<u>Project Notes</u>

<u>Project Title:</u> Synchronizing Navigation Apps and Traffic Signals to Decrease System-Wide Travel Time
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<u>Contents:</u>

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
Current traffic system models	Watching video which explains how	Article #6 Notes	9/18/22
Current approaches and methods towards TST	Reading a review article	Article #5 Notes	9/28/22
How does GPS work?	Watching TED-Ed video	Article #7 Notes	10/13/22
How can we estimate travel time between two locations?	Read journal article	Article #8 Notes	10/13/22
How to simultaneously assign routes and optimize traffic signal timing?	Found journal article describing it	Article #13 Notes	11/19/22
What factors affect fuel emissions?	Read journal article	Article #14 Notes	12/12/22

Literature Search Parameters:

These searches were performed between (Start Date of reading) and XX/XX/2019.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
WPI Library	Traffic signal optimization,	Discovered article: *Traffic Signal Optimization in "La Almozara" District in Saragossa Under Congestion Conditions, Using Genetic Algorithms, Traffic Microsimulation, and Cluster Computing*
Google Scholar	TST optimization	Discovered article: *State-of-art review of traffic signal control methods: challenges and opportunities*
Google Scholar	Google Maps, Travel Time estimation	Discovered article: *Estimating O–D travel time matrix by Google Maps API: implementation, advantages, and implications*
WPI Library	route assignment AND traffic signal	Discovered article: *Solving simultaneous route guidance and traffic signal optimization problem using space-phase-time hypernetwork*

Article #1 Notes: LIDAR Laser Radar Finding More Uses

Article notes should be on separate sheets

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Source Title	LIDAR laser radar finding more uses
Source citation (APA Format)	NBCUniversal News Group. (2004, November 12). *Lidar laser radar finding more uses*. NBCNews.com. Retrieved October 17, 2022, from https://www.nbcnews.com/id/wbna6468236
Original URL	https://www.nbcnews.com/id/wbna6468236
Source type	General Article (Over the summer)
Keywords	LIDAR, laser-beam, mapping, scanning

Summary of key points + notes (include methodology)	**Summary** In this article, I learned about LIDAR, which stands for Light Detection And Ranging. This laser-based system can calculate distance by bouncing off a light beam and seeing how fast it comes back. If the process is done multiple times it can map out an entire area, which is one of its main uses. By quickly mapping over an area, LIDAR can help with flood plain mapping, monitor beach erosion and the condition of electrical transmission lines, or can even help assess the damage of a natural disaster. Overall it is clear that it is a very versatile technology. **Notes** <u>Methodology of LIDAR</u> - LIDAR can calculate distance by bouncing off light beams and seeing how far they come back. <u>Uses</u> - LIDAR can map an area by applying it millions of times by flying over terrain. Fastest way to map terrain - Finding the speed of wind and cars - As computational power gets better, LIDAR does to - Scans are mostly done by helicopter or airplane - Can examine earthquakes and volcanoes. Measuring elevation - Monitoring beach erosion - Condition of electrical transmission lines - Agriculture: monitoring dust, water vapor, ammonia - Forests: scanning the tops of trees to see how thick they are
Research Question/Problem/ Need	What is LIDAR and how can it be used?
Important Figures	(none)
VOCAB: (w/definition)	LIDAR (light detection and ranging): method for determining ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver Laser-beam: stream of focused, coherent light in a single wavelength Radar: a detection system that uses radio waves to determine the distance, angle, and radial velocity of objects relative to the site
Cited references to	(none)

follow up on	
Follow up Questions	1. How precise is LIDAR? 2. How expensive is it to use LIDAR? 3. Is it easy to implement LIDAR in your gadget? Does it have to be connected to a computer?

Article #2 Notes: This Is How The Sun Moves In The Sky Throughout The Year

Article notes should be on separate sheets

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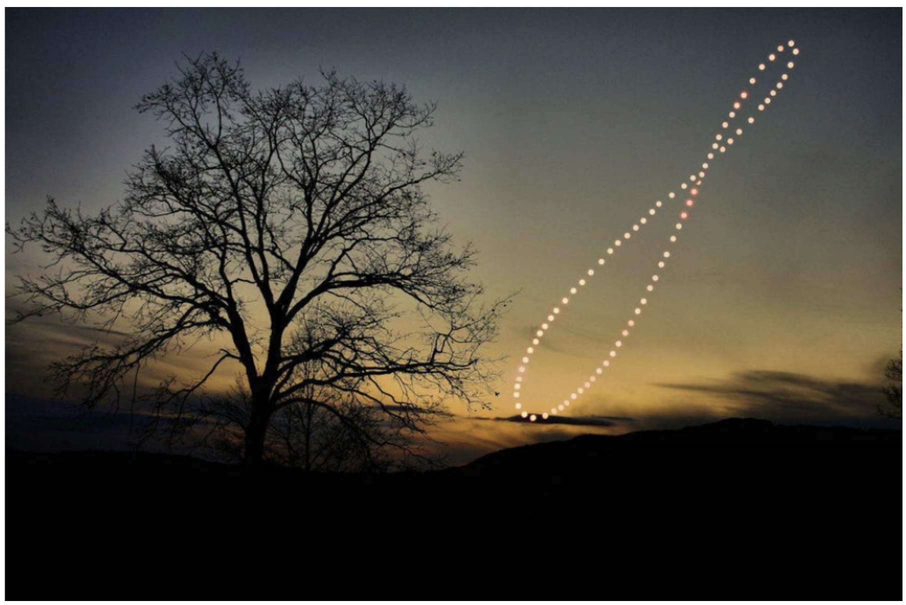
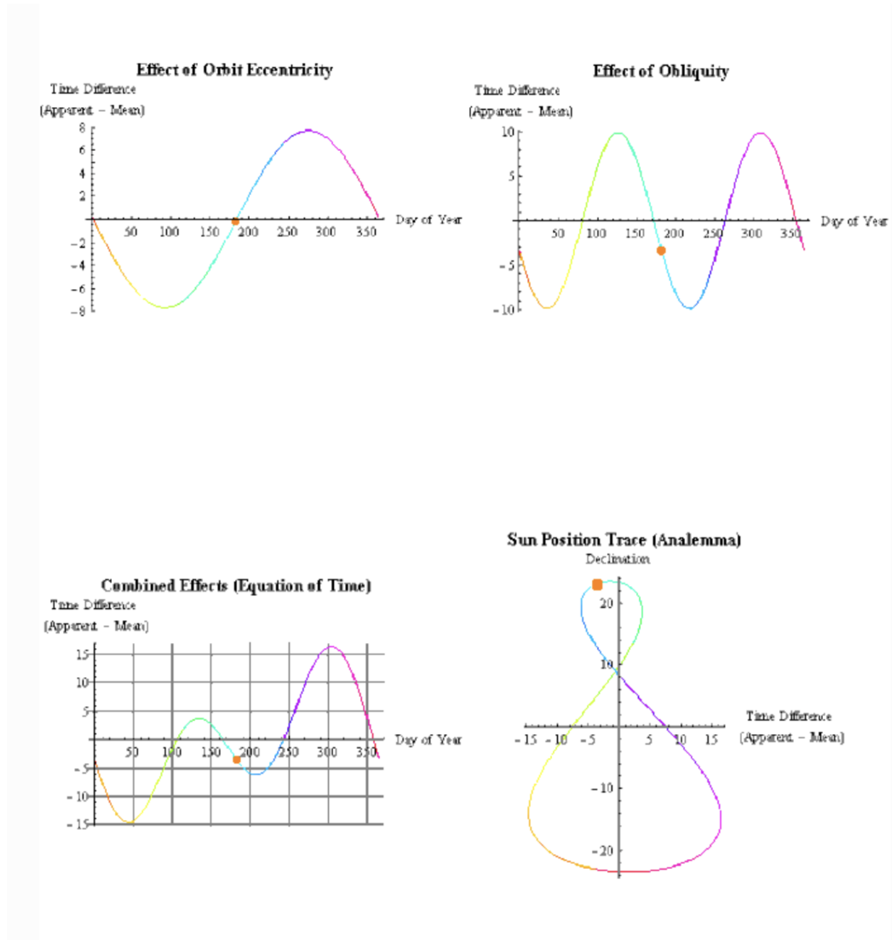
Source Title	This Is How The Sun Moves In The Sky Throughout The Year
Source citation (APA Format)	Siegel, E. (2019, January 1). *This is how the Sun moves in the sky throughout the year.* Forbes. Retrieved October 17, 2022, fromhttps://www.forbes.com/sites/startswithabang/2019/01/01/this-is-how-the-sun-moves-in-the-sky-throughout-the-year/?sh=632d8373037e
Original URL	https://www.forbes.com/sites/startswithabang/2019/01/01/this-is-how-the-sun-moves-in-the-sky-throughout-the-year/?sh=632d8373037e
Source type	General Article
Keywords	Axial tilt, analemma, elliptical orbit
Summary of key points + notes (include methodology)	**Summary** In this article, I learned about the way the sun moves above the sky. I learned that the position of the sun depends on many factors. The time of day, time of the year, and the location of Earth (most importantly Northern hemisphere or Southern hemisphere) all determine its position in the sky. This is due to the elliptical orbit of the Earth, and the fact that the Earth's axis has a tilt of approximately 23.5 degrees. Some interesting facts emerge, for example at a specific location throughout the year the sun would form a "figure 8" shape. **Notes** - The sun changes its position in each sky each day by just a bit

	- This is because of axial tilt, which also causes the seasons.
	- Sun always rises in the Eastern hemisphere
	- Sunset and sunrise vary throughout the year, due to the elliptical orbit of Earth
	    - Earth is closer to sun at some points
	    - Earth spins at a faster rate at some points
	- We can combine all these factors to create the equation of time, which is a graph determining where the sun will be at any given time
	- The location of where you are also affects the orientation of your analemma.

Research Question/Problem/ Need	How does the sun move in the sky throughout the year?
Important Figures	 ^Figure showing analemma

<table>
<tr><td></td><td>

^graphs showing the different factors and in the bottom left, the equation of time</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>Analemma: diagram showing the position of the Sun in the sky as seen from a fixed location on Earth at the same mean solar time, as that position varies over the course of a year.

Zenith: the time at which something is most powerful or successful.

Aphelion: the point in the orbit of a planet, asteroid, or comet at which it is furthest from the sun.

Perihelion: the point in the orbit of a planet, asteroid, or comet at which it is closest to the sun.</td></tr>
<tr><td>Cited references to follow up on</td><td>(none)</td></tr>
<tr><td>Follow up Questions</td><td>- Is there a way to mathematically describe the analemma?
- Is there a way to compute the area of the analemma?
- Can this be used for crop rotation?</td></tr>
</table>

Article #3 Notes: The Equation Of Time

Article notes should be on separate sheets

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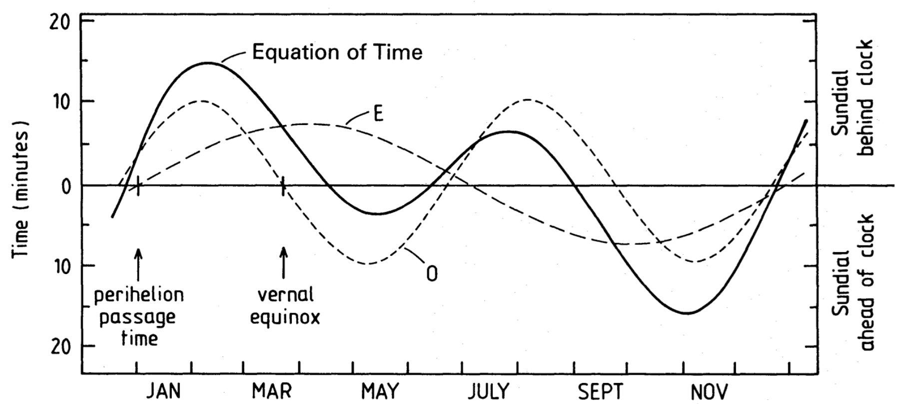
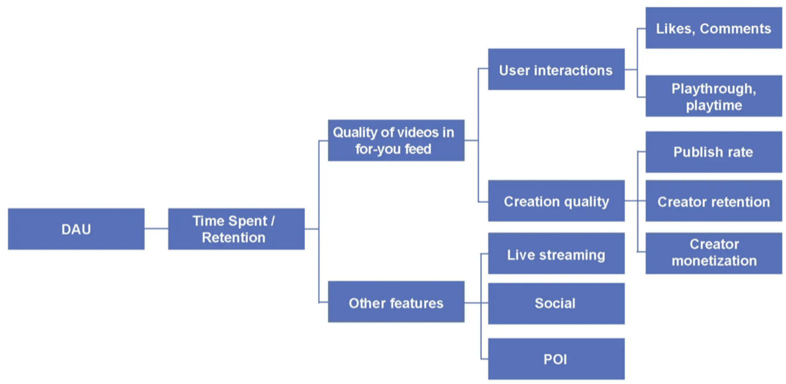
Source Title	The Equation of Time
Source citation (APA Format)	Hughes, Yallop, B. D., & Hohenkerk, C. Y. (1989). The Equation of Time. *Monthly Notices of the Royal Astronomical Society, 238*(4), 1529–1535. https://doi.org/10.1093/mnras/238.4.1529
Original URL	https://doi.org/10.1093/mnras/238.4.1529
Source type	Journal Article (Summer)
Keywords	Ephemeris time, apparent sun, mean sun,
Summary of key points + notes (include methodology)	**Summary** After reading the previous article, I wanted to learn more about the equation of time, which promised a way to calculate the position of the sun at any place and time. The paper explained that the equation of time was the difference between mean time and solar time, mean-time is the time shown on a clock, and solar time is based on the actual position of the sun. These two times differ depending on the year (due to factors such as the Earth's tilted rotation and elliptical orbit). The paper offers an algorithm to compute the difference given the date, which is a long list of simple calculations (nothing too mathematically crazy). It also includes a graph, which takes the difference as a function of time. **Notes** - Mean time is the time shown on a clock, solar time is the actual position of the sun (sundial time) - Variation of position of the sun is due to eccentricity of orbit - There are different ways of representing mean time, such as Ephemeris time and Universal time - There’s an algorithm to calculate the UT for any date within 30 centuries of present day to 3s of time

	- A graph for the equation of time is given below. Sometimes the curve goes below the line, which means that solar time is less than mean time. - There's an approximation formula, which is shown below: $$E = -2e\sin(L-\omega) + \tan^2\frac{\varepsilon}{2}\sin 2L$$ -
Research Question/Problem/ Need	How can we calculate the position of the sun at any given time?
Important Figures	 ^ Equation of time as a function of month.
VOCAB: (w/definition)	Ephemeris: a book with tables that gives the trajectory of naturally occurring astronomical objects as well as artificial satellites in the sky, i.e., the position over time Diurnal: of or during the day. Barycentre: The point at the centre of a system
Cited references to follow up on	Hughes, D. W., 1989. *J. Br. astr. Ass.,* in press. Hatcher, D. W., 1984. *Q. Jl. R. astr. Soc.,* 25, 53.
Follow up Questions	- This equation only applied for dates in between 30 centuries. Is it possible to find this for any date in history? - On the same topic, is it important to find it on the same day in history? - Does this equation change as different astronomical forces affect different things over time?

Article #4 Notes: How TikTok Reads Your Mind

Article notes should be on separate sheets

Source Title	How TikTok Reads Your Mind
Source citation (APA Format)	Smith, B. (2021, December 6). *How tiktok reads your mind.* The New York Times. Retrieved August 20, 2022, from https://www.nytimes.com/2021/12/05/business/media/tiktok-algorithm.html
Original URL	https://www.nytimes.com/2021/12/05/business/media/tiktok-algorithm.html
Source type	Website
Keywords	Machine Learning, retention, time spent
Summary of key points + notes (include methodology)	**Summary:** TikTok's is addicting because its algorithm is optimized, as it employs machine learning on personalized user data that attempts to maximize the time you spend on the app. This can be dangerous especially if the user is not mature, as they could be manipulated and led down rabbit holes by the app. **Notes:** - TikTok has become a huge part of the youth's culture - Tik Tok's is addicting because its algorithm is optimized - User data and machine learning is designed to keep you on the app for as long as possible. - The algorithm uses variables such as watch time, comments, and likes to develop a scary understanding of the user. - The recommender system creates a rating of the videos based on these variables, and give the user the videos which have the highest ratings - This can be dangerous especially if the user is not mature, as they could be manipulated and led down rabbit holes by the app. - Depressed people can be brought to drugs by the algorithm - User data can be easily bought, which is concerning.
Research Question/Problem/ Need	Why is the TikTok algorithm so addicting?

Important Figures	 ^ Figure of the goals of the tiktok algorithm
VOCAB: (w/definition)	Rabbit-hole: used to refer to a bizarre, confusing, or nonsensical situation or environment, typically one from which it is difficult to extricate oneself. Dispersion: the action or process of distributing things or people over a wide area.
Cited references to follow up on	None
Follow up Questions	- How can we moderate dangerous or explicit content better on the app? - How can we protect user data so that it can be used for good and not for manipulation? - Is there a way to create a better algorithm that does not try to maximize watch time but rather maximize enrichment?

Article #5 Notes: The lie of “expired” food and the disastrous truth of America’s food waste problem

Article notes should be on separate sheets

Source Title	The lie of “expired” food and the disastrous truth of America’s food waste problem

Source citation (APA Format)	Wilkinson, A. (2021, July 8). *The lie of "expired" food and the disastrous truth of America's food waste problem.* Vox. Retrieved August 20, 2022, from https://www.vox.com/22559293/food-waste-expiration-label-best-before
Original URL	https://www.vox.com/22559293/food-waste-expiration-label-best-before
Source type	Website
Keywords	Expired, non-standardized, safe to eat

Summary of key points + notes (include methodology)	**Summary**
	Expired food is indeed safe to eat, and doing so can help many social problems such as food inequality. Food waste is a big problem in the US, and a big contributor to it is the culture of trashing expired food. Not only are food labels non-standardized, but don't represent when a food has become unsafe to eat.
	
	Notes
	- Food waste is a huge cultural problem in the US
	- Food labels aren't federally standardized.
	    - Inconsistent, since some are "best sold" and some are "best by"
	    - Food labels are
	- Expiration labels aren't accurate: well-intentioned, but haphazard and confusing
	- Best to use your nose and mouth to determine if food is good. Food past the expiration date is still good to eat.
	- Average American family throws away between $1,365 and $2,275 worth of food.
	- 25% of fresh water goes towards uneaten food
	- 21% of landfill is food
	- 42 million living with food insecurity and hunger in US
	- Most a cultural problem: consumerism

Research Question/Problem/ Need	Is expired food safe to eat?

Important Figures	 ^Billboard in minnesota showing how much food America wastes
VOCAB: (w/definition)	Food insecurity: the state of being without reliable access to a sufficient quantity of affordable, nutritious food. standardization: to bring into conformity with a standard especially in order to assure consistency and regularity
Cited references to follow up on	None
Follow up Questions	- Can we develop an automated and easy way to check if a food is safe to eat? - Can we find better ways to determine how long a certain food item is good for? - Are there good ways to recycle thrown away food

Article #6 Notes: Data Collection, Modeling, and Classification for Gunshot and Gunshot-like Audio Events: A Case Study

Article notes should be on separate sheets

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Source Title	Data Collection, Modeling, and Classification for Gunshot and Gunshot-like Audio Events: A Case Study
Source citation (APA Format)	Baliram Singh, Zhuang, H., & Pawani, J. K. (2021). Data Collection, Modeling, and Classification for Gunshot and Gunshot-like Audio Events: A Case Study. *Sensors (Basel, Switzerland)*, *21*(21), 7320–. https://doi.org/10.3390/s21217320
Original URL	https://wpi.primo.exlibrisgroup.com/discovery/fulldisplay?docid=cdi_doaj_primary_oai_doaj_org_article_c1b80dd7b6524bf88b4eac063b162f97&context=PC&vid=01WPI_INST:Default&lang=en&search_scope=MyInst_and_CI&adaptor=Primo%20Central&tab=Everything&query=any,contains,classification%20for%20gunshot&sortby=rank&mode=basic
Source type	Journal Article
Keywords	gunshot; plastic bag pop; binary classification; convolution neural network; Melfrequency cepstral coefficients; Mel-spectrogram
Summary of key points + notes (include methodology)	**Summary** It's important for gunshot detection systems to distinguish between gunshot sounds and similar sounds in order to deploy safety personnel when actually needed. A preexisting machine learning model, which trained on a variety of sounds similar to gunshots, was not able to effectively differentiate non-threatening sounds. A new model was made which only trained on one type of sound (plastic bag popping), and was able to accurately distinguish between bag explosions and gunshots. **Notes** - Bag-popping data set was created by exploding bags at different distances, environments, bag materials and sizes. The audio was captured by a variety of different devices and microphones. The gunshot data was gained from a pre-existing Urban Sound dataset, and any other sounds

	were deleted. - A four-layer Convolution Neural Network was used as the classification model. - Data including other sounds (such as “gun_shot, dog_bark, children_playing, car_horn, air_conditioner, street_music, siren, engine_idling, jackhammer, and drilling”) was run through this model, which was very inaccurate when distinguishing gunshots from plastic bag popping. - When only bag-popping data and gunshot-data was run in the model, it was very accurate with low false positive and false negative values. - This means that in theory, if we create many different binary-classifications, such as gunshot and dogbark, gunshot and horn, gunshot and engine, etc., we can accurately identify these sounds.
Research Question/Problem/ Need	How can systems distinguish gunshot sounds from harmless but similar sounds?
Important Figures	75% of the plastic bag pop sounds were misclassified as gunshot sounds with the first model (data with other sounds) A false positive (FP) or type-I error occurs when the actual value was negative but the model predicted a positive value, 2 in both cases (100 total). The false negative (FN), a type-II error, occurs when the actual value was positive but the model predicted a negative value, i.e., 4 and 6 for the MFCC and Mel-spectrogram cases, respectively (100 total).
VOCAB: (w/definition)	Convolutional neural network: type of artificial neural network used in image recognition and processing that is specifically designed to process pixel data. Spectogram: a visual representation of the spectrum of frequencies of a signal as it varies with time
Cited references to follow up on	Ahmed, T.; Uppal, M.; Muhammad, A. Improving efficiency and reliability of gunshot detection systems. In Proceedings of the 2013 IEEE International Conference on Acoustics, Speech and Signal Processing, Vancouver, BC, Canada, 26–31 May 2013; pp. 513–517. [CrossRef] Singh, J.; Joshi, R. Background Sound Classification in Speech Audio Segments. In Proceedings of the 2019 International

	Conference on Speech Technology and Human-Computer Dialogue (SpeD), Timisoara, Romania, 10–12 October 2019; pp. 1–6. [CrossRef]
Follow up Questions	- How can we efficiently create many of these models with binary classification? - How can we get data in many different environments easily? (such as in plastic bag) - How can we cheaply implement these systems?

Article #7 Notes: Traffic Signal Optimization in “La Almozara” District in Saragossa Under Congestion Conditions, Using Genetic Algorithms, Traffic Microsimulation, and Cluster Computing

Article notes should be on separate sheets

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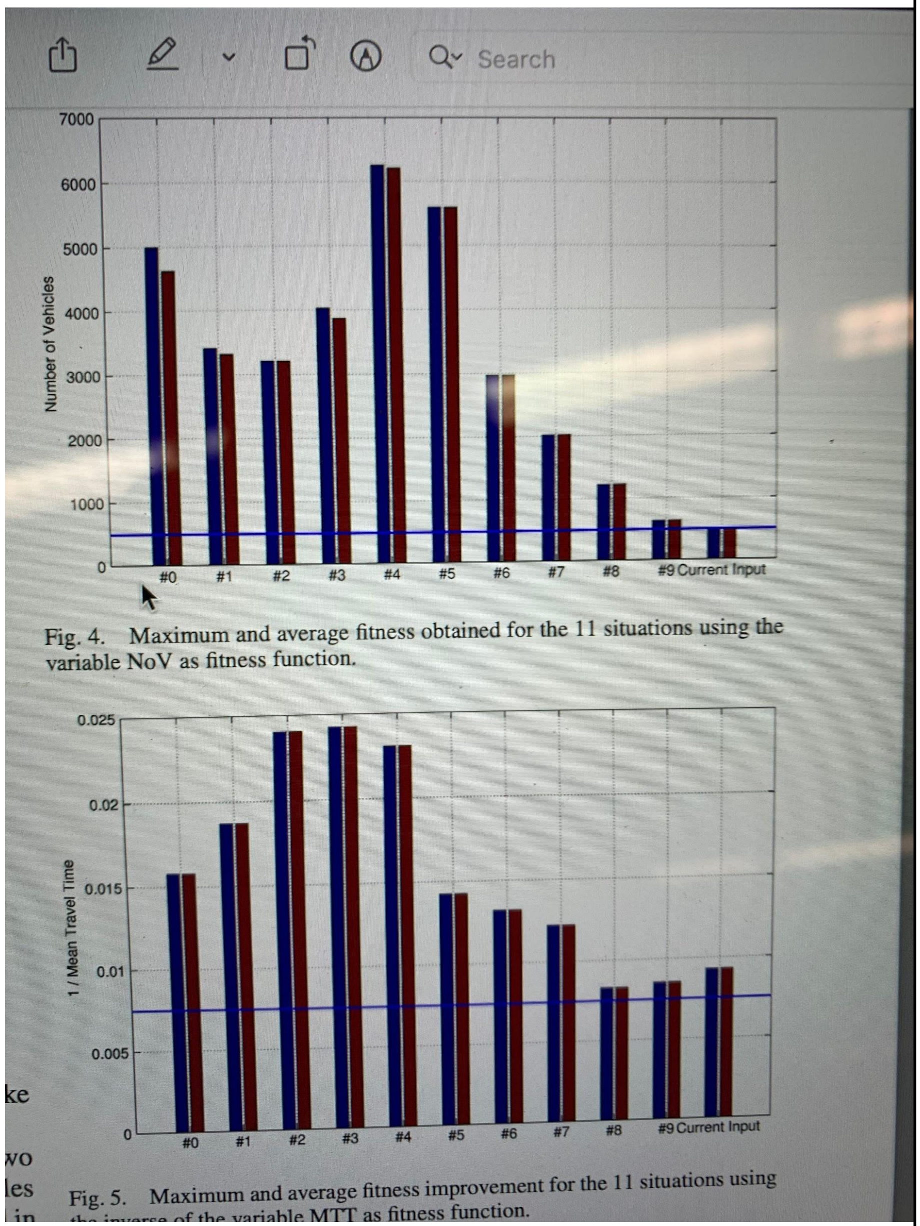
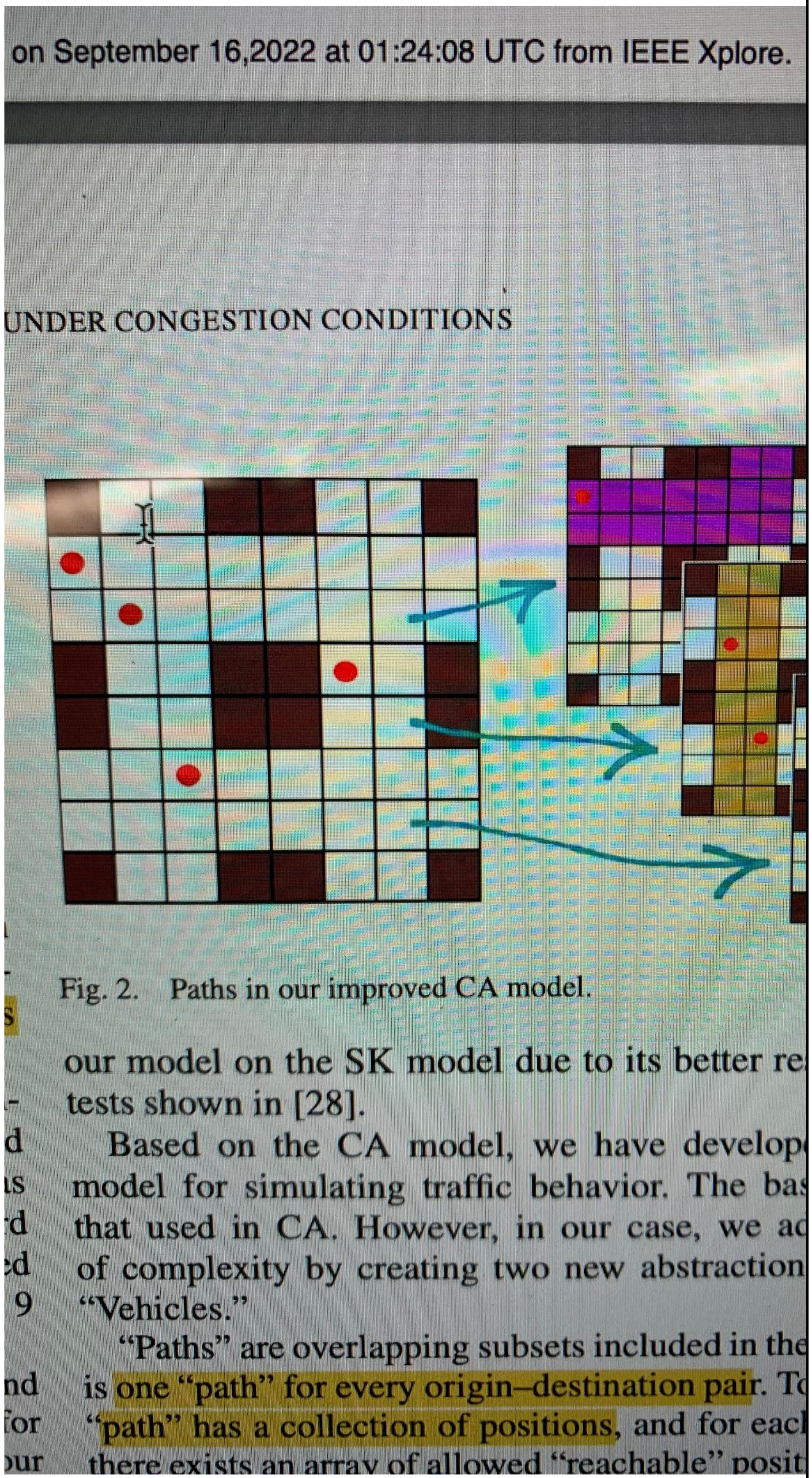
Source Title	Traffic Signal Optimization in “La Almozara” District in Saragossa Under Congestion Conditions, Using Genetic Algorithms, Traffic Microsimulation, and Cluster Computing
Source citation (APA Format)	Sanchez-Medina, Galan-Moreno, M. J., & Rubio-Royo, E. (2010). Traffic signal optimization in “la almozara” district in saragossa under congestion conditions, using genetic algorithms, traffic microsimulation, and cluster computing. *IEEE Transactions on Intelligent Transportation Systems, 11*(1), 132–141. https://doi.org/10.1109/TITS.2009.2034383
Original URL	https://wpi.primo.exlibrisgroup.com/permalink/01WPI_INST/1pchs3f/cdi_proquest_journals_856587175
Source type	Journal Article
Keywords	Cellular automata (CA), genetic algorithms (GAs), intelligent transportation systems, microsimulation, traffic congestion, traffic modeling.
Summary of key points + notes (include methodology)	**Summary:** In order to improve traffic flow, the researchers tried to solve the traffic light cycle problem. To do this, they optimized the

	red-light/green-light/yellow-light cycle times using a genetic algorithm, and used a CA for simulation. Finally, they were able to use a Beowulf for scalable computation.
	
	Notes:
	- They did research on the “traffic-light cycle optimization” problem which was unsolved.
	- They used three main techniques:
	    - A genetic algorithm for optimization
	    - Cellular automata for simulation
	    - Beowulf Cluster for great price/performance ratio and scalability.
	- Tested their model in a large **congested** traffic network
	- They briefly talked about the state of art, talking about how some previous researchers used GA’s and microsimulation.
	- Their model can simulate overtaking and multiple lane and is **highly scalable**
	- For their GA, they used four criteria for their fitness function:
	    - Number of vehicles that left the system
	    - Mean travel time
	    - TOC/SOC
	    - Global mean speed
	- Encoded “chromosomes”
	- Traffic simulator (good)
	    - Cellular Automata simulation
	    - Each vehicle occupies one path
	    - Has a position, speed, and path
	    - Multiple lanes
	    - Smooth braking
	    - Stops at a red light
	- Traffic simulator (bad)
	    - Does not consider inclusion of path changes (DTA)
	    - Stop and go waves
	- Used Beowulf Clusters for computation
	- Results:
	    - Significantly better criteria for congested networks compared to the new network.
	    - Not much optimization for small number of cars
	    - Two variables evolved
	    - Took a while for the tests, but highly scalable
	    -

Research Question/Problem/ Need	How can we optimize the cycling of traffic lights to improve traffic flow?

Important Figures	 ^Graph of maximum and average fitness for the different function fitness



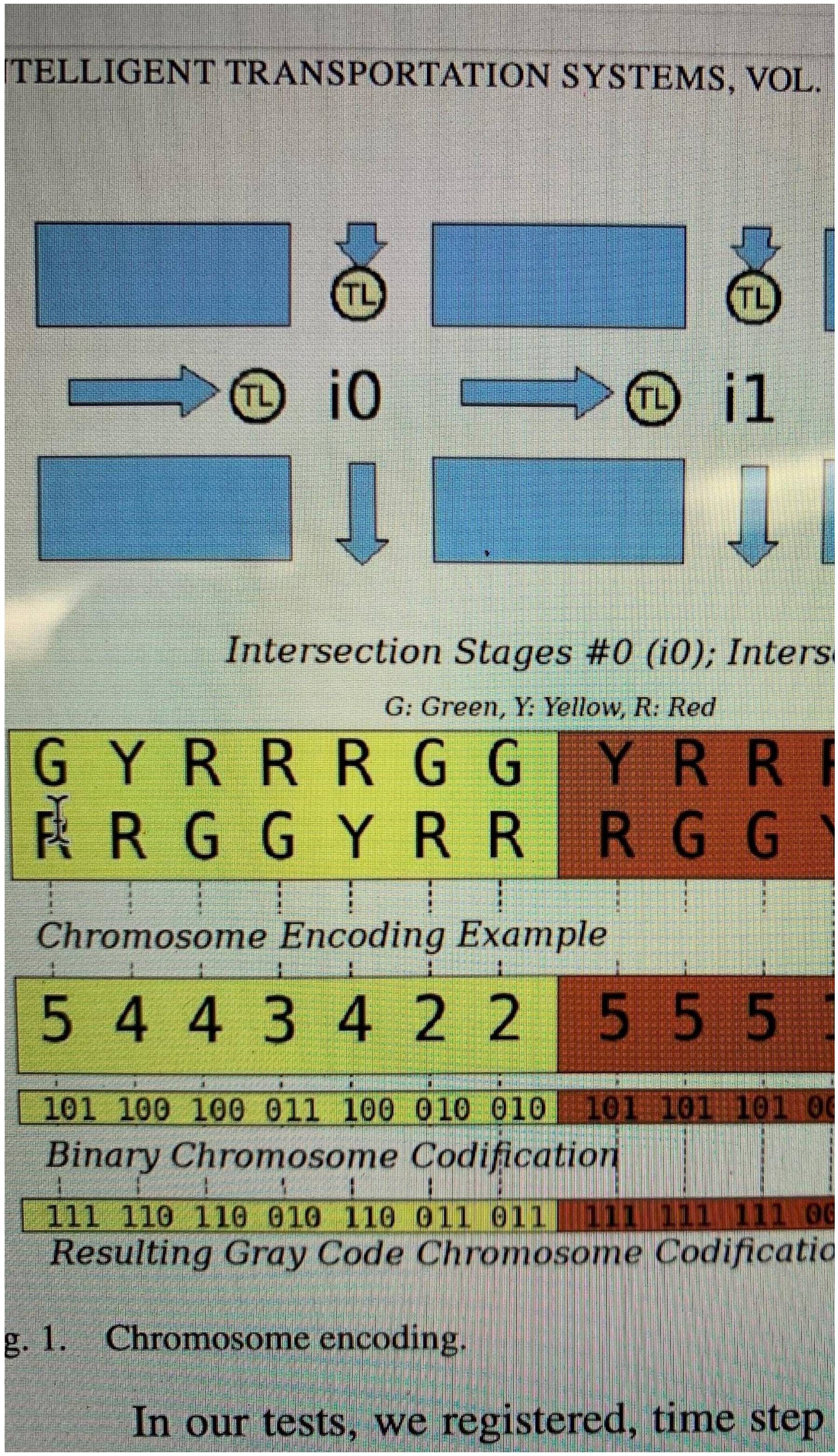
UNDER CONGESTION CONDITIONS

Fig. 2. Paths in our improved CA model.

our model on the SK model due to its better re
tests shown in [28].

Based on the CA model, we have develop
model for simulating traffic behavior. The bas
that used in CA. However, in our case, we ac
of complexity by creating two new abstraction
"Vehicles."

"Paths" are overlapping subsets included in the
is one "path" for every origin–destination pair. To
"path" has a collection of positions, and for each
there exists an array of allowed "reachable" posit

	^Figure showing how the cellular automata simulation works  ^Figure showing chromosome encoding in the GA

VOCAB: (w/definition)	Cellular Automata: discrete, abstract computational systems that have proved useful both as general models of complexity and as more specific representations of non-linear dynamics in a variety of scientific fields. Genetic Algorithm: metaheuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms Beowulf Clusters: computer clusters of what are normally identical, commodity-grade computers networked into a small local area network with libraries and programs installed which allow processing to be shared among them. Chromosome (GA): set of parameters which define a proposed solution to the problem that the genetic algorithm is trying to solve
Cited references to follow up on	E. Brockfeld, R. Barlovic, A. Schadschneider, and M. Schreckenberg, “Optimizing traffic lights in a cellular automaton model for city traffic,” Phys. Rev. E, Stat. Phys. Plasmas Fluids Relat., vol. 64, no. 5, p. 056132, Oct. 2001. Y. S. Hong, J. Kim, J. Kwangson, and C. Park, “Estimation of optimal green time simulation using fuzzy neural network,” in Proc. Fuzzy Syst. Conf., FUZZ-IEEE, 1999, pp. 761–766.
Follow up Questions	- How can we extend this algorithm for lane switching? - Would obstacles, such as emergency vehicles or construction affect this algorithm? - Would the cost of scaling and using this system outweigh the benefits of saved time? - Would GPS data help this model?

Article #8 Notes: State-of-art review of traffic signal control methods: challenges and opportunities

Article notes should be on separate sheets

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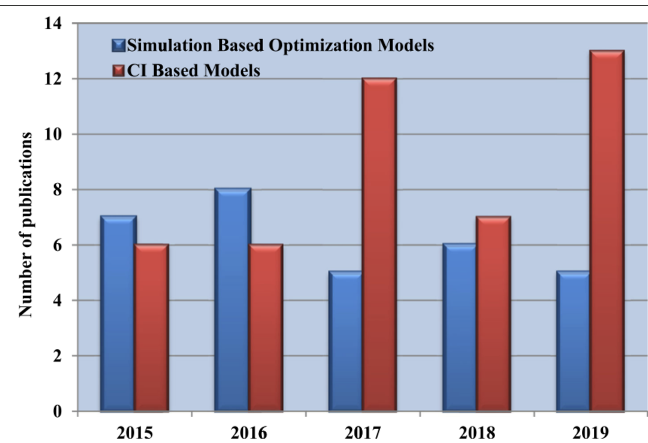
Source Title	State-of-art review of traffic signal control methods: challenges and opportunities
Source citation (APA	Qadri, Gökçe, M. A., & Öner, E. (2020). State-of-art review of traffic

Format)	signal control methods: challenges and opportunities. *European Transport Research Review, 12*(1), 1–23. https://doi.org/10.1186/s12544-020-00439-1
Original URL	https://etrr.springeropen.com/articles/10.1186/s12544-020-00439-1
Source type	Journal (Review) Article
Keywords	“TST optimization”, “traffic congestion optimization”, “TSC settings”, “microscopic traffic simulation-based optimization (SimOpt)”, “dynamic traffic management system”, and “signalized urban intersection”

Summary of key points + notes (include methodology)	**Notes**
	- 77% of papers used microsimulation.
	- Five parameters to consider when optimizing average wait delay time:
	  - Green time (how long to keep it green)
	  - Cycle time (how long signal takes to finish one cycle)
	  - Phase sequence
	  - Change interval (how long the clearance is)
	  - Offset (relationship of phases in terms of time)
	- Fixed time TSC is fine when flow of traffic is stable, but is insufficient in dynamic areas where collisions and construction can significantly alter traffic.
	- Actuated/adapted TSC uses sensors to plan accordingly in present-time signal conditions
	- With these sensors data is now in abundance
	- Two types of simulation:
	  - Microscopic > contemplates the individual behavior of the driver along with the interaction with other vehicles or pedestrians
	  - Macroscopic > approach considers the vehicular flow as a whole.
	- AIMSUN, CORSIM, MATSim, Paramics, SUMO, VISSIM are widely used microsimulation packages, and there’s a table in the article showing their different strengths and weaknesses.
	  - Most people used VISSIM or SUMO
	- Two main methodologies for traffic signal timing settings
	  - Microsimulation based approach (SimOpt)
	    - Useful since evaluating the effects of minor changes in decision variables regarding TST can be assessed accurately through microsimulation without actual implementation.
	    - In these models, a proposed algorithm asks the microsimulation model to evaluate the current solution and results are given back.

	- For the optimization of TST problems, deterministic approaches aren't effective because of the large number of local optimum points.
	- Approaches using AI had many different objectives, such as the minimization of average delay [22, 27], total travel time [24, 25], average queue length [26], optimization of TST plan [23], and maximization of the flow rate [28].
	- Seems to be not a lot of problems using a multi-objective SimOpt for the TST problem.
	- Computational intelligence approaches
	  - They use some sort of an estimation function to evaluate potential solutions during the search process
	  - Approaches used included fuzzy models, neural networks, machine learning algorithms, evolutionary computation (EC), swarm intelligence (SI), and other population-based metaheuristic algorithms.
	  - Some of the algorithms are inspired by nature and evolution.
	  - Some research focused on multi-objective models to optimize TST, with popular objectives being minimization of vehicle delay, stopping time, and vehicle emission.
	  - *Important to me:* one paper, which is different from other preexisting models, focused on minimizing average delay time per person, rather than the delay of vehi- cles from traffic intersections.
	- Conclusions from the article:
	  - Unfortunately, fuzzy logic and machine-learning-based traffic controllers are not economically feasible and require a large investment
	  - Population-based algorithms are the most widely used metaheuristic algorithms in optimizing TSC strategies
	  - Analytical models are useful to gain insights into the problem but getting useful results is difficult.
	  - Only approximately 50% of papers focused on a network of intersections rather than just one.
	  - *Metaheuristic approaches are best for real-time control.*

	- Testing with real-life data is important. - The larger the network, the more difficult solution or even representation of a solution is. - Further research: - Modeling TST when an emergency happens - Using a digital twin?! - Analyze effects of pedestrians and driver behavior on these models. - Autonomous vehicles? **Methodology** - Analyzed recent literature (2015-2020) on simulation based and CI based approaches to TSC and TST systems. - Used keywords to find them on multiple databases - Studies related to the connected vehicles, pedestrians, simulation model calibration, as well as macroscopic and mesoscopic traffic simulation were excluded from the study. **Brief Summary** - In order to help reduce traffic congestion, this review discussed the many approaches to solve the TST optimization problem. It looked through many related articles between 2015 and 2020. It found that VISSIM and SUMO were the best simulation software, and that metaheuristic algorithms were the best for optimization.
Research Question/Problem/ Need	How can we optimize traffic signal timing to curtail congestion at intersections and improve traffic flow in an urban network?
Important Figures	(the figures have their caption at the bottom)  **Fig. 3** Publications per year according to the category

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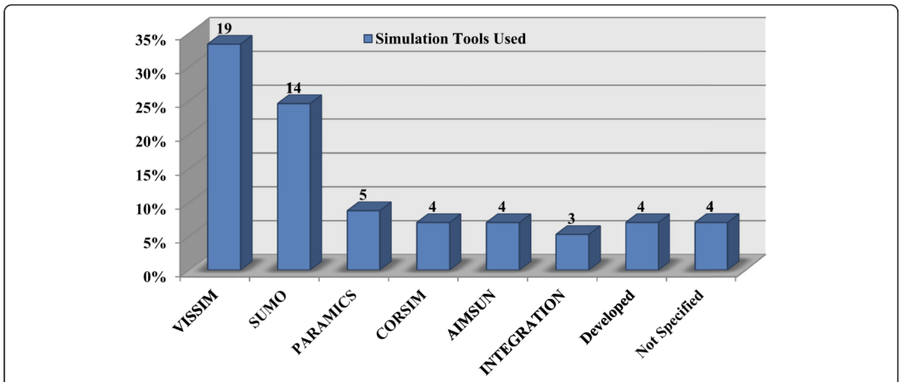

Fig. 2 Number of publications utilizing microsimulation tool

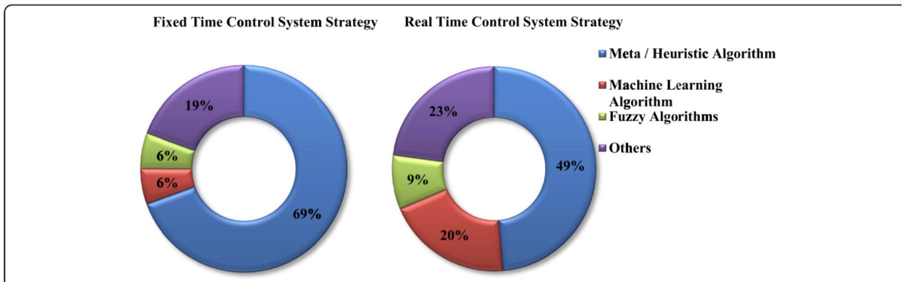

Fig. 4 Research publication according to approaches
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<td>VOCAB: (w/definition)</td>
<td>
Fuzzy logic: an approach to variable processing that allows for multiple possible truth values to be processed through the same variable

Metaheuristic Algorithm: higher-level procedure or heuristic designed to find, generate, or select a heuristic that may provide a sufficiently good solution to an optimization problem, especially with incomplete or imperfect information or limited computation capacity.

Stochasticity: property of being well described by a random probability distribution.

Analytical model: mathematical models that have a closed form solution
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<tr>
<td>Cited references to follow up on</td>
<td>
More reviews:

- Koukol, M., I, L. Z., Marek, L., & I, P. T. (2015). Fuzzy logic in traffic engineering : A review on signal control. Mathematical Problems in Engineering, 2015, 1–14. https://doi.org/10.1155/2015/979160.
- Araghi, S., Khosravi, A., & Creighton, D. (2015). A review on computational intelligence methods for controlling traffic signal timing. Expert Systems with Applications, 42, 1538–1550. https://doi.org/10.1016/j.eswa.2014.09.003.
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	Commonly used simulation tools Simulation - Ratrout, N. T., & Rahman, S. M. (2009). A comparative analysis of currently used microscopic and macroscopic traffic simulation software. Arabian Journal for Science and Engineering, 34, 121–133. - Deng, G. (2007). Simulation-based optimization doctoral dissertation, University of Wisconsin-Madison. Average time-per-person - 88. Jiao, P., Li, Z., Liu, M., et al. (2015). Real-time traffic signal optimization model based on average delay time per person. Advances in Mechanical Engineering, 7, 1–11. https://doi.org/10.1177/1687814015613500.
Follow up Questions	- The referenced article which talked about average delay time per person only looked at a single intersection as seen in Appendix 2. Can it be adapted for a network of intersections? - Is there a benefit for looking at average time per person over average time in the system? Only one article looked at this. - Why do not all papers use real time data if it's more impactful? - What approach is best for optimizing traffic flow when the paths of all the cars are known?

https://docs.google.com/presentation/d/1Zt1pzcsI-8KV-QwzkjqRwSnWkTDFq30NYMDN5IHBK3I/edit?usp=sharing

36, 38, 42, 44, 46
54, 55, 59, 60, 63, 67, 69, 71, 74, 82, 83, 85, 87, 91, 97, 99,

Article #9 Notes: How Do Traffic Signals Work?

Article notes should be on separate sheets

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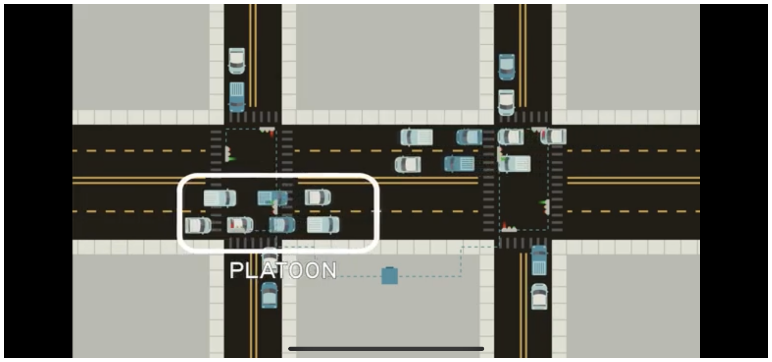
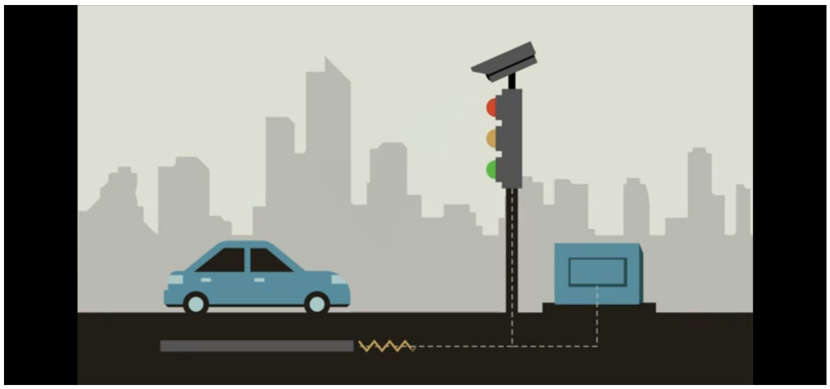
Source Title	How Do Traffic Signals Work?
Source citation (APA Format)	Practical Engineering. (2019). *How Do Traffic Signals Work?* YouTube. Retrieved September 18, 2022, from https://www.youtube.com/watch?v=DP62ogEZgkI.
Original URL	https://www.youtube.com/watch?v=DP62ogEZgkI

Source type	Video
Keywords	Phases, Actuated signals, Clearance Interval, Set-time signals,

Summary of key points + notes (include methodology)	**Summary:**
	Traffic signals are meant to control the flow of traffic at intersections. Fixed-time signals were created, but now mostly actuated signals using sensors are being used. In the future, more signal networks using ASCT can be used to coordinate entire cities and significantly reduce traffic congestion.
	
	Notes
	- Traffic light designers need to take in many things into consideration, such as how long each sequence of a phase should last.
	    - A green light should (in theory) clear the queue that built up during a red light, but this isn't always possible
	    - Yellow light needs enough time for drivers to see the light and slow down.One second for every ten miles per hour for the speed limit is a general rule, but the slope of approach and other locations are also taken in consideration.
	    - Most traffic signals are actuated signals, which use sensors to detect input about traffic volume (most commonly metal detectors in road surface). This is different from fixed-time signals which have the same sequence each time.
	    - Actuated signals are much more flexible.
	    - Signal coordination considers the status of nearby intersections. These are commonly found on long coordinators with minor cross streets
	    - Next step is coordinating all the signals in a network (ASCT). All information is sent to a central system which optimizes traffic flow using algorithms. These systems are only starting to become implemented in urban areas.

Research Question/Problem/ Need	How do traffic signals work?
Important Figures	

	  Figure 1: Showing a “platoon” of cars in a traffic intersections Figure 2: Showing how sensors work at actuated signals
VOCAB: (w/definition)	<u>Set-time signals</u>: follow a predetermined sequence of signal operation, always providing the same amount of time to each traffic movement, whether traffic is present or not <u>Actuated Signals</u>: prioritize movement along the primary corridor and can present obstacles to cross traffic and pedestrians if timed to prioritize vehicle movements only. <u>Phases</u>: Traffic movements that can be grouped at a signal (for example, the left turn on opposite approaches can be grouped because they can be done at the same time). <u>Adaptive Signal Control Technology</u>: technologies that capture current traffic demand data to adjust traffic signal timing to optimize traffic flow in coordinated traffic signal systems
Cited references to follow up on	(none it’s a video)
Follow up Questions	- Does the cost of using actuated signals or more advanced ones outweigh the cost of pollution and wasted time on the road? - How can the future of self-driving cars enhance the

	performance of traffic signal systems? - Is it safe to have a centralized unit that can possibly be prone to hackers? - Can this be implemented into more rural areas as well?

Article #10 Notes: How does your smartphone know your location? - Wilton L. Virgo

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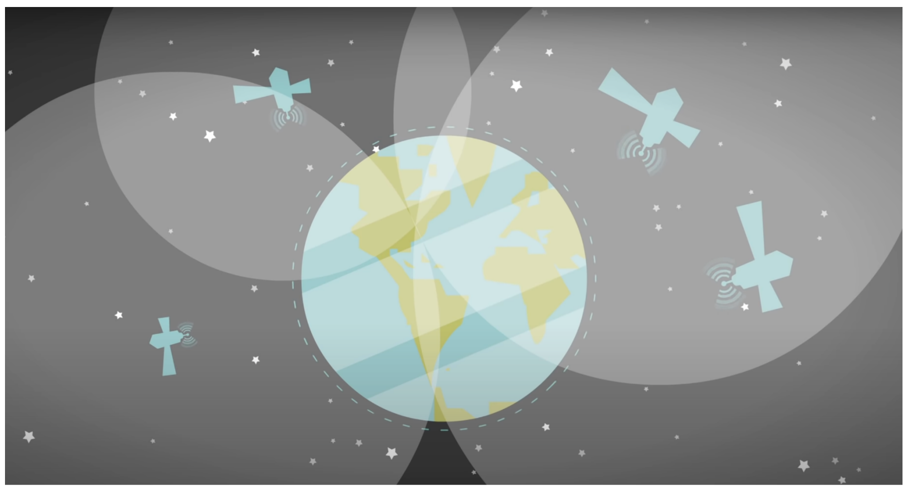
Source Title	How does your smartphone know your location?
Source citation (APA Format)	Hilditch, N. (2015). *How does your smartphone know your location?* YouTube. YouTube. Retrieved October 13, 2022, from https://www.youtube.com/watch?v=70cDSUI4XKE.
Original URL	https://www.youtube.com/watch?v=70cDSUI4XKE
Source type	Video
Keywords	Satellites, Atomic Clock, Frequency

Summary of key points + notes (include methodology)	<u>Notes</u>:
	- GPS works in a smartphone through satellites. There are many satellites orbiting Earth, and they send signals at the speed of light.
	- The smartphone receives these signals and checks how long it took. Using the d = rt equation they can calculate how long the distance is based on the time.
	- <u>Method of calculation of distance:</u>
	    - Since the rate of travel is very fast (since it's the speed of light), the "t" in the equation must be very precise. To do this, the system needs an atomic clock.
	    - An atomic clock uses the frequency of cesium and rubidium atoms for time keeping, since they it's the same everywhere in the universe (unlike pendulums and quartz clocks)
	    - This allows the time reading to be accurate to one billionth of a second, which is enough for calculating distance from a satellite.
	- Knowing the distances from 4 satellites, it's possible for the

	smartphone to know your location. It's interesting to note that general relativity must be used to do this. <u>Summary</u>: Your smartphone can calculate your location through satellites. Using atomic clocks for timekeeping, the distance from the satellite to your phone makes it possible to identify your location with only 4 satellites.
Research Question/Problem/ Need	How does GPS work in a smartphone?
Important Figures	 ^(figure showing how a unique location is found from the 4 satellites)
VOCAB: (w/definition)	Atomic clock: an extremely accurate type of clock which is regulated by the vibrations of an atomic or molecular system such as cesium or ammonia. Oscillation: movement back and forth at a regular speed. Satellite: an artificial body placed in orbit around the earth or moon or another planet in order to collect information or for communication.
Cited references to follow up on	(none)
Follow up Questions	- Is using this technology expensive? - Does this work even without cellular data? - Is there a cheap way to use this technology in a gadget that's not as expensive as a smartphone?

Article #11 Notes: Estimating O–D travel time matrix by Google Maps API: implementation, advantages, and implications

Article notes should be on separate sheets

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Source Title	Estimating O–D travel time matrix by Google Maps API: implementation, advantages, and implications
Source citation (APA Format)	Wang, & Xu, Y. (2011). Estimating O-D travel time matrix by Google Maps API: implementation, advantages, and implications. *Annals of GIS, 17*(4), 199–209. https://doi.org/10.1080/19475683.2011.625977
Original URL	https://doi.org/10.1080/19475683.2011.625977
Source type	Journal Article
Keywords	O–D travel time matrix; Google Maps API; network analysis; spatial analysis

Summary of key points + notes (include methodology)	Summary
	In order to efficiently calculate an O-D travel matrix, the program employed ArcPy along with the Google Maps API. This was shown to be more efficient and accurate than the current solution for short solutions, as it accounts for traffic conditions and doesn't require a prepared network.
	
	Notes
	- Computing an O-D travel matrix is an important task in many areas of spatial analysis.
	- Travel time estimation requires a transportation network dataset (represented as a graph). In these networks, there are many elements to consider when calculating
	    - Speed limit
	    - Turn restrictions
	    - Time penalty at each turn
	- Creating such a dataset can be expensive and infeasible for many applications. Without certain parameters, assumptions must be made which can make the travel time algorithm less accurate.

	- Google maps allows users to find the travel time from one location to another. Getting an OD matrix requires computing the travel times for possibly thousands of paths. - Thus, the goal of this research is to make the process of finding the OD matrix automated with the help of Google Maps API, making it easy to get travel times without creating a network dataset. *Methodology* - First convert the origin/distance locations into geographical coordinates (latitude and longitude) - Use python for coding, specifically the module *ArcPy*. *Urlib* allowed them to access the API. - Creates two input files (one for origin and one for destination), iterates over the files and the API then computes the travel time, storing it into the OD. *Results* - Compared it to the ArcGIS Network Analyst, which was frequently used to find the OD matrix before. Google Maps API had several benefits over this status quo: 1. Unlike the ArcGis, Google Maps doesn't need to prepare a network dataset 2. Updated and more accurate data **3. Accounts for road congestion** 4. Considers the time-of-day - Google Maps had a greater predicted travel time, which was more accurate. It takes into consideration the start time and ending time of the trip, since it takes some time getting on/off the road. ArcGis doesn't account for this. - Difference in travel times decreases exponentially as the distance increase - Testing 2134 paths took 15 minutes - Drawbacks of using the API is that there's a limit in the number of requests you can make
Research Question/Problem/ Need	How can we reliably estimate an O-D Travel Time Matrix?

Important Figures	

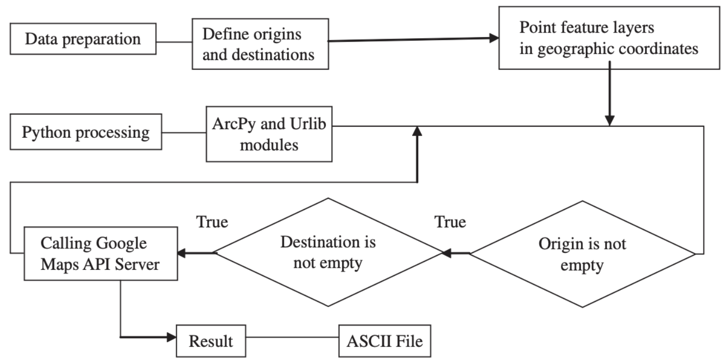


Figure 1. Travel time estimation process by Google Maps API.

^ Figure showing a flowchart of the methodology

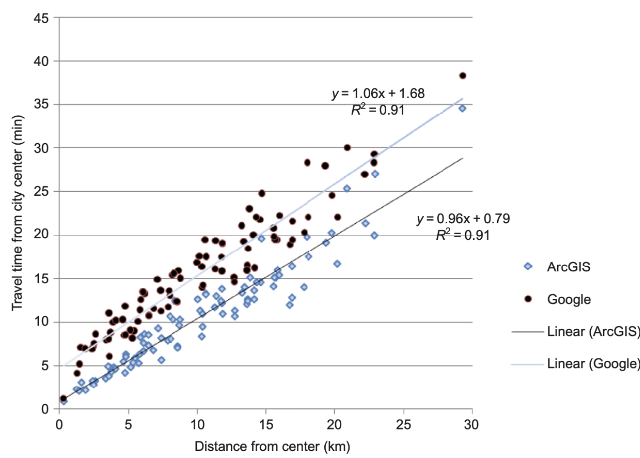
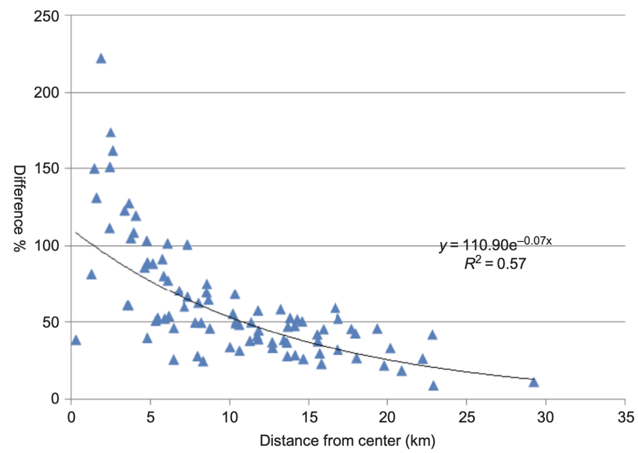


Figure 8. Estimated travel time from the city center by ArcGIS and Google.

^ Figure shows the difference between Google average travel time and ArcGIS travel time

	206 *F. Wang and Y. Xu*  Figure 9. Spatial pattern of differences in estimated travel time by ArcGIS and Google. ^Figure shows the difference in estimated travel times
VOCAB: (w/definition)	O-D Travel Time matrix: Estimation of travel time between a set of origins and a set of destinations Spatial analysis: a type of geographical analysis which seeks to explain patterns of human behavior and its spatial expression in terms of mathematics and geometry API (application programming interface): a way for two or more computer programs to communicate with each other
Cited references to follow up on	Black, W.R., 2003. Transportation: a geographical analysis. New York: Guilford. Schwartz, B., 2010. How does Google's predictive traffic maps work? [online]. Available from: http://www.seroundtable. com/archives/023155.html [accessed 7 October 2011]. Papadias, D., Zhang, D., and Kollios, G., (eds.), 2007. Advances in Spatial and Temporal Databases, Proceedings of 10th International Symposium, SSTD, 16–18 July, Boston, MA, Lecture Notes in Computer Science 4605. Berlin: Springer- Verlag, 460–477.
Follow up Questions	- How could we adapt this for dynamic origins and destinations? - Is this scalable computationally-wise? - How can this be adapted for real-time changing conditions such as weather? - Is there ways to reduce computation time by iterating more

	efficiently?

Article #12 Notes: A model and genetic algorithm for area-wide intersection signal optimization under user equilibrium traffic

Article notes should be on separate sheets

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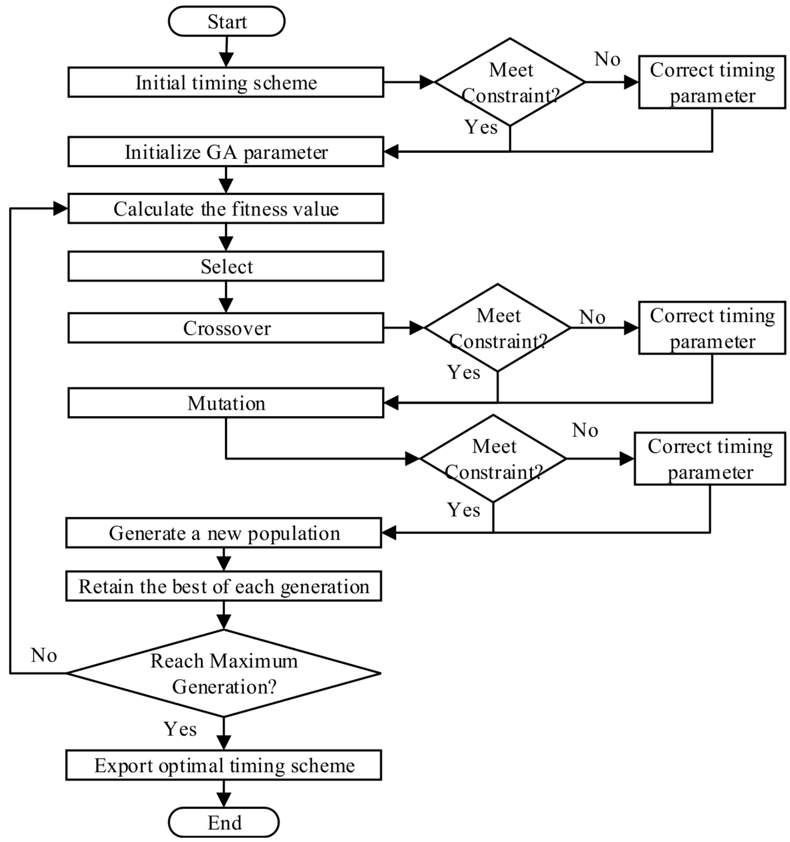
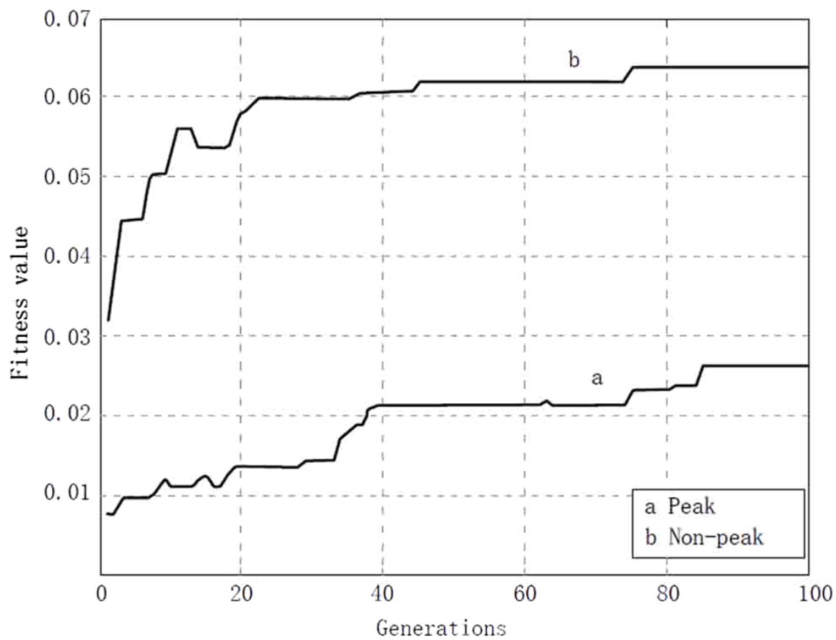
Source Title	A model and genetic algorithm for area-wide intersection signal optimization under user equilibrium traffic
Source citation (APA Format)	Guo, Kong, Y., Li, Z., Huang, W., Cao, J., & Wei, Y. (2019). A model and genetic algorithm for area-wide intersection signal optimization under user equilibrium traffic. *Mathematics and Computers in Simulation, 155*, 92–104. https://doi.org/10.1016/j.matcom.2017.12.003
Original URL	https://doi.org/10.1016/j.matcom.2017.12.003
Source type	Journal Article
Keywords	Signal control; User equilibrium; Traffic simulation; Optimization

Summary of key points + notes (include methodology)	**Summary**
	
	In order to optimize traffic signal timing at a network of intersections under Wardrop user equilibrium, a genetic algorithm was employed on data acquired from sensors. The algorithm aimed to minimize the product of travel time and variance. The results showed that there was a decrease in average and total delay in the network.
	Notes
	- Current control systems focus on single intersections or one corridor, which isn't looking at the system as a whole
	- Using the Wardops user equilibrium principle:
	    - When the network is in balance, the cars all take the shortest route to their destination
	    - When the network is not in balance, the cars adjust their routes until balance is achieved
	- The variance of travel time represents equilibrium of a

	system, and total travel time is a way to show performance, so the product of both is a good measure of success
	- The distribution of traffic flow is affected by traffic signal timing
	- This study uses these parameters: cycle lengths, green splits, and offsets
	$$y = (\sum x_i) * \frac{1}{n} \sum (\frac{1}{s_i}(x_i - \overline{x}))^2$$
	-
	- ^objective function. First part of product is total travel time, second part is variance
	- The model had several constraints:
	    - Offset nonnegative
	    - Length of effective green time nonnegative
	    - Max greentime > The green time of the lane group > minimum green
	- Performance model is multi-objective
	<u>Methodology</u>
	- Use a genetic algorithm to solve:
	    - Heuristic algorithm based off natural evolution
	- Chromosomes coded not with binary but with real numbers
	- Fitness function is reciprocal of objective function
	- Genetic operators used: selection, crossover, mutation
	- Use PARAMICS microsimulation software
	    - Since it uses this software, any assumptions it makes influences the program
	- Selected a specific road network for testing, used sensors to get real-life data
	
	<u>Results</u>:
	- There was a decrease in both average and total delay at urban street segments, intersections, and the network as a whole

Research Question/Problem/ Need	How can we optimize traffic signal timing for an entire network under user-equilibrium traffic?

Important Figures	 **Fig. 2.** Iterative process of the proposed genetic algorithm. ^Flowchart of process of their model  ^Picture of the network

	 ^Fitness function over the generations
VOCAB: (w/definition)	Wardrop's user equilibrium (UE): The journey times on all the routes actually used are equal and less than those which would be experienced by a single vehicle on any unused routes Parameter calibration: that are used in the simulation but cannot be measured easily or directly in the physical tests Parallelism: techniques to make programs faster by performing several computations at the same time.
Cited references to follow up on	H.Z. Aashtiani, T.L. Magnanti, Equilibria on a congested transportation network, SIAM J. Algebr. Discrete Methods 2 (3) (1981) 213–226. D.J. Dailey, Travel-time estimation using cross-correlation techniques, Transp. Res. B 27 (2) (1993) 97–107. M.J. Smith, M. Ghali, The dynamics of traffic assignment and traffic control: A theoretical study, Transp. Res. B 24 (6) (1990) 409–422.
Follow up Questions	- Is this computationally expensive? Does the benefit outweigh the costs? - The average delay only decreased by around 5% for street segments. Is this significant? - Does this scale for a larger network?

Article #13 Notes: Solving simultaneous route guidance and traffic signal optimization problem using space-phase-time hypernetwork

Article notes should be on separate sheets

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Source Title	Solving simultaneous route guidance and traffic signal optimization problem using space-phase-time hypernetwork
Source citation (APA Format)	Li, Mirchandani, P., & Zhou, X. (2015). Solving simultaneous route guidance and traffic signal optimization problem using space-phase-time hypernetwork. *Transportation Research. Part B: Methodological, 81*, 103–130. https://doi.org/10.1016/j.trb.2015.08.011
Original URL	https://doi.org/10.1016/j.trb.2015.08.011
Source type	Journal Article
Keywords	Dynamic traffic assignment, Network traffic signal control, Route guidance, Lagrangian relaxation, Dynamic programming Optimization, Network flow modeling
Summary of key points + notes (include methodology)	**Summary** This article aimed to reduce travel time by simultaneously providing route guidance and optimizing traffic signals. They employed a space-phase-time hypernetwork to represent the system, and then treated the problem as an integer programming problem. After using Lagrangian relaxation and dynamic programming, they found that travel time was reduced to varying levels of congestion. **Notes** ● There has been previous works on this problem, some formulating it as an mixed integer linear programming model and others as a cell transmission model ● They use a space-phase-time hypernetwork, which is really just two separate networks: space-time and phase-time network. ○ Space-time network ■ Expanding the physical network of nodes to

show time in the network
    - Uses one second as time resolution
    - There is a cost associated with traveling on each link. Four types of links with different costs
- Phase-time network
    - 4 different phases
    - Flexible or cyclic
    - Shows how the traffic signal phases in all the intersections of the system change over time

Methodology

- In order to optimize the model, they treated it as an integer programming problem.
    - Object function was sum of all the costs of all the links chosen by every vehicle
    - In terms of decision variables x and w for each car, take values 0 or 1
        - X is the travel link variable, if a link is traveled by a vehicle at a certain time frame (0 for no, 1 for yes)
        - W is the signal link variable, whether or not a certain intersection has a certain phase for a time period
    - Had four constraints
        - Network flow is conserved: Every vehicle used exactly one link to enter node and one to leave, except for waiting and destination nodes
        - Links don't overflow their capacity
        - Vehicles can't enter links filled by a queue
        - Traffic signals obey logic
            - Min green
            - Max green
            - Mutual exclusiveness
- Relax conditions using lagrangian relaxation, which results in P2. The minimum for P2 gives a lower bound for system optima, but the solution for P2 put into P1 gives the upper bound. We want to find the minima for P2:
    - P2 can be expressed as Px + Pw, where Px is an expression only in terms of and Pw is an expression only in terms of w
    - Px and Pw can both be solved using dynamic programming by treating it as a least-cost path problem. The "costs" here are the original cost function along with penalties evoked by the lagrangian multipliers
- Now, they want to reduce the gap between the upper and

	lower bound given by this process. They do this by adjusting the lagrangian multipliers. They find the maximum solution using a process similar to gradient descent. *Discussion* - Cyclic or flexible signal phasing sequence - Can model high priority vehicles such as ambulances - Multiobjective - P2 suitable for distributed computing *Results* - Tested it on an example with 960 vehicles and 9 intersections, for 400s. - (diagram in important figures) - Computing took 90s - Looking at three specific vehicles, it was clear that the total travel time was reduced - Tested it where not all vehicles were guided, average travel time will decrease, but more when more vehicles are guided
Research Question/Problem/ Need	Simultaneous route guidance and traffic signal optimization problem (RGTSO): Guiding vehicles in a network and setting the traffic signals in the most optimal way in order to minimize total travel time.
Important Figures	(all figures are labeled in the pictures)

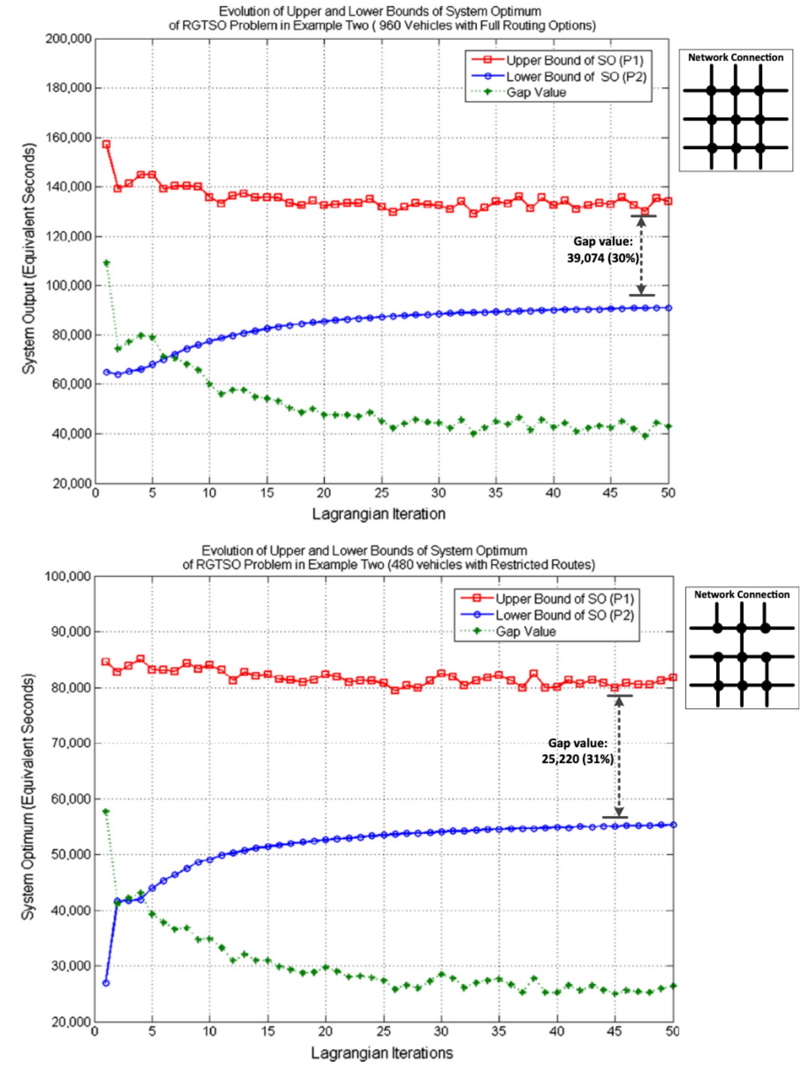


Fig. 17. Upper bound and lower bound over lagrangian iterations (100% guided vehicles).

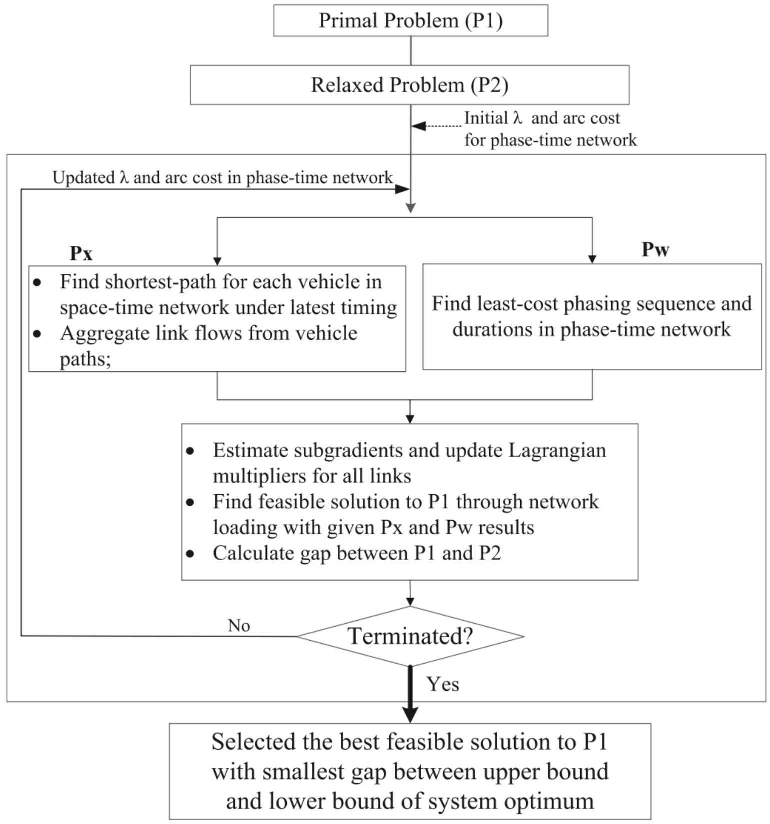


Fig. 9. Flowchart of solving the RGTSO problem.

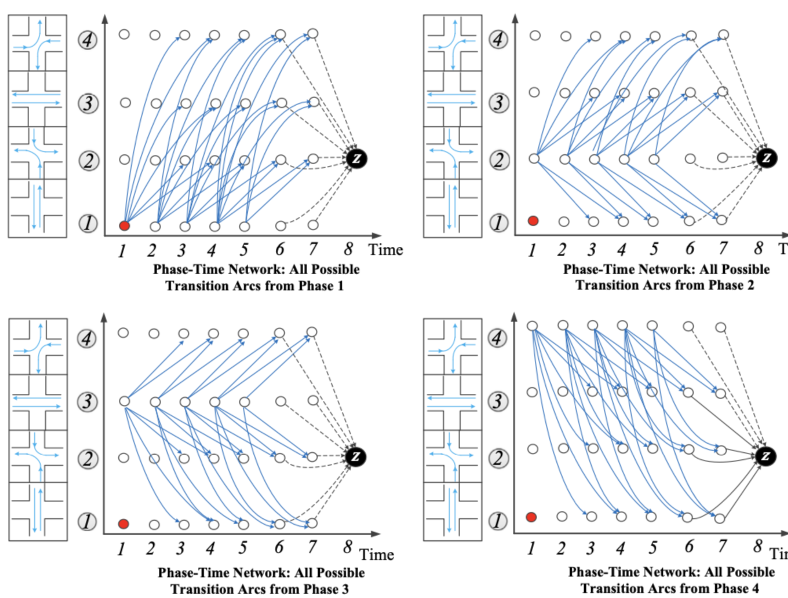
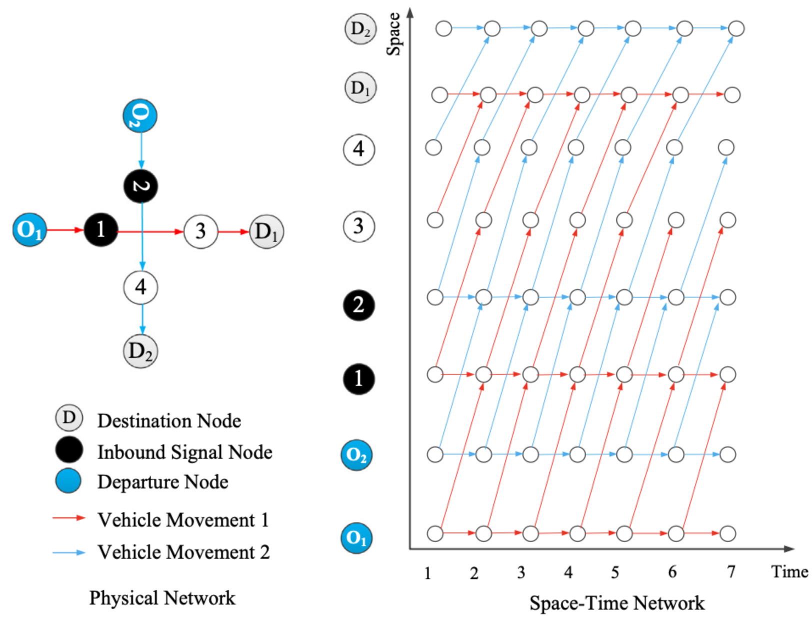


Fig. 5. Building a phase-time network with flexible four signal phases (decomposed into four sub plots for illustration).

	 **Fig. 3.** Illustration of expansion from physical networks to space-time networks.
VOCAB: (w/definition)	Lagrangian relaxation: a relaxation method which approximates a difficult problem of constrained optimization by a simpler problem. Nodes: location on a road network Links: paths on the road connecting two nodes Dynamic programming: an algorithmic technique for solving an optimization problem by breaking it down into simpler subproblems and utilizing the fact that the optimal solution to the overall problem depends upon the optimal solution to its subproblems. Integer programming: optimization or feasibility program in which some or all of the variables are restricted to be integers.
Cited references to follow up on	Lin, W.-H., Wang, C., 2004. An enhanced 0-1 mixed-integer LP formulation for traffic signal control. *IEEE Transactions on Intelligent Transportation Systems 5* (4), 238–245. Lo, H.K., 1999. A novel traffic signal control formulation. *Transportation Research Part A 33* (6), 433–448.
Follow up Questions	1. Can this be readily applied in real life? Is it too computationally taxing? 2. What if a car decides to change their destination, or makes a wrong turn? 3. If this is implemented, are there ethical concerns?

Article #14 Notes: Effects of Vehicle Speed and Engine Load on Motor Vehicle Emissions

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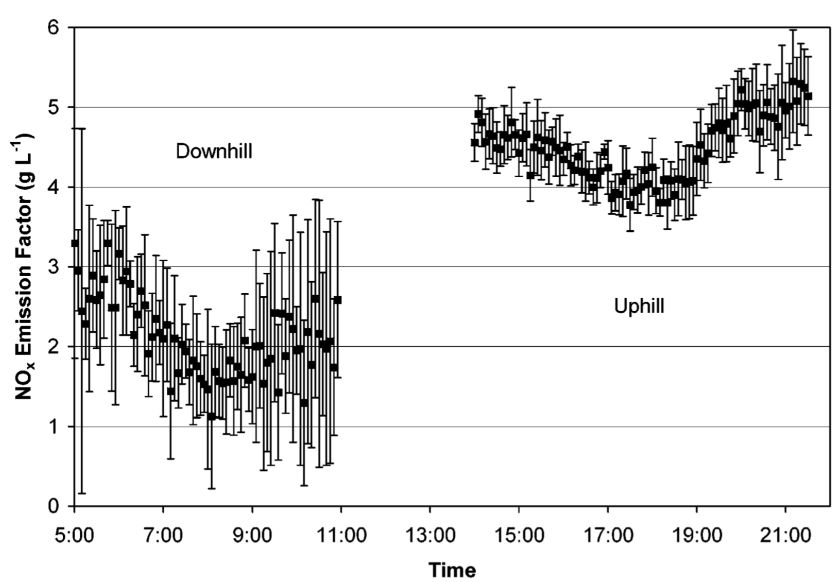
Source Title	Effects of Vehicle Speed and Engine Load on Motor Vehicle Emissions
Source citation (APA Format)	Kean, Harley, R. A., & Kendall, G. R. (2003). Effects of Vehicle Speed and Engine Load on Motor Vehicle Emissions. *Environmental Science & Technology, 37*(17), 3739–3746. https://doi.org/10.1021/es0263588
Original URL	https://doi.org/10.1021/es0263588
Source type	Journal Article
Keywords	Specific power, emission factors, engine load, vehicle speed
Summary of key points + notes (include methodology)	**Summary** In order to figure out which factors affect fuel emissions, this study aimed to determine the relationship between fuel emissions and specific power and vehicle speed. They measured the fuel emissions and traffic conditions in highway tunnels which featured varying levels of inclination. This allowed them to capture data on the vehicle speeds and the type of cars in the tunnel, as well as how much fuel was emitted. From the data it was shown that increasing specific power and vehicle speed increase fuel emissions, although it is unknown if one factor better represents emissions than both. **Notes** ● Fuel emission is dependent on many factors, such as vehicle speed, road condition, and specs on the car ● Vehicles emit the following greenhouse gasses: ○ CO ○ NOx ○ NMHC ● They wanted to see how fuel emissions depended on specific power and vehicle speed *Methodology* ● They studied vehicles in a tunnel which has three bores

	● The tunnel has an uphill and a downhill so they could analyze fuel emissions for different inclined roads ● They took continuous measurements of CO and NOx at each ends of the tunnel using chemical equipment such as gas-filter correlation spectrometers ● Traffic was monitored using cameras, from which velocity and acceleration were computed ● Vehicles were categorized based on size *Results* ● Able to get data on how fuel emissions and traffic changed over time. ● Fuel emissions were lowest a certain peak time, which was when the speed was the lowest ● Emissions are not linear with speed, increasing speed increases fuel emissions up until some point. ● More emissions downhill than uphill (common sense) ● Greater specific power results in greater fuel emissions ● Emissions of CO and NOx have been shown to increase with both speed and SP ● Unknown if a combination of both variables is better able to describe on-road vehicle emissions than either one alone.
Research Question/Problem/ Need	How can we express fuel emissions as a function of specific power and vehicle speed?
Important Figures	(all figures are labeled in picture)  **FIGURE 2. NO_x emission factor (±95% CI) as a function of time of day.**

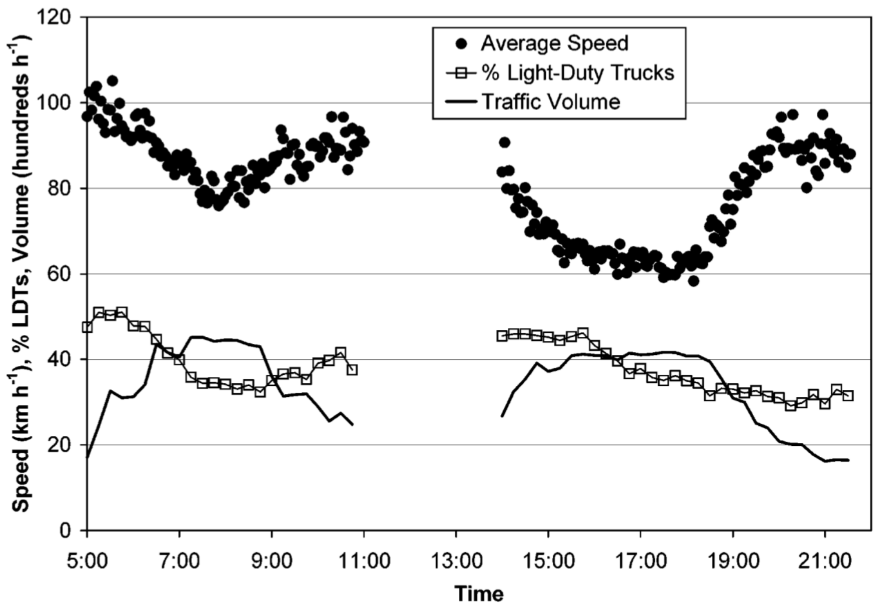


FIGURE 3. Average vehicle speed, percentage of light-duty trucks in the fleet, and total traffic volume as a function of time of day.

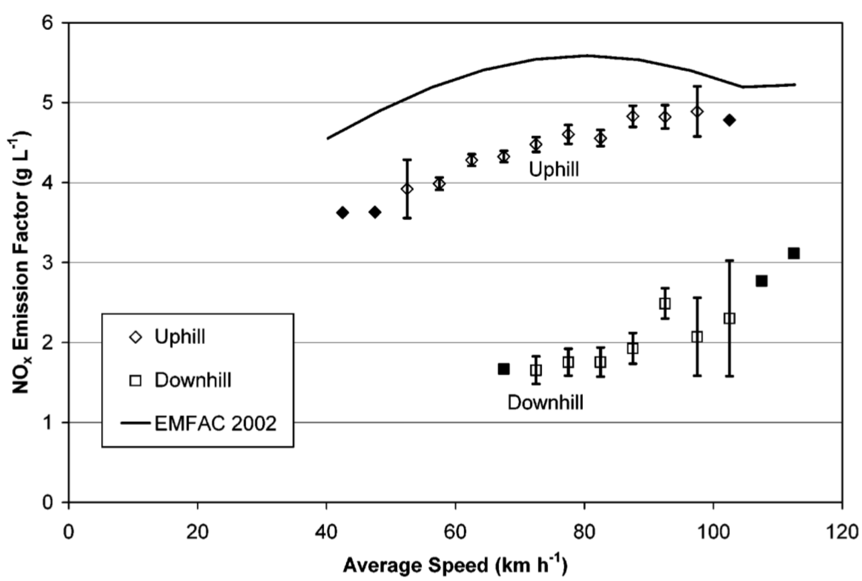


FIGURE 5. NO_x emission factor (±95% CI) vs average vehicle speed with comparison to EMFAC2002. Data are organized into 5 km h^{-1} bins and plotted vs the speed bin average. Closed symbols represent speed bins with single data points.

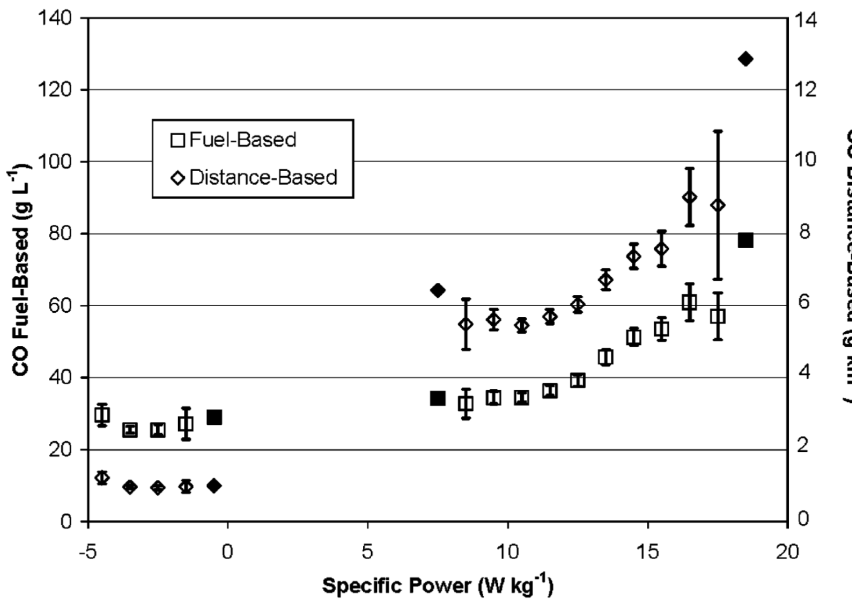


FIGURE 6. CO emission factors plotted versus specific power. Data are organized into 1 W kg^{-1} bins and plotted vs the SP bin average. Closed symbols represent SP bins with single data points.

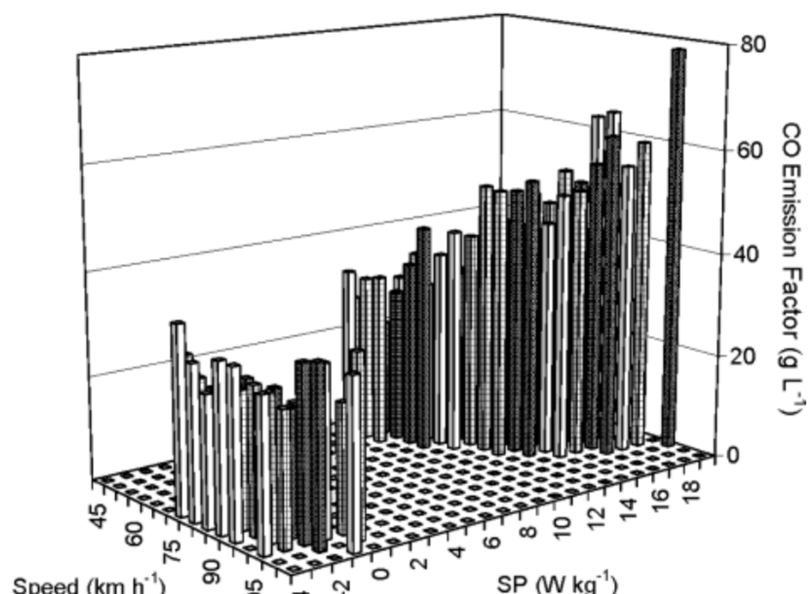


FIGURE 8. CO emission factor as a function of both average vehicle speed (5 km h^{-1} bins) and specific power (1 W kg^{-1} bins). The bin labels shown correspond to the bin maxima, except for the zero bin, which has negligible width.

VOCAB: (w/definition)	Specific power: the sum of external forces opposing vehicle motion multiplied by vehicle speed and divided by vehicle mass

	Engine load: the force that acts against the power an engine produces Emission factors: a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant
Cited references to follow up on	*EMFAC2002, V2.2*; California Air Resources Board: Sacramento, CA, 2002 Pierson, W. R.; Gertler, A. W.; Robinson, N. F.; Sagebiel, J. C.; Zielinska, B.; Bishop, A. W.; Stedman, D. H.; Zweidinger, R. B.; Ray, W. D. *Atmos. Environ*. 1996, *30*, 2233-2256. Sjo ̈din, A.; Persson, K.; Andreasson, K.; Arlander, B.; Galle, B. *Int. J. Vehicle Des.* 1998, *20*, 147-158.
Follow up Questions	1. What would be the optimal speed for a vehicle in order to minimize fuel emissions? 2. Would this still apply to hybrid vehicles? 3. Which of the three gasses would be the best to avoid/which is most dangerous?

Article #15 Notes: Unified Framework for Dynamic Traffic Assignment and Signal Control with Cell Transmission Model

Article notes should be on separate sheets

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Source Title	Unified Framework for Dynamic Traffic Assignment and Signal Control with Cell Transmission Model
Source citation (APA Format)	Aziz, & Ukkusuri, S. V. (2012). Unified Framework for Dynamic Traffic Assignment and Signal Control with Cell Transmission Model. *Transportation Research Record*, *2311*(1), 73–84. https://doi.org/10.3141/2311-07
Original URL	https://doi.org/10.3141/2311-07
Source type	Journal Article

Keywords	Cell transmission model, mixed integer program, dynamic traffic assignment
Summary of key points + notes (include methodology)	**Summary** The goal of this study is to provide a unified framework for traffic signal optimization and route guidance in order to reduce travel time along with other objectives such as lost time from phase changes and intersection delays. This was done through mixed integer programming modeled with a CTM, which allowed the researchers to express objective functions and constraints with integer variables. Afterwards, they tested it for a single intersection and a network of intersections at varying levels of congestion, and found that it was indeed able to change routes to reduce travel time. **Notes** ● Goal is to provide a unified framework for traffic signal optimization and route guidance. ● Two important parameters in traffic signal timing are cycle length and lost time from phase switches. ● Not a lot of research focuses on flexible cycle length and lost time caused by the phase change pattern. ● Modeled the network with a cell transmission model (defined in vocab) ● Common approaches include an interactive approach with bilevel programming techniques. ● Overall approach was a mixed-integer program with binary integer variables. *Methodology* ● Created variables for CTM which controlled routes and signals. ● From there, they wrote four cases for objective functions in terms of these variables: ○ Case 1: Optimizing travel time only ○ Case 2: Travel time and intersection delays ○ Case 3: Optimizing travel time and lost time ○ Case 4: Travel time, intersection delays, and lost time ● They also included a base case for current day models ● Afterwards, they wrote four constraints which the functions must follow ○ Initialization constraints ○ Flow conservation constraints ○ Demand satisfaction constraints ○ Flow propagation constraints ● This allowed them to use mixed integer programming *Results* ● They tested it for a isolated intersection and for three intersection

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- Tested at varying levels of congestion
- Found that Case 1 was best for optimizing travel time and Case 2 for intersection delay.
- Found that indeed the routes/traffic was indeed changing
- Case 1 gives minimal travel time but has higher lost time
- For fairness (delays at intersections not too high), Case 4 is the best
- One drawback is that its computationally expensive due to the high number of variables

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<tr><td>Research Question/Problem/ Need</td><td>How can we create a unified framework for traffic signals and route guidance in order to reduce travel time?</td></tr>
<tr><td>Important Figures</td><td>

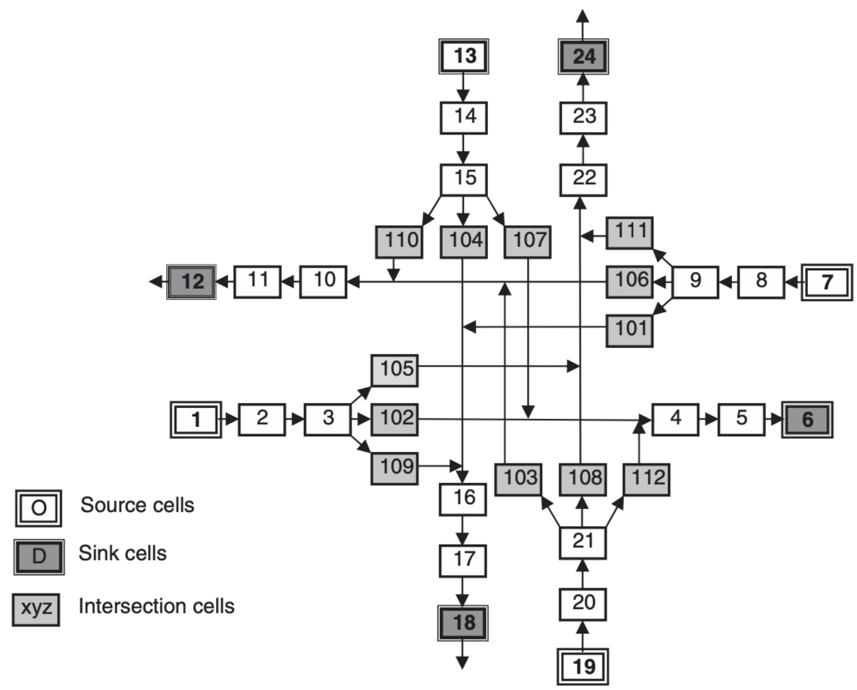

FIGURE 2 Cell representation of isolated signalized intersection (Network 1).

^ CTM of a single intersection

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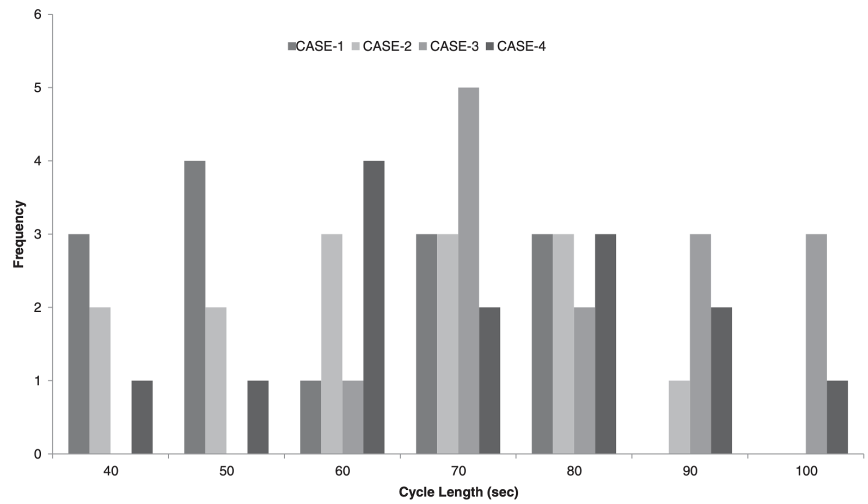
</table>

	 FIGURE 4 Cycle length variation for demand of 1,800 vphpl (Network 2). ^How the cycle length (one of the parameters) varied for the four cases
VOCAB: (w/definition)	Cell transmission model: dividing each link of the network into cells. Mixed integer programming: one where some of the decision variables are constrained to be integer values at the optimal value Bilevel optimization: special kind of optimization where one problem is embedded (nested) within another
Cited references to follow up on	Abdelfatah, A. S., and H. S. Mahmassani. System Optimal Time-Dependent Path Assignment and Signal Timing in Traffic Network. In *Transportation Research Record 1645,* TRB, National Research Council, Washington, D.C., 1998, pp. 185–193. Meneguzzer, C. Review of Models Combining Traffic Assignment and Signal Control. *Journal of Transportation Engineering,* Vol. 123, No. 2, 1997, pp. 148–155. Gartner, N. H., and M. Al-Malik. Combined Model for Signal Control and Route Choice in Urban Traffic Networks. In *Transportation Research Record 1554,* TRB, National Research Council, Washington, D.C., 1996, pp. 27–35.
Follow up Questions	1. How accurate is a CTM model to real life conditions? 2. How can this be adapted for disruptions in traffic such as accidents? 3. Is this computationally expensive for servers/super computers?

Article #16 Notes: A robust transportation signal control problem accounting for traffic dynamics

Article notes should be on separate sheets

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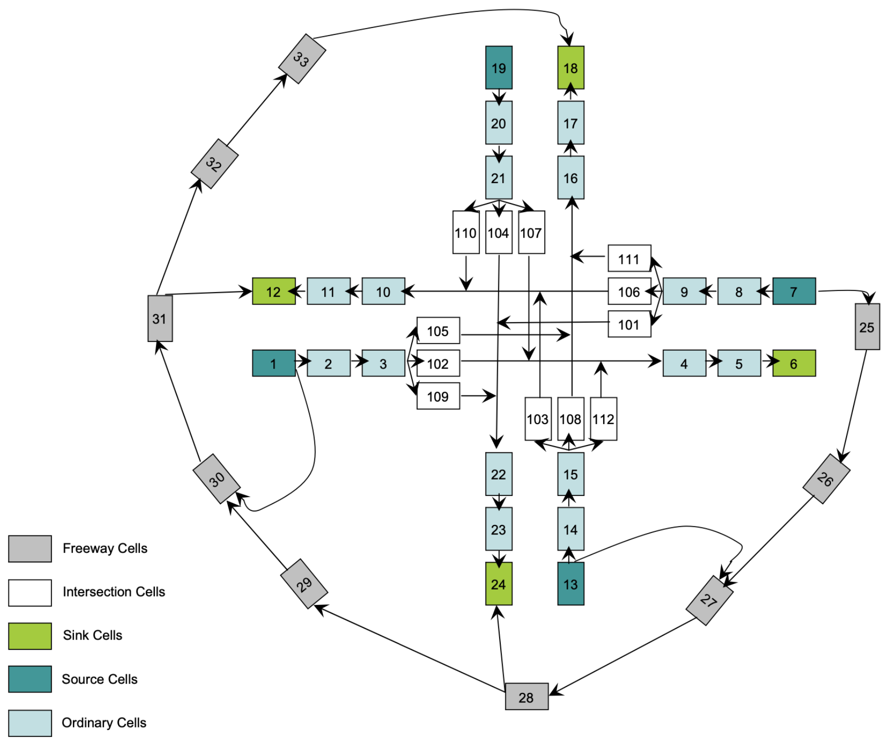
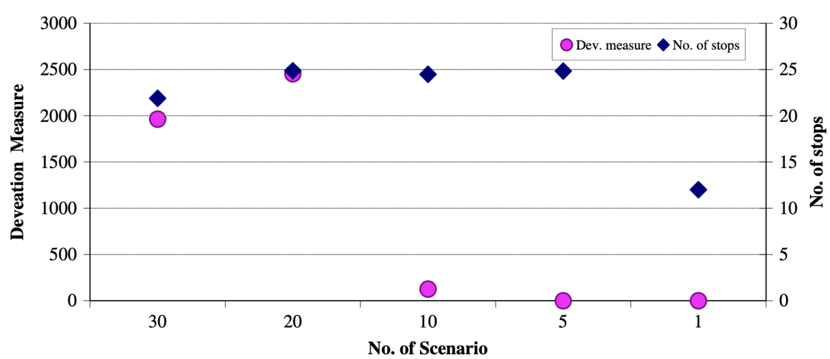
Source Title	A robust transportation signal control problem accounting for traffic dynamics
Source citation (APA Format)	Ukkusuri, Ramadurai, G., & Patil, G. (2010). A robust transportation signal control problem accounting for traffic dynamics. *Computers & Operations Research*, *37*(5), 869–879. https://doi.org/10.1016/j.cor.2009.03.017
Original URL	https://doi.org/10.1016/j.cor.2009.03.017
Source type	Journal Article
Keywords	Robust optimization, dynamic traffic assignment, CTM
Summary of key points + notes (include methodology)	**Summary** This study aimed to create a robust traffic signal optimization model which reduces variances in solutions to traffic demand. It reflected uncertainties in the different paths the vehicles will take through a probability distribution, and then tested their model to a stochastic model which did not care about variance. They used a linear program from modeling the objective functions and expressions. The results showed that the two models had different solutions and performance, which shows that it is important to take robustness into consideration when planning and optimizing traffic. **Notes** ● The focus is to develop a robust dynamic signal optimization formulation which incorporates both dynamic traffic assignment and signal control ● It estimates how much demand is forecasted, but this is only a guess ● It will reflect uncertainties in O-D demand ● The problem with many network design models is that they have good average performance but they can perform quite poorly in many cases. ● Some previous studies had variance in their objective function so that highly volatile solutions are discouraged. *Methodology*

	• Use a CTM to capture vehicle flow in the network, where each turning movement on each approach at the intersection is designated a separate single cell.
	• A linear program is used for the robust system optimal signal control, where traffic flow is written as linear expressions and linear positive deviation measures robustness.
	• From there they wrote the objective function in terms of linear variables:
	$\text{Min} \sum_{\omega \in \Omega} [\lambda p^{\omega} z^{\omega}(x,y) + (1-\lambda) p^{\omega} \Delta(z^{\omega}(x,y), \bar{z}(x,y)) + \beta z_4^{\omega}],$
	• This objective function takes into account the total system (network) travel time, delay at intersections and the number of stops. It also takes into account positive deviation (variance), so robustness is part of the objective function.
	• Constraints were also written in linear expressions. The constraints specifically were:
	  ○ Flow conservation equations
	  ○ Demand satisfaction constraint
	  ○ Flow propagation constraints
	  ○ Non-negativity and initialization constraints:
	  ○ Constraints restricting the maximum flow:
	  ○ Constraints to ensure correct coordination between different signal phases
	  ○ The total green time for any phase should at least equal the minimum green time
	Testing
	• The model was tested on the network as shown in the figures. There are 8 O-D pairs with a path connecting them, with 5 having an alternative route to follow.
	• Source of uncertainty was from the O-D demand. Realistic probability distributions modeled this uncertainty.
	• The stochastic model (trying to minimize travel time) was tested against the robust (trying to minimize variance), and for different demand levels.
	
	Results and Conclusion
	• Introducing uncertainty has a significant effect on path choice and signal solutions
	• Signal timings are different for stochastic compared to robust
	• Most important objective was travel time when optimizing
	• More complexity can be incorporated but that will change it from a linear program to an integer program which makes it harder to find a solution.

Research	How should the traffic signal control settings be designed optimally

Question/Problem/ Need	over time to best meet the requirements of the transportation network performance, given uncertainties in point to point demand over time and the need to account for robustness, recognizing that there are constraints that limit the cycle times, green times at intersections and restrictions in capacities and jam densities on the road network?
Important Figures	 **Fig. 2.** Example network. ^ Tested network modeled with CTM  **Fig. 4.** Performance measure values for various number of scenarios. ^Deviation and number of stops for test cases
VOCAB: (w/definition)	Robust optimization: an important subfield of optimization that deals with uncertainty in the data of optimization problem

	Robust solution: one that guarantees the feasibility of the solution if, for a given number i, less than i constraint coefficients change Mesoscopic: A hybrid of microscopic (individuals) and macroscopic (flows) simulation Stochastic: the property of being well described by a random probability distribution
Cited references to follow up on	Lighthill MJ, Whitham JB. On kinematic waves, i: flow movement in long river; ii: a theory of traffic flow in long crowded roads. Proceedings of the Royal Society A 1955;229:281–345. Daganzo CF. The cell transmission model: a simple dynamic representation of highway traffic consistent with the hydrodynamic theory. Transportation Research B 1994;28:269–87. Daganzo CF. The cell transmission model ii: network representation. Transportation Research B 1995;29:79–93.
Follow up Questions	1. What are the computational requirements? Can this be applied? 2. How large can the variance be? Wouldn't it be ethically permissible to have one bad solution once in a while to keep the average low? 3. How can this be adapted so that integer programming could be applied?

Article #17 Notes: Determining the main factors influencing the energy consumption of electric vehicles in the usage phase

Article notes should be on separate sheets

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Source Title	Determining the main factors influencing the energy consumption of electric vehicles in the usage phase
Source citation (APA Format)	Li, Stanula, P., Egede, P., Kara, S., & Herrmann, C. (2016). Determining the Main Factors Influencing the Energy Consumption of Electric Vehicles in the Usage Phase. *Procedia CIRP, 48*, 352–357.

	https://doi.org/10.1016/j.procir.2016.03.014
Original URL	https://doi.org/10.1016/j.procir.2016.03.014
Source type	Journal Article
Keywords	DoE, energy consumption, electric vehicles, HVAC
Summary of key points + notes (include methodology)	**Summary:** In order to find out what factors affect energy consumption in electric vehicles, this study tested an EV 25 times with varying conditions. They varied the topography, traffic, and infrastructure and used ANOVA and linear regression to find an equation relating these variables to energy usage. They found that the climate was the most significant factor, although all did have an effect on battery usage. **Notes:** ● Electric vehicles are a good alternative to internal combustion engine vehicles. ● EVs don't have tailpipe emissions but producing the energy does emit fuel and gas. Electricity is generated from coal ● Some factors found from previous studies include: ○ Battery of vehicle ○ Air conditioning or other auxiliary components such as radio ○ Vehicle mass, tire friction, rolling resistance ○ <u>Traffic:</u> more congestion leads to more energy consumption ○ Road conditions ○ Topography, weather, climate ○ Driver behavior ● This study only looks at topography, infrastructure, traffic, and climate *Methodology* ● A DoE was used (design of experiments) with a generic modeling approach ● Tested vehicle was a Nissan Leaf 2011. ● 25 Test runs on a 4.17 km route, sometimes with congestion sometimes without. Temperature was around the same so climate was modeled using air conditioning ● Dependent variables that were changed are shown below:

Table 1: List of dependent and independent variables

Factor	Parameters	Unit
	Dependent Variables	
Energy Consumption	SOC / GID	Convert to Wh/
	Independent Variables	
Topography	ascent per km / descent per km / ascent and descent per km	m/km
	standard deviation of the altitude	m
Infrastructure	average speed limit / average speed limit with school zone	km/h
	forced stops per kilometre	n./km
Traffic	average velocity	km/h
	idle time share[1]	%
	congestion index[2]	-
	ratio of stops and forced stops[3]	-
Climate	temperature	°c
	HVAC average consumption	kW

- Instead of testing all possible combinations of factors, they used fractional factorial design to test how the factors related

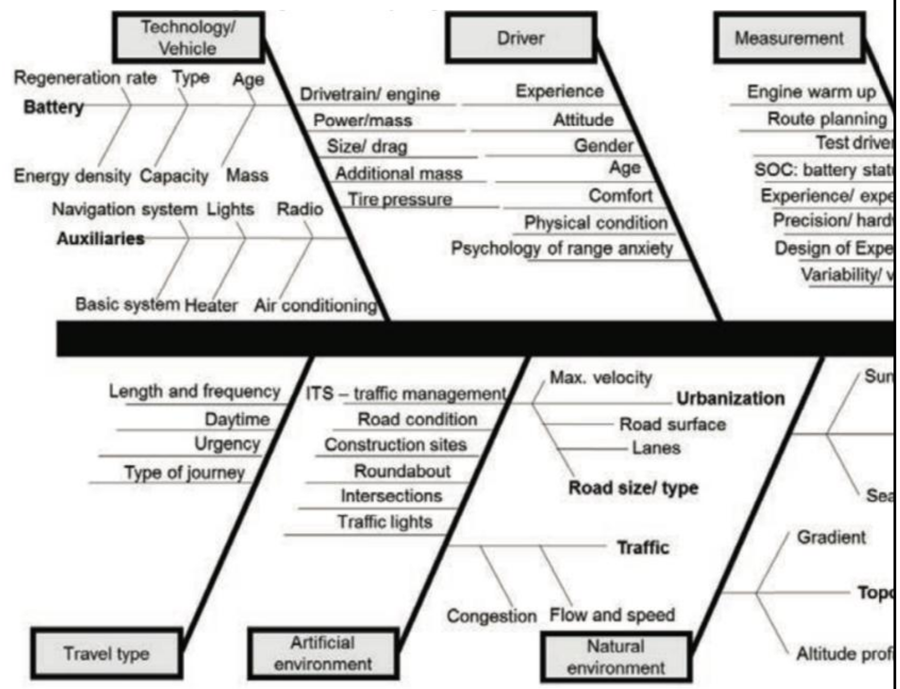
Results and Conclusions

- Data was normal so an ANOVA Was tested for mean. They found that all factors did have an effect on energy consumption.
- After doing multiple linear regressions, they found this equation relating the factors to energy consumption :

$$y = 108.19 + 41.22 * D + 39.34 * C + 22.4 * B + 17.88 * A$$

- The HVAC was found to have the greatest effect (climate and air conditioning)
- This study is only really valid for the region it was tested on (Sydney)

Research Question/Problem/ Need	What factors affect the energy consumption of electric vehicles?

Important Figures	 Figure 1. Ishikawa diagram of the impact factors on the energy consumption
VOCAB: (w/definition)	Design of Experiments: branch of applied statistics that deals with planning, conducting, analyzing, and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters. Fractional factorial design: experimental designs consisting of a carefully chosen subset of the experimental runs of a full factorial design ANOVA:type of statistical test used to determine if there is a statistically significant difference between two or more categorical groups by testing for differences of means using variance
Cited references to follow up on	Yang, S.C., Li, M., Lin, Y., Tang, T.Q., 2014. Electric vehicle's electricity consumption on a road with different slope. Physica A: Statistical Mechanics and its Applications 402, p. 41–48. Yuksel, T., Michalek, J., 2015, Effects of Regional Temperature on Electric Vehicle Efficiency, Range, and Emissions in the United States. Available online at http://pubs.acs.org/doi/full/10.1021/es505621s, visited on 22/05/2015. Shankar, R., Marco, J., 2013. Method for estimating the energy consumption of electric vehicles and plug-in hybrid electric vehicles

	under real-world driving conditions. IET Intelligent Transport Systems 7 (1), p. 138–150.
Follow up Questions	1. Are hybrid cars different? 2. Do warmer or colder temperatures affect consumption more? 3. Is testing one car enough?

Article #18 Notes: Method of automatically controlling an autonomous vehicle based on electronic messages from roadside infrastructure or other vehicles

Article notes should be on separate sheets

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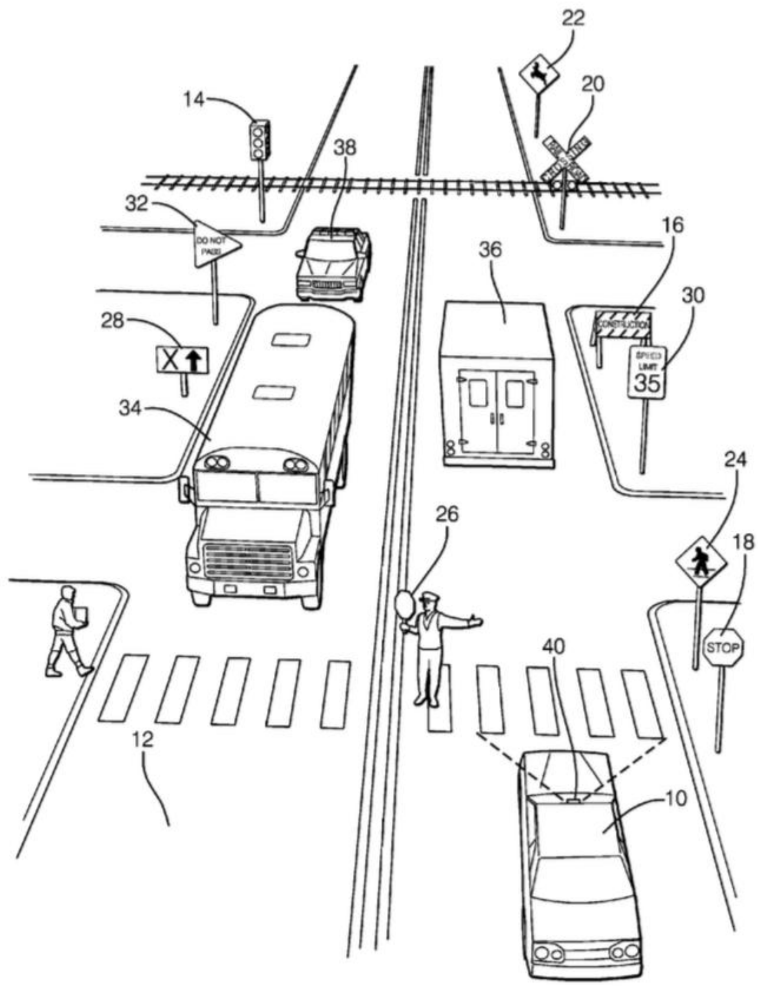
Source Title	Method of automatically controlling an autonomous vehicle based on electronic messages from roadside infrastructure or other vehicles
Source citation (APA Format)	“*Method of Automatically Controlling an Autonomous Vehicle Based on Electronic Messages from Roadside Infrastructure Or Other Vehicles” in Patent Application Approval Process (USPTO 20180012492*) (p. 749–). (2018). NewsRX LLC.
Original URL	https://patents.google.com/patent/US20180012492A1/en
Source type	Patent
Keywords	autonomous vehicles, roadside infrastructure, wireless transmitter
Summary of key points + notes (include methodology)	**Summary** Instead of relying on sensors, this patent proposes using wireless transmitters between infrastructure and automated vehicles to control the vehicle. Here road signs and crossings can send data to the vehicle which then uses the computer system to control braking, speed, and path of the vehicle. This can be accomplished through WIFI or other protocols. **Notes** ● This patent proposes a way to control autonomous vehicles through signals from external structure or from other vehicles ● Normally autonomous vehicles use sensors, but weather or

	other conditions can block it so a more reliable method of navigating would be necessary. ● Once the message is sent the car receives it and then moves ● One example would be for traffic signals. A traffic signaling device sends the data to the car and the vehicle system uses this to determine the best vehicle speed, path, and braking ● Similarly, it can also get information about: ○ construction ○ stop signs ○ railroads ○ animal crossing ○ pedestrian crossing ○ school crossings ○ speeding limit ● For all the signs and crossings as listed above, the system receives info on their locations and length, which allows the vehicle system to alter breaking, speed, and pathing ● This can also be applied to other vehicles, such as emergency, maintenance, which can send their data to the autonomous vehicle to navigate. *Methodology* ● The way that this would actually be implemented would be through a wireless transmitter which can send data about the infrastructure ● The vehicle has a computer system connected to a wireless receiver . ● They could communicate either with WIFI or DSRC ● The computer system may be centralized or distributed such as a CAN.
Research Question/Problem/ Need	How can we automatically control autonomous vehicles?

Important Figures	 FIG. 1 ● ● ^figure showing a network where the autonomous vehicles can interact with

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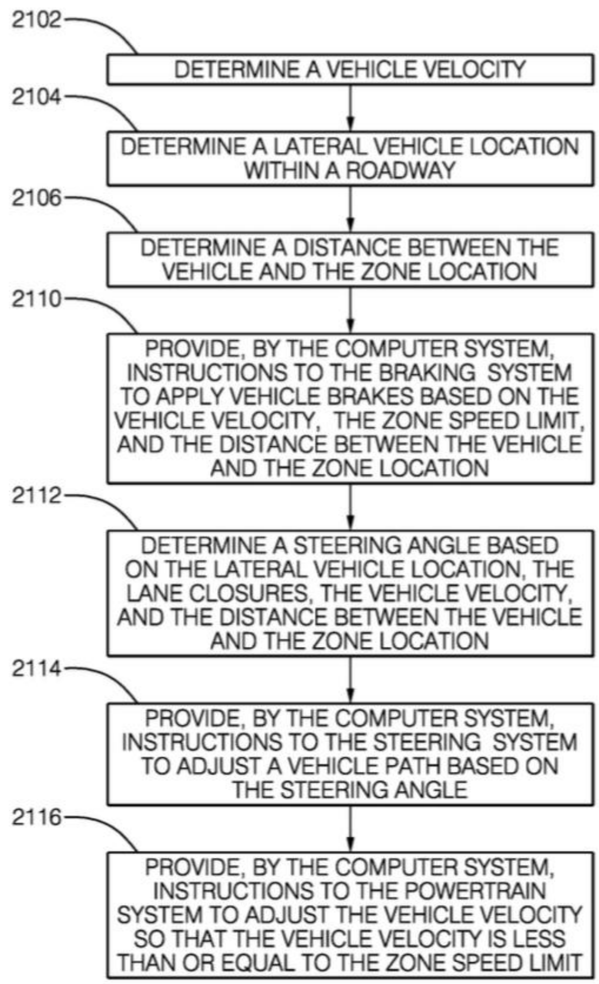

FIG. 4

-
- ^Chart showing what the system does witht he sent info
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<td>VOCAB: (w/definition)</td>
<td>DSRC: one-way or two-way short-range to medium-range wireless communication channels specifically designed for automotive use and a corresponding set of protocols and standards.

Wireless transmitter: use electromagnetic waves (rather than some form of wire or fibre optic cable) to carry voice, data, video or signals over part or all of the communication path.

CAN: protocol was developed primarily for communication between sub-systems in motor vehicles when the use of microcontrollers in engine control, window motors, airbags, anti-lock braking and so on became established.</td>
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Cited references to follow up on	https://patents.google.com/patent/DE4410895B4/en https://patents.google.com/patent/US7650210B2/en https://patents.google.com/patent/US20050187701A1/en
Follow up Questions	1. Is this prone to cyber attacks 2. What would happen if there is a disruption? Would there need to be sensors as a backup? 3. What is the accuracy of this system?

Article #19 Notes: Traffic control agency deployment and signal optimization for event planning

Article notes should be on separate sheets

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Source Title	Traffic control agency deployment and signal optimization for event planning
Source citation (APA Format)	XING SONGHUA, LIU XUAN, HAMPAPUR ARUN, & HE QING. (2016). *Traffic control agency deployment and signal optimization for event planning.*
Original URL	https://patents.google.com/patent/US9293038B2/en
Source type	Patent
Keywords	Traffic control agent, traffic prediction and optimization, traffic signal setting
Summary of key points + notes (include methodology)	**Summary** This patent aims to improve planning for large scale events and the traffic they bring along with them. This is accomplished through camera monitoring which captures data on real time traffic conditions. This is sent to an adaptive computer which simulates and optimizes the traffic signals to produce optimal flow. **Notes** ● Large scale events result in a significant increase in congestion as the road network is overloaded.

	● Normally individuals deal with these irregular changes in traffic flow. Also, current traffic signals aren't adaptive enough to deal with large masses of vehicles. ● In order to plan for this, an overall method is proposed: a. Information is sent to the system b. Estimates of demand is calculated c. Simulating the traffic network d. Optimizing traffic signals based on a cost function ● This is a tool which can be used for both traffic prediction and optimization *Methodology* ● To make this, they have a computer which can receive an estimate of a traffic demand in the transportation network. ● This data will be acquired through video camera monitoring. The plan will change based on new information gained by the cameras. ● From there, the computer simulates the traffic flow based on the given info. ● A model is then used to vary the TCA so that the cost is minimized. More specifically, they create a cost function in terms of decision variables, from which they are able to compute the minimum using optimization algorithms. $$\text{Minimize } \alpha \sum_t \sum_i x_{it} + \beta \sum_t \sum_m y_{mt} + C_{init} B_{max} + \sum_n \sum_t C_{hr} B_n \omega_{nt}$$ ● ● The decision variables also have constraints in order to ensure a valid and reasonable solution.
Research Question/Problem/ Need	How can we reduce and plan for traffic congestion for large events?

Important Figures

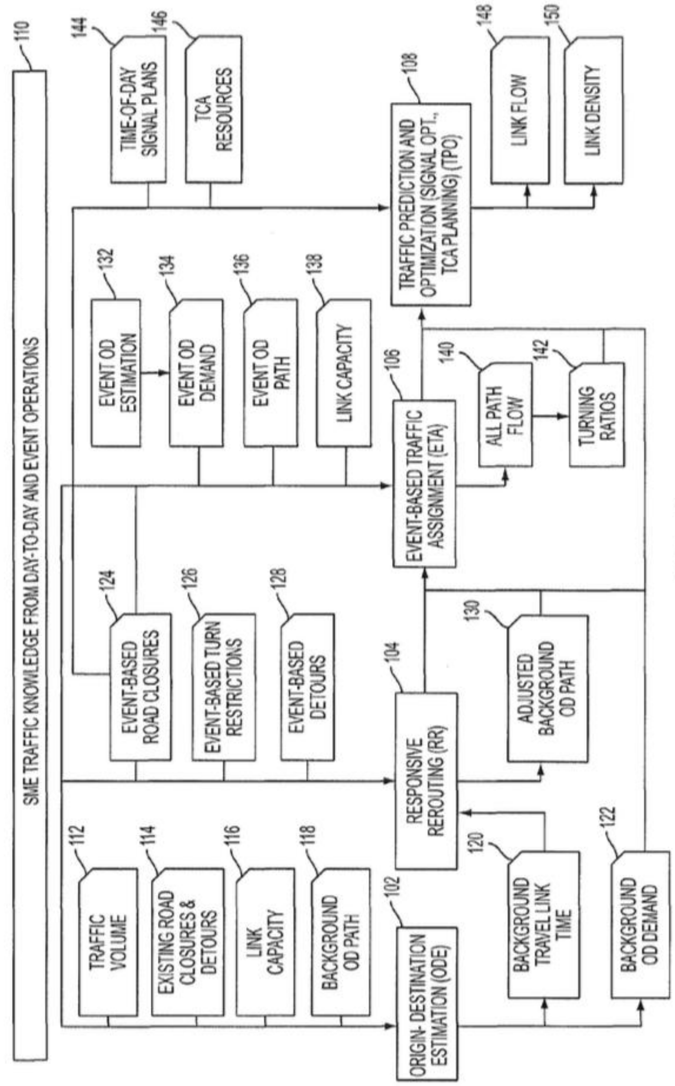
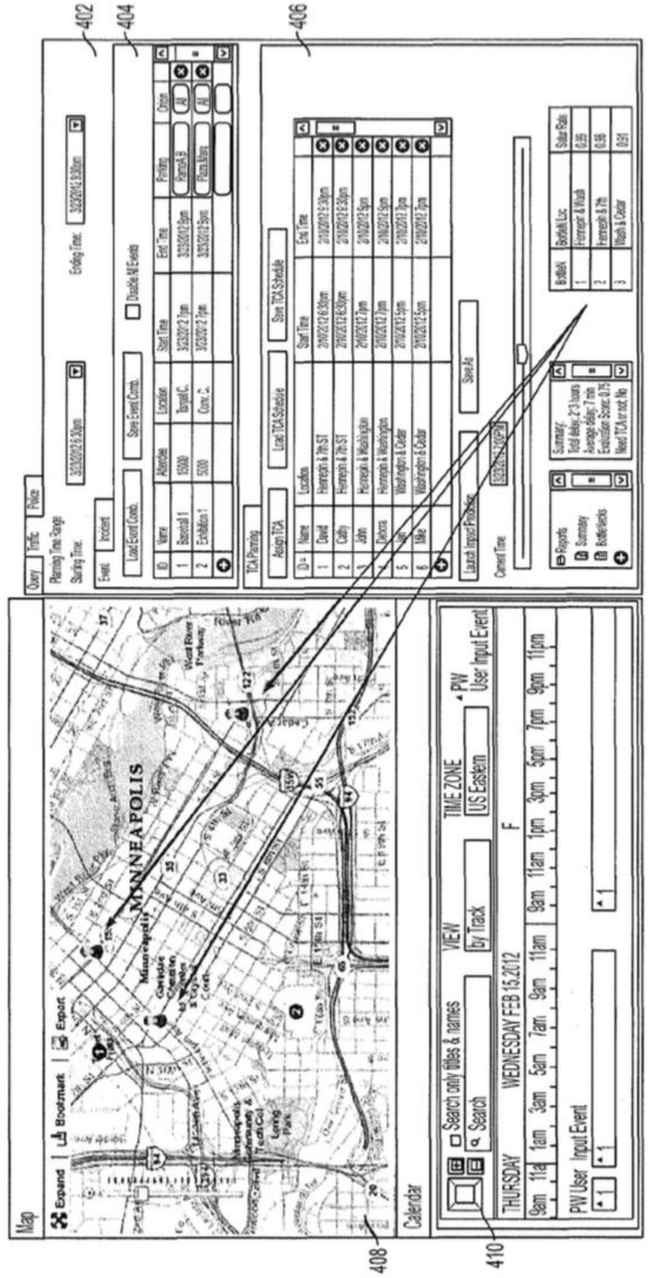


FIG. 1

-
- ^Figure showing the different factors which are considered when optimizing

	 ● ● ^sample user interface
VOCAB: (w/definition)	Traffic control agent (TCA): coordinate, setup, manage, and remove traffic control Traffic prediction: accurate estimation of traffic flow in a given region at a particular interval of time in the future
Cited references to follow up on	https://patents.google.com/patent/US5917432A/en

	https://patents.google.com/patent/US6633238B2/en https://patents.google.com/patent/US20100026520A1/en
Follow up Questions	1. Is optimizing traffic signals enough to prevent significant delays? 2. Are the costs of implementing this more than the drawbacks of traffic? 3. Would it be feasible for an AI to control the user interface to get better performance?

Article #20 Notes: The basics of spatio-temporal graph neural network

Article notes should be on separate sheets

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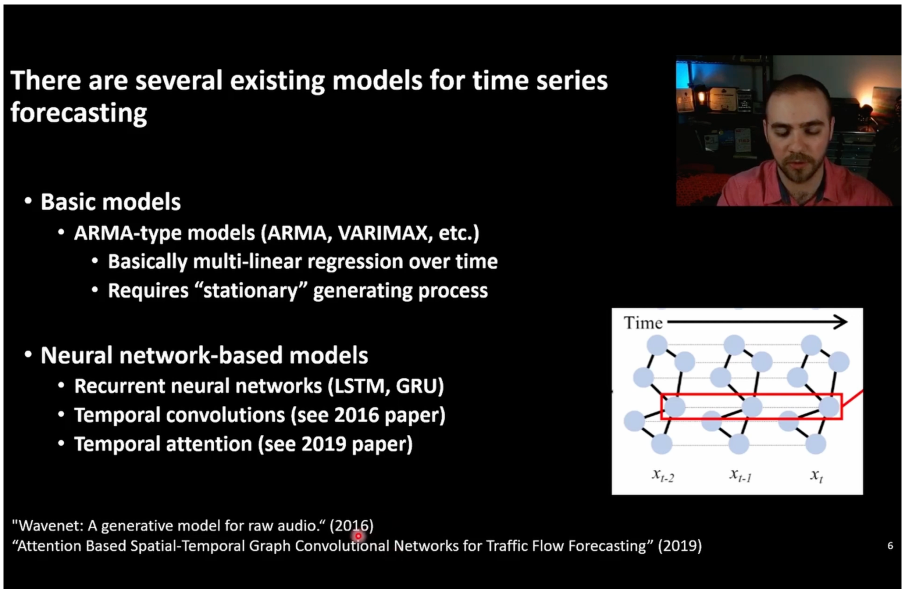
Source Title	The basics of spatio-temporal graph neural network
Source citation (APA Format)	Jacob Heglund. (2021). The *basics of spatio-temporal graph neural networks*. YouTube. Retrieved January 28, 2023, from https://www.youtube.com/watch?v=RRMU8kJH60Q&t=2s&ab_channel=JacobHeglund
Original URL	https://www.youtube.com/watch?v=RRMU8kJH60Q&t=2s&ab_channel=JacobHeglund
Source type	Video
Keywords	Spatio temporal, graph neural networks, temporal attention, kalman filter
Summary of key points + notes (include methodology)	● Attributed graphs are graphs which have additional components to model the real world better ● **Spatio-temporal** graphs are used to have a static structure with time varying features ● **Dynamic graph** has a time-varying structure and features ● Time series data is different than normal spatio data ● Many tools to consider ● **Kalman filter**? Extended kalman filter → predicts states. Maybe I can use this for predicting stuff? ● Time-series forecasting: predicting future from past ● **Temporal attention** ?

	● Split the spatial block with the temporal block? ● They use an adjacency matrix Ideas from this: ● Maybe apply ML on predicting the structure of the space-time network? ● Split the spatial block with the temporal block
Research Question/Problem/ Need	How can we study graphs that change with respect to time?
Important Figures	 Figure 1: preexisting models

```python
class STGNN():
    """Processes a sequence of graph data to produce a spatio-temporal embedding
    to be used for regression, classification, clustering, etc.

    """
    def __init__(self):
        # spatial block can be any standard GNN from the literature
        self.spatial_block = GNN()

        # temporal block can be any method for learning over sequences of data
        ## temporal convolution, temporal attention, etc.
        self.temporal_block = TemporalConv()
        self.fc = torch.nn.Linear(F_in, F_out)

    def forward(self, X, A):
        """
          Args:
          X (array): matrix of node features, X.shape = (B, N, F, T)
          A (array): adjacency matrix (potentially sparse), defines graph structure,
          if non-sparse A.shape = (N, N)

          where
          B = batch size for batch training
          N = number of nodes in the graph
          F = number of features per node
          T = number of previous timesteps we consider
        """
        tmp = self.temporal_block(X)
        tmp = self.spatial_block(tmp, A)
        tmp = self.temporal_block(tmp)
        tmp = self.fc(tmp)

        return tmp
```

Figure 2: pseudocode

VOCAB: (w/definition)	Kalman filter: an algorithm that uses a series of measurements observed over time, including statistical noise and other inaccuracies, and produces estimates of unknown variables that tend to be more accurate than those based on a single measurement alone, by estimating a joint probability distribution over the variables for each timeframe. Spatio-temporal graph: Neural networks which are developed to deal with time-varying features of the graph
Cited references to follow up on	None
Follow up Questions	1. Can this be paired with dynamic programming 2. What is the running time? Suitable for traffic?