use machine learning to determine a1 and b1;
        Use number of cars as a feature
        Use speed limit as a feature
        Min_time = a1;
        Max_time = b1;
```

}
Our model gives each light 2 attributes, max limit and min limit.
The idea is that the model keeps checking the amount of cars on a lane, whenever the amount of cars on one lane is greater than the amount of cars on another lane then it does the following:

1. Checks if the lane currently with a green light has been green for a time less than min limit, if it is less than it keeps it green.
2. If it has exceeded the min limit and the other lane has more cars then it makes it red and makes the other lane green

The model also has a listener function that starts when the light becomes green, it checks if the green light bas been green for a time greater than or less than max limit, if the time was greater than it makes the light red and gives the other lane a green light (or the next lane in sequence). If not then it keeps it green (keeping in mind that this lane still has more cars than the other lane).

Extra Feature:

According to the interviews we conducted, we deduced that we should use an aspect of prototype 2 with this one.

Mainly we will be using google maps to teach our model which future lanes are affected when one digested lane becomes undigested since the people we interviewed believe that when one location gets undigested, the nature of lebanese roads won't allow the spread of the digestion but only relocate it, thus the need for implementing in the model a feature which anticipates the relocation of digestion and plans ahead accordingly.

The machine learning involved takes place in 3 places.

1. The cameras and sensors will need to be accurate and return the correct amount of cars on a lane, this will require a function that analyses the pixels from images. The machine learning involved could use the heat signatures of cars to calculate the amount of cars.
2. The parameters max and min limit used will also need a machine learning model to calculate them. This is especially important and will be calculated for each lane since if we are not accurate in choosing them then it would decrease efficiency.

3. The digestion relocation also requires a model, which will be mainly used as sequential data from google maps (return in pairs; where a nearby digestion occurred after another nearby digestion was reduced).

D- Test Output:

In total, we came up with 4 prototypes including the best solution found, and conducted 2 physical experiments with 5 people in each one. We gained a lot of insight on how the best solution could be implemented gradually in the best possible way, such as:

-Managing issues of synchronization between multiple intersections to avoid more delay or even accidents.
-Take into consideration that people don't always respect traffic lights which would lead to miscalculations by the sensor for future calculations.
-At least for a testing period, human intervention (traffic officers) are needed, after all, for our solution.
-A bug could occur if one lane keeps having more cars than the other lane, then the light will never open to the next lane.
-Should consider lane's speed limit that is used to calculate traffic light phase durations. This could eventually be added as a feature to our model in order to avoid miscalculations.
-Accidents and unexpected occurrences may cause a hindrance to the functionality of our model.

We also tried to write a machine learning program based on the best solution to find a hypothesis function for a basic way of managing traffic lights using Neural Networks. However, this task ended up being too implausible for us as the input data required was very broad and complex, and wasn't available for us to use. Hence, the data that we worked with mainly consisted of research, simulation, prototyping and feedback, but people with more expertise than us will absolutely be able to elaborate on our work which will be their stepping stone.

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