PRIMARY + STEM

Teaching Resource

ACTIVITY: Smart Roads

ACTIVITY OVERVIEW

Self-driving cars, GPS navigation, ride-hailing services, cars that can communicate with other cars - there is so much connectedness of different digital systems to bring about greater ease and convenience on the roads... but how about the roads themselves?

How do roads manage traffic? How do different systems bring about smoother traffic and greater safety for road users? In this real-world example, students not only explore what has already been put in place, they also imagine the possibilities of what could be.

SYNOPSIS

Self-driving cars, GPS navigation, ride-hailing services, cars that can communicate with other cars - there is so much connectedness of different digital systems to bring about greater ease and convenience on the roads... but how about the roads themselves?

How do roads manage traffic? How do different systems bring about smoother traffic and greater safety for road users? In this real-world example, students not only explore what has already been put in place, they also imagine the possibilities of what could be.

Foundation – Year 2

- Identify and explore digital systems (hardware and software components) for a purpose (VCDTDS013)
- Follow, describe and represent a sequence of steps and decisions (algorithms) needed to solve simple problems (VCDTCD017)

Years 3-4

- Explore a range of digital systems with peripheral devices for different purposes, and transmit different types of data (VCDTDS019)
- Define simple problems, and describe and follow a sequence of steps and decisions involving branching and user input (algorithms) needed to solve them (VCDTCD023)

Years 5-6

- Define problems in terms of data and functional requirements, drawing on previously solved problems to identify similarities (VCDTCD030)
- Design, modify and follow simple algorithms represented diagrammatically and in English, involving sequences of steps, branching, and iteration (VCDTCD032)

ACTIVITY, MATERIALS AND INSTRUCTIONS

Activity

Students explore how different components of traffic systems interact to bring about smooth and safe traffic flow around the school. Through the activity, students not only learn about the hardware - they also try to identify some algorithms that have been programmed into the traffic system pedestrian crossing so that they can design an ideal one.

Materials for 30 students (working in 10 groups)

Toys and figurines to represent elements of a pedestrian crossing with a traffic signal (e.g. cardboard tubes, icy pole sticks, cardboard paper, or paper and writing/colouring instruments if drawing it on paper).

Instructions

1. Go for a walk in the neighbourhood around the school with students and make observations of the following:

   - types of vehicles on the road – cars, public transport (e.g. buses, trams, bicycles)
   - users – vehicles, pedestrians, people of different ages and abilities
   - conditions – peak traffic periods, rain, accidents
   - problems they have encountered while using the road

2. Introduce the topic of traffic management as something civil engineers – and in particular traffic engineers - consider when they create a solution.

   Watch these videos from VicRoads, which describe how traffic lights work.

   - How traffic signals work : VicRoads
   - https://youtu.be/lZtOgqbNMVE

   Also watch Managing Motorways in Victoria

   - https://youtu.be/pahIsJEFEMU

3. Theory

   Basic components of a traffic signal system, including,

   Hardware:

   - traffic signals with coloured lights, red/green man lights, and any, or all, of the following: timer display, sound, priority lights for buses, etc.
   - detectors, such as push buttons, radars, or cameras, as well as in-road sensors.
   - signal controllers, that act like the brain of the system and carry out instructions.
   - cameras that can either be used to monitor traffic/pedestrians, or take photos of offending vehicles.

   Software:

   - These instructions are what make the different components of hardware work together. The instructions (algorithms) can be changed to make the traffic smoother.

   How these systems work, including:

   - *Input*: Push button and detectors to collect information.
   - *Processing*: Detectors send information to the signal controller in the signal controller box. The signal controller contains the algorithms and ability to process different data it receives from the detectors, to determine what traffic signal patterns to use. In more sophisticated systems, signal controllers are connected wirelessly to others along the same road so that traffic is smooth throughout the journey.

- *Output*: Traffic signals that respond to the signal controller, visual timer to help the visually impaired, a speaker to help the hearing impaired, etc.

4. Provide student teams with materials (e.g. toys and figurines, or pen and paper), so that they can construct an ideal pelican road crossing (these are pedestrian crossings with traffic lights) to represent the following elements:

   - A road, a traffic signal, normal push buttons or ones with audio or touch features, detectors (e.g. cameras, radar, or pressure detectors on the ground to sense people), a traffic signal controller box, speaker, countdown timers, etc.

   Students consider the needs of a range of pedestrians:

   - young children
   - people with a disability (e.g. blindness, deafness)
   - people who move a little slower
   - a large group of people

   What are their detectors? What are the algorithms (set of instructions) in the signal controller?

   What are their outputs?

   Students discuss the merits of the technologies they put in place.

5. Students present their ideal pedestrian crossing to the rest of the class for others to critique and share feedback about.

Suggested solution

- Inputs could include normal push buttons or ones with audio or touch features, pressure pads on the ground to sense people, cameras to detect people waiting to cross, cameras to detect how many people have crossed the roads, cameras to detect how many cars are waiting, etc.

- Some examples of simplified algorithm
  - the red light for cars and the walking green figure for pedestrians come on 30 seconds after the push button has been pressed. It stays this way for 30 seconds no matter what;

    or

  - the red light for cars and walking green figure stays on for as long as it takes for the last person to cross the road;

    or

  - on rainy days, pedestrians get priority and so the signal change takes place after 15 seconds so that pedestrians do not get soaked through while they wait to cross safely.

- Outputs could be activating either the walking green figure or standing red figure, sounds to alert people who are hard of hearing, red-light cameras to capture drivers who do not stop, etc.

HOW TO USE THIS ACTIVITY WITH YOUR STUDENTS

Foundation - Year 2

There are many 'Ride, Walk or Scoot to School' initiatives to get students more active. This is an opportunity not only to get more familiar with the infrastructure in the community, but also to think about how they would make it different. What changes would students make to the road traffic system to make their commute to school safer or more comfortable?

What would make it safer for students when the roads are busy, e.g. at busy intersections or during school drop-offs and pick-ups? What effects might their changes have on other road users?

To make their learning more relevant for students, give them a map of the neighbourhood surrounding the school. An easy way to do this is to use Google Maps and take a screenshot. On the map, students highlight the path that they take to school, the traffic lights, the roads that they cross, the bus or tram stops, etc.

They then choose ONE of these features to make an improvement to, for example, making it impossible for cars to come out of driveways when children are cycling, walking, or scooting past it by putting sensors on the pavement that will communicate with sensors in the car which will activate the brakes.

Years 3/4

We often take it for granted but a lot of planning and technology is involved in getting people from place to place smoothly and safely by road.

There has been unbelievable progress in road traffic management since the late 1800s when the first traffic signal was invented.

With more sophisticated components and powerful computing technology, we now can fine-tune traffic management even further.

Students research the types of detectors that are currently being used, e.g. radars on buses that tell the signal controller that it has arrived, traffic cameras (not red-light or speed cameras), even rain detectors!

Can students select a busy intersection near the school, and design a way to prioritise road users like buses/trams, ambulances, cyclists?

Years 5/6

Accidents, peak hour, and weather changes can make drivers behave very differently than they would under normal circumstances. A signal controller (which acts like the brain of the signals in an intersection) has to be programmed to consider each of these scenarios separately and instruct the signals to respond to these changes. In reality, the process of calculating the best outcomes for unpredictable and rapidly changing traffic conditions is implemented using machine learning.

What are some algorithms (sets of instructions) to apply when traffic doesn't operate under normal conditions?

Can students identify some atypical situations, e.g. accidents, emergency vehicles passing, wet weather, peak-hour; and write simplified algorithms that will work towards smoother traffic flow?

This could be done diagrammatically or in English, using 'IF' and 'REPEAT' statements.

Students consider how such a scenario can be detected, for example, with radar, cameras, in-road wire loop detectors, rain detector; what algorithms to execute; and what the outcome might look like, e.g. the red light stays on until the emergency vehicles have passed.

Students work collaboratively and present their findings to their classmates for feedback and improvement.

DISCUSSION SECTION AND KEY THEMES

From the first traffic signals using gas-lit lights, to sophisticated systems that now include red-light speed cameras - roads have become even more critical in keeping a community running smoothly.

Traffic systems now comprise hardware, such as traffic signal and detectors, as well as software that gives instructions to run the hardware in response to traffic conditions. These components help to ensure smooth traffic flow, and greater safety for all road users.

KEY THEMES

Detectors

Most traffic signals have detectors (sensors) of some form in each lane at the stop-line of every intersection. These could be in the ground, i.e. magnetic wire loops located just under the road surface, or above the ground (e.g. using radar or camera-based video detection).

In a sense, people are also a type of detector – with many calling the traffic management centres to alert them of accidents, broken-down vehicles, water over roads, and other unfavourable road conditions.

The magnetic wire detector loop is probably the most common sensor used in traffic control.

This detector is buried under the road and, for it to work, a vehicle must be physically over part of the loop. The detectors work by sensing large masses of metal in vehicles and would struggle to detect bicycles, so more sensitive detector loops must be used if there are more cyclists on the roads.

The information from the detector allows the signal controller to know how many vehicles are waiting, how many vehicles are passing, which direction requires a green signal, and how long a green signal should stay.

Radar technology, cameras and video detection are increasingly used as detectors. They are generally more economical because they are easier to install. They are mounted on poles or directly on top of traffic signals to get a clear view of the road.

Cameras that are used to manage traffic flow feed information to the central computer, so that changes can be made to the signal patterns. There are also speed and red-light cameras which work automatically at all times of the day.

Some systems have one camera that does both functions, i.e. red-light speed camera. The data from these cameras gets sent to the computers of the relevant enforcement agencies.

Push buttons at pedestrian crossings

Push buttons allow pedestrians to request the green walking figure to be displayed. These are designed to be easy for everyone to use.

Some produce a clicking sound and vibrations to help people with a disability to cross the road safely.

Some state transport agencies are trialling smart crossings, using advanced detectors (e.g. infra-red sensors and high-definition cameras facing the road where pedestrians cross).

These sensors are mounted on existing traffic lights and modify the traffic signal timings to give longer crossing times only when there are slower-moving pedestrians or a larger number of pedestrians.

- Smarter Roads: Five benefits of new crossing tech being rolled out across Melbourne : VicRoads

Signal Controllers

Signal controller boxes are located close to an intersection or pedestrian lights. The microprocessor control unit and electrical switches in the box, act like the brain of the traffic signals. They receive information from detectors, such as the wire detector loops, radars, cameras, and pedestrian push buttons.

With the information they are given, the controller follows sets of instructions (algorithms) to determine the pattern of the lights (e.g. length of the green signal for each traffic movement, how quickly the lights change colour, which sequence of lights to activate, etc.). Considerations in the algorithms of the program include prioritising a specific road user, such as a bus or ambulance.

This information could be processed locally at the signal controller box or get sent wirelessly to a central server that is connected to other signal controllers. This latter will allow the signals to be synchronised along a main road to achieve smoother traffic flow. With very sophisticated systems, a green corridor can be achieved to ensure continuous traffic flow on the main road, while minimising waiting time for cars on the side roads.

Prioritising users

- *Buses*

  There are generally two ways to improve service and reduce delay for public transportation, such as buses, on roads. One way is to pre-program the best signal timings and coordination for all traffic signals along a bus route at different times of the day. This improves traffic for all vehicles on this route and does not require special equipment, such as bus detectors and specialised traffic signal controllers.

  The other way is to rely on detecting buses as they approach a traffic signal, then adjust the signal timing to improve the service for the bus. Unlike the earlier method, this dynamic approach requires specialised equipment, such as a transmitter on the bus, several detectors at the intersection, and more sophisticated signal controllers. This will enable actions, such as longer green lights, a shorter red light, an earlier red light, and even special signals only for the bus to make turns on busy roads.

- *Cyclists*

  In 2016, the City of Rotterdam introduced bicycle traffic lights fitted with rain sensors, so that, in the event of wet weather, cyclists get priority over cars.

  - When It Rains, Rotterdam's Bikers Get To Go Through Lights Faster (fastcompany.com)

QUESTIONS AND ANSWERS

How does my car know the speed limit on roads?

Cars that possess the technology to 'see' speed limit signs come with forward-facing cameras that are connected to a computer in the car.

The computer continually receives images from the camera and uses image-recognition software to detect the shape and numbers written on the sign.

This used to be feature of 'premium' cars but, as technology becomes more affordable, it is now becoming more common.

- Traffic sign recognition explained | CarExpert

Why do we sometimes have to wait a long time before we are allowed to turn?

It has to do with detectors on the road, as well as how the signal controller has been programmed. In the wire loop detector, which is buried under the road, cars have to be directly over it to be detected; and in above-ground systems, such as radar or video-based cameras, cars have to be within the range of the detectors.

If the signal appears to be taking a long time to appear, it could be that the first car waiting to turn is not waiting at the right position.

It could also be that the signal patterns have changed in response to how busy the roads are and waiting longer to turn is part of the solution to make the traffic at large move more smoothly.

Why do we sometimes drive through only green lights? And, when we are particularly unlucky, why do we get stuck at all the red lights along a road?

With more advanced technology able to gather more detailed information, traffic management has become more sophisticated. The algorithms (set of instructions) in a signal controller are based on how busy roads get at different times of the day. This could mean that the timings between colour changes and the length of each light colour can be modified for smoother traffic flow.

In even more sophisticated systems, data from all signal controllers along a road are fed into a central system wirelessly. This allows traffic signals to be coordinated along the entire roadway and this synchronisation could result in green lights for most of the journey – leaving road users feeling very lucky. This is referred to by many as a green corridor.

What is the next big thing in managing traffic on roads?

Instead of relying only sensors that are built into or onto roads, how about using cars as well? Vehicle-to-vehicle communication could be a reality on our roads soon, with cars being able to exchange information wirelessly with surrounding vehicles. Benefits include avoiding crashes and easing traffic congestion. But the greatest benefit can only be achieved if all vehicles have this capability. Just imagine if cyclists were able to forewarn drivers of their presence – this would prevent so many collisions.

- Vehicle-to-Vehicle Communication | NHTSA

Watch this video to learn about what vehicle-to-vehicle communication is and how it works:

- https://youtu.be/3z09fCqmILU.

Why are there traffic signals on freeway ramps?

Traffic on freeways needs to be managed carefully to ensure smoother traffic flow and avoid major accidents. Vehicle detectors and CCTV cameras at segments of the freeway send live information wirelessly to traffic engineers at the Traffic Management Centre. Depending on the traffic condition, complex algorithms are applied to the equipment on the freeway, i.e. variable speed signs, ramp signals, and travel time signs.

How do red-light speed cameras work to keep users safe on roads?

Authorities have installed red-light speed cameras at high-risk intersections to help reduce crashes. Review of data collected over several years in NSW have shown that since the cameras have been implemented, the number of accidents has reduced significantly because most drivers do not want to be ticketed and pay a hefty fine!

These cameras detect, record the speed, and take photos of offending vehicles by using detectors, such as radar technology mounted on the road, or wire loops that are buried under the road.

The red-light detection is connected to the traffic signals and is activated to take photographs when a vehicle crosses the white stop line after the lights have turned red.

These images are stored digitally and encrypted to ensure that it is not tampered with at any stage.

With all these sensors, do I still need to look on both sides of the road before crossing?

Absolutely! Technology may fail us, and drivers can be unpredictable. It is important that all road users pay attention to road conditions. Just as drivers shouldn't be using their mobile phones when they are driving, other road users shouldn't either.

How does Google Maps report on traffic flow on roads?

Google Maps uses drivers who use the app to gather data! When mobile phone users with Google Maps installed have their GPS location enabled, the phone sends back data to Google to let the company know how fast their cars are moving. As more and more drivers use the app, the traffic predictions become more reliable.

- How Does Google Maps Predict Traffic? | HowStuffWorks
- How does Google Maps collect real-time traffic information? - Quora

Is Google Maps traffic information reliable?

The logic is that, if many users are moving at the same speed, it must be because of the road condition. Therefore, if road users are moving slowly, chances are that the traffic is busy. See how a person experimented with this logic and outsmarted the system while he was doing it!

- https://youtu.be/k5eL_al_m7Q

Roundabouts vs traffic signals

Installing traffic signals are generally safer for pedestrians – plus they take up less space and are less expensive than roundabouts. Traffic signals are used at busy intersections, while roundabouts are good enough for less busy intersections. In a very busy intersection, roundabouts do not work well because heavier traffic in one direction can cause traffic to build up going in other directions.

OUTSIDE OR SUPPLEMENTARY READING

How do traffic signals work?

- Traffic Signals Information (Department of Transport and Main Roads) (tmr.qld.gov.au)
- Pedestrians should get the green light on traffic signal prioritisation | Research Centre for Integrated Transport Innovation (rCITI) (unsw.edu.au)

What are some new technologies to manage traffic?

- Traffic Signal Optimization and Coordination in Connected Cities - C2SMART Home (nyu.edu)

Red-light speed cameras

- Red-light speed cameras | NSW Government

How does Google Maps help people navigate roads?

- This Is How Google Maps Works - Pritesh Pawar

TOPIC WORDS

- Algorithms
- Data
- Software
- Hardware
- Input
- Output
- Detectors (Sensors)
- Signal controller
- Processor
- Information systems
- Components
- Computational thinking
- Data collection
- Decisions
- Transmit data
- Traffic
- Pedestrian
- Vehicle
- Management

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