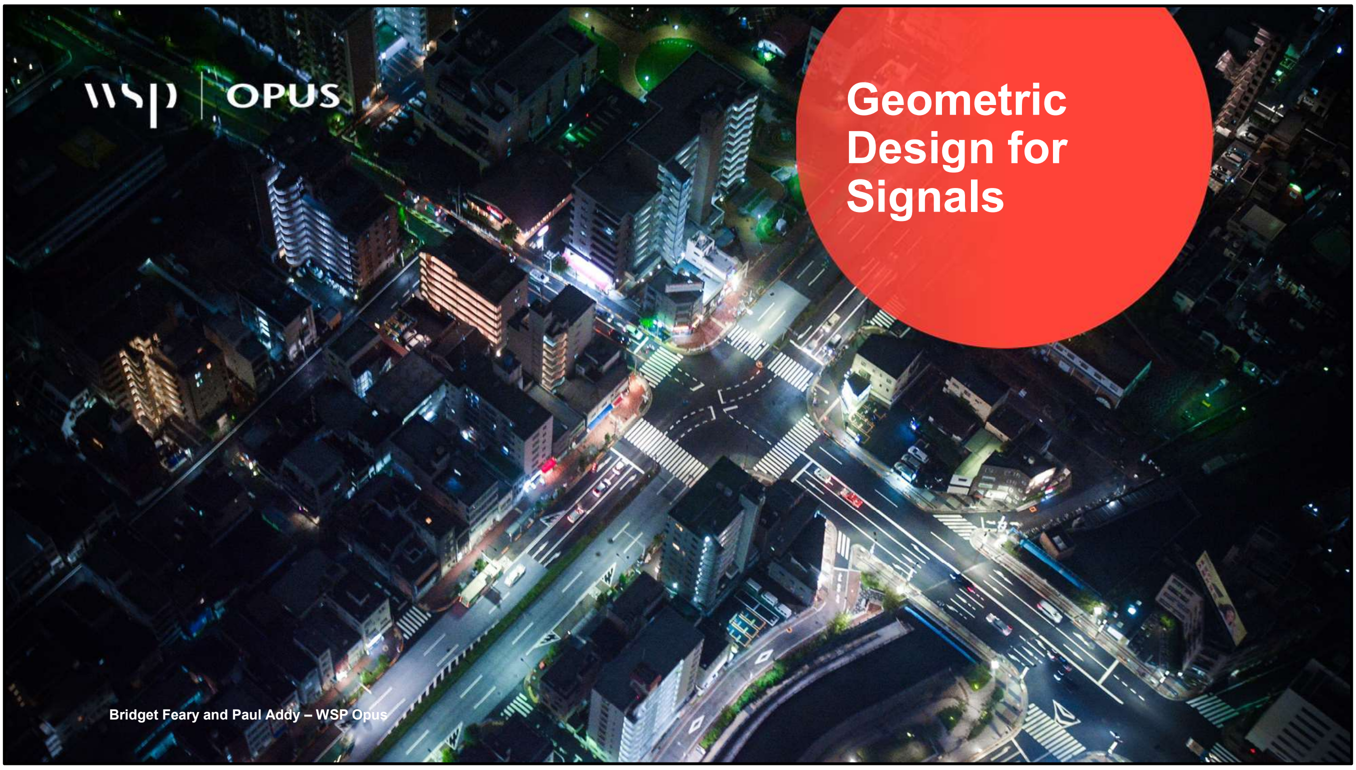


This presentation has been put together from an internal geometric design guide compiled by Bridget Feary, our Principal Traffic Engineer at WSP-Opus in Westhaven.
Her intention was to provide a document for geometric designers and signals engineers to use to work together on signalised intersection designs.
I have generously offered to present it on her behalf. We would also like to acknowledge the use of reference material from Austroads and NZTA in the presentation.

The design information included is intended to supplement existing design guidance by highlighting key design issues specific to the design of traffic signals that should be considered during the geometric design process - to make designs safer and the design process more efficient.

In practice the design of traffic signals is frequently commissioned after the intersection geometric layout has been determined. The layout design may have been undertaken with traffic modelling results in mind in terms of lane numbers, layout and length, but is often completed prior to consideration of how the signals are to operate and what signals equipment will be required to be installed within the intersection.

The design of signalised intersections and crossings should be a collaboration between the traffic modeller, geometric designer, signals designer and traffic safety engineer to ensure design decisions are evaluated for both the safety of those constructing, operating/using, maintaining and demolishing signals infrastructure and the efficiency of operation.

Safety in Design asks us to consider whether our design presents any risks of injury to those involved in the whole of life of the signals we are designing – construction, operations, maintenance and demolition.
It is about the Health and Safety of people and consideration should start before design commences. When we create intersections – we not only create multiple points of conflict between vehicles and people we create infrastructure that people can crash into, fall from, trip over and be electrocuted by.

If you start your signals design at the geometric design stage of the project with some broad goals about preventing people from being exposed to risks that could injure them you are on the right track to creating a safe design. You may not be able to achieve all the goals, but thinking about your design in these terms should show you where you can have an influence over health and safety for the life of the signals.

These broad goals could include:
Safe maintenance access to all infrastructure – can you get to all infrastructure that needs maintenance without traffic management? Needing traffic management means your maintenance workers will be exposed to live traffic,

and road users and pedestrians will be affected by maintenance activities. Do you have somewhere to park a maintenance vehicle, a level space you can safely walk to, space to put up a ladder, put down your tools and materials, and complete the work efficiently without affecting how people use the signals, footpaths or cycle facilities?

Low Maintenance Frequency – can you choose long life materials that require less intervention, are more resilient and function at a high level for longer. For example tactile pavers –stick on pavers frequently start lifting soon after installation and are a slip hazard, they are meant for indoors. High quality pavers with the colour through the whole paver perform better for longer.

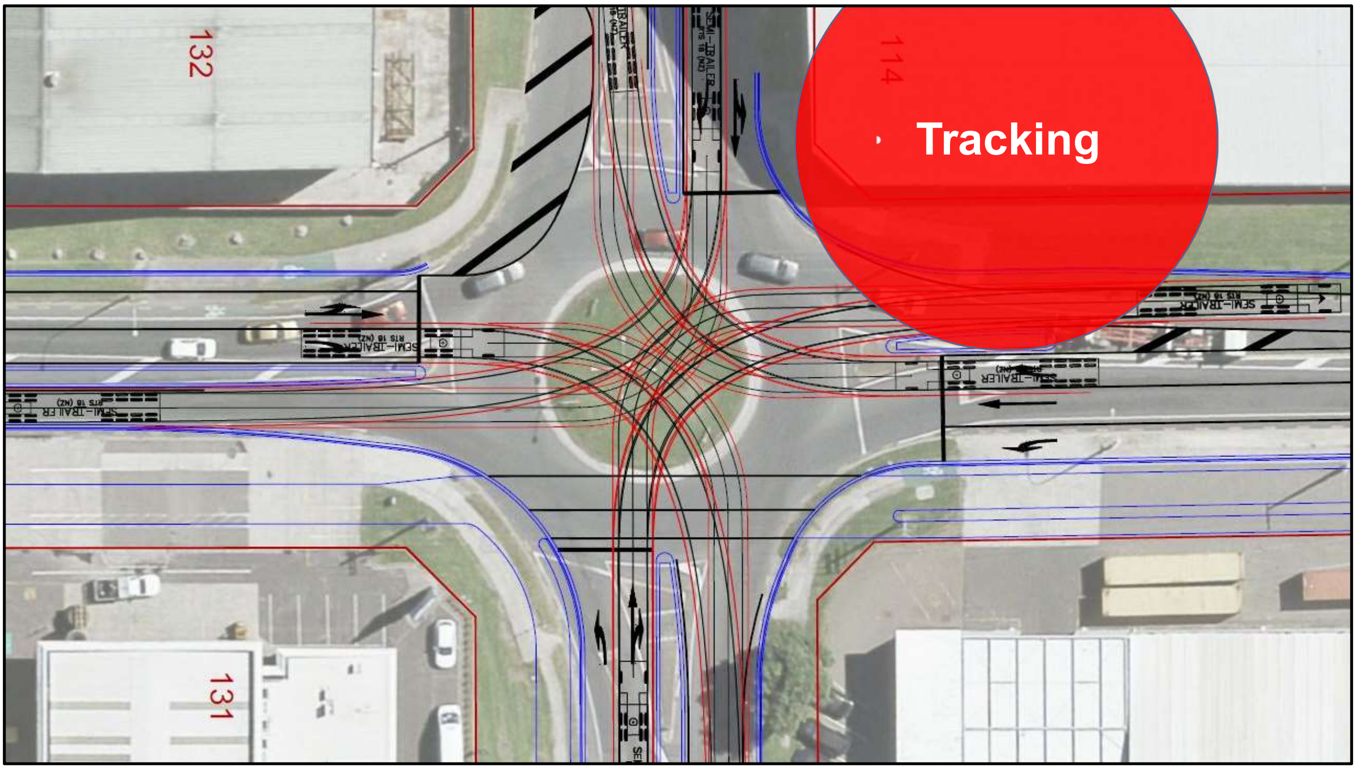
Safety Equipment Locations – are they at likely conflict points. Poles on islands and directly opposite an approach are like magnets to errant vehicles. Are there locations where equipment may be affected by stormwater, animals and insects or overgrown by landscaping? Are there other utilities in the area that will need to be accessed that mean your equipment may be damaged or out of action in the process?

Minimise environmental hazards – are you adding environmental hazards that need to be a safety consideration during maintenance or demolition, like electricity, chemicals, vapours, confined spaces – can they be eliminated or managed?

Safe Operating Environment – is your design in context with the road operating environment? New signals on existing roads can be invisible to people who use the route frequently, new phasing or crosswalks at existing signals can be easily ignored by users used to an existing phase sequence and level of priority. Urban intersection designs in rural areas can create crash problems rather than solve them, all because the signals are out of context with the road operating environment.

These broad goals can help you start your design with the most significant health and safety risks managed.

Then you can think about the specifics of your design as you work through the design process, evaluate the likelihood and consequence, eliminate more health and safety risks and finally communicate any residual risks to those down the track who may be affected.



Vehicle tracking is an essential design tool to help establish that your intersection can actually safely operate the way it has been modelled and that vehicles can turn through your intersection without damaging other vehicles or your signals or roading infrastructure.
The design vehicle used typically depends on the classification and function of the road and is usually a semi-trailer but can also be a smaller truck or a bus. The space used to turn depends on the vehicle size but also the configuration of their axles and whether they are towing a trailer. We also use a car for tracking of dual lanes with the design truck or bus as the most likely vehicle combination rather than two semi-trailers together.

The tracking curves show the paths followed by the tyres and by the outermost parts of the vehicle body and define the physical space the vehicle needs for the manoeuvre. They don't include any clearances, so you need to add half to one metre to each side of the tracking curve from the chassis as a buffer to protect pedestrians, cyclists, other vehicles and street furniture, to account for driver judgement errors, the difference between a design vehicle and an actual vehicle, and trailer swing. Half a metre is for a single vehicle, one metre is for opposing vehicles.

What you need first is the location of your limit lines – where are you tracking from. Tracking should start from a vehicle stopped at the limit line and be smooth without transitions. You are also looking to ensure the design vehicle can turn left or right from a lane and not cross adjacent lane lines, and that the rear wheels of your design vehicle do not have such a small turn radius that they damage the road surface.

What you need to look at tracking to evaluate for signals design includes:

1. What movements can physically run together in your phasing plan – not just opposing right turns but adjacent left and right turns.
2. Whether there are conflicts between the design vehicle and likely locations for signals equipment - can your poles be installed, in particular ones on traffic islands so they are safe from being struck during normal use of the intersection.
3. Where vehicles are likely to drive over stopline loops when they exit the intersection because of lack of visibility of limit or lane lines on other approaches or the geometric layout supports shortcutting – you can add traffic islands or lane markings
4. Whether vehicles entering short lanes will block adjacent lanes.
5. If the intersection can operate at the modelled entry, exit and negotiation speeds
6. Whether your kerb radii are suitable and safe for your design vehicle.
7. Where vehicle turns overlap other facilities, i.e. cycle lanes, pedestrian facilities, parking lanes, traffic islands, kerbs. For example, trailers can swing and take out cyclists in a cycle lane or pedestrians on a pram ramp.
8. Where dual turning lanes need additional guidance (markings or islands) in wide or skew intersections or additional space downstream.
9. Overdimension route clearance envelopes.

Short lanes are used to separate turning movements from through traffic so they can run separately, to provide additional capacity for turns or to provide a head start for priority traffic such as buses.

Short lane lengths can be determined by modelling to identify how much capacity is needed for a set level of service. The capacity will relate to your traffic mix, but the length will not necessarily accommodate your design vehicle. So the model lane length shouldn't be directly adopted without also considering if your design vehicle can use the lane without blocking adjacent lanes, and the diverge length needed so vehicles can safely access the short lane especially if you have parking or kerblines restricting the lane you can provide.

For right turn lanes, the safest layout for opposing right turn lanes is to align them head to head, rather than offset them. Offset right turn bays restrict sight distance for turning traffic, affecting safety and efficiency. Drivers with restricted sight distance may delay making a turn or take unsafe gaps. If they are concentrating on opposing vehicles they are also less likely to observe cyclists and pedestrians – in particular if you allow filter right turns or run parallel pedestrian movements without full protection.
If you cannot align opposing right turn bays you may need to consider banning

one of the right turns or splitting the phasing so they do not run together.

For left turn lanes, you are potentially crossing a cycle lane or running a left turn phase with opposing pedestrians or cyclists. Design practice is evolving in this area, particularly with the advent of cycle crossings. The sub-committees are working on best practice for pedestrian and cycle crossings so the conversation is continuing in this area.

Corner kerb radii should be minimised where possible for safety.
Smaller radius corners have the following benefits:

1. Pedestrian crosswalks can be perpendicular to the path of travel, creating shorter more direct crossings which are simpler to layout tactile pavers in and more efficient in terms of crossing and clearance times.
2. Smaller kerb radii decrease turning speeds.
3. The location and number of signal poles can be optimised.

Here is where the debate heats up. Shared paths with segregated or shared crossings? Nearside or farside displays? Cycle displays at the crossing only or also facing path users. Combined push buttons, multiple push buttons, left or right side push buttons, guide dogs on the left, symbols on the road, green tactile pavers, locking or non-locking calls, radar, in-ground sensors, countdown timers, advance detectors… Best practice guidance is under development by the cycling signals sub-committee but the debate goes on.

However at the geometric design stage some of your primary considerations should be:

1. Design for current and future user numbers, for vulnerable and mobility impaired users and your operating environment.
2. The type of facility you design will affect your crosswalk width, footpath depth, crosswalk location, limit line locations, pole locations and number of poles, signals operation and efficiency.
3. If you want cyclists to be able to legally ride across your crossing it must have 3-stage cycle signals.
4. Number of crossings - Crosswalks should only be included on approaches where they are required – based on pedestrian demand and desire lines, safety and efficiency.
5. Crossing location - Crosswalks should be as close to the intersection as possible or a minimum of 30 metres downstream from the intersection for safety and operational reasons. Where possible, crosswalk lines should be

marked approximately 0.6m from the prolongation of the kerbline for visibility and efficiency reasons. Intervisibility is a key safety issue – left turning traffic cannot filter safely if they can't see the crosswalk they are giving way to.

6. Crossing length – the longer the crossing distance, the longer pedestrians will be exposed to traffic hazards and the longer the delay will be other intersection users.
7. Staggered crosswalks are a useful tool both for midblock crossings and crossings at intersections to manage large volumes of pedestrians or long crossing distances, as they allow you to store pedestrians in the median and run pedestrian movements on the same leg at different times. The preferred stagger is left to right, so pedestrians face oncoming traffic. Some jurisdictions use the opposite stagger at intersections to maximise lane capacity on the approach and provide queuing space on the departure leg. When you consider using a stagger you need to ensure a mobility scooter can turn within the island and access the push button, so the island needs to be a minimum of 3 metres wide.

Traffic signals in New Zealand must have a minimum of 3 displays at the primary, secondary and tertiary positions on each vehicle approach. Additional displays can be dual primary or secondary displays and overhead displays. These can be on poles shared with displays for other approaches and other facilities including pedestrians, cyclists, buses and trams depending on their location. Separate standard, joint use or stub poles can be added for additional displays and push buttons and poles can have handrails incorporated for cyclists.

So during the geometric design stage you need to ensure you have a safe place to put all these poles, which will be on all corners of your intersection, potentially also on median islands and in cycle lane dividers and at all road crossings for pedestrians and cyclists. You need to consider:

1. Each pole must be behind a kerb and will be set out longitudinally in relation to a vehicle limit line, crosswalk line or kerbline.
2. Each pole will be offset from the face of the kerb at least 300mm based on the width of their backing board or depth of their display. Backing board widths depend on the size of your lanterns and the number of columns in your display.
3. Space for poles shouldn't conflict with space for pedestrian or cycle paths and safe space for maintenance access should be provided where possible.
4. There may be displays on all sides of the poles so safe offsets should be maintained

for displays perpendicular to traffic lanes

5. Additional space will be required for cycle handrails and pedestrian fencing
6. Poles with push buttons will need to be a maximum of 300mm from a pram ramp.
7. Poles may be joint use with lighting or CCTV extensions, so pole types may be revised in conjunction with the lighting and ITS design.
8. Each pole also has a foundation. Its dimensions are site specific based on ground conditions and loading. All poles will require cable entry below ground level.
9. Hinged poles can also require space for a chamber with a counterweight and they need space in the direction they fold down.
10. Socketed poles need to be lifted up at least a metre to be removed and mast arms move in the wind so the proximity of overhead utilities needs to be considered.
11. There are a maximum number of displays you can fit on a pole – you may need to use brackets to install some displays, affecting safe offsets.
12. Try to minimise the number of poles you use, each is a roadside hazard.

During the geometric design process the signals designer should be contributing to the design of traffic islands to ensure that they are in the right locations and the right size and shape for signals equipment to be installed on or for pedestrian facilities to be provided.
Often island nose shape and length or island width is compromised to ensure tracking works. Cycle separators and pedestrian islands are also narrowed to maintain turning lane widths. Reducing the separation between traffic lanes and street furniture increases the likelihood for conflict and reduces the safe space for maintainers to work in.

Signals equipment is not the only street furniture installed on traffic islands and space for lighting poles, traffic signs, fencing, handrails and the storage of pedestrians and cyclists also needs to be considered. As a minimum the geometric design should consider:

1. Space in the island for signals and lighting equipment and their foundations.
2. Everything installed on the island will need a safety buffer and will be offset from the face of kerbs.
3. Islands need to be wide enough to store users in both directions and accommodate the turning paths of cycles, prams and mobility scooters.

4. Space in traffic islands to install chambers outside pedestrian/cyclist paths
5. Tracking of vehicles past the island – are lane widths sufficient to ensure vehicles don’t mount the island and snag fencing or hit poles or backing boards.
6. Space for a maintenance engineer to place tools and a ladder within the island at each pole.
7. A median island nose needs to extend at least 1.2m beyond a signal pole.

NZTA requires official overdimension routes to have a clearance envelope of 10.5 metres by 6 metres. Some RCA's and some projects may require a larger overdimension clearance envelope.

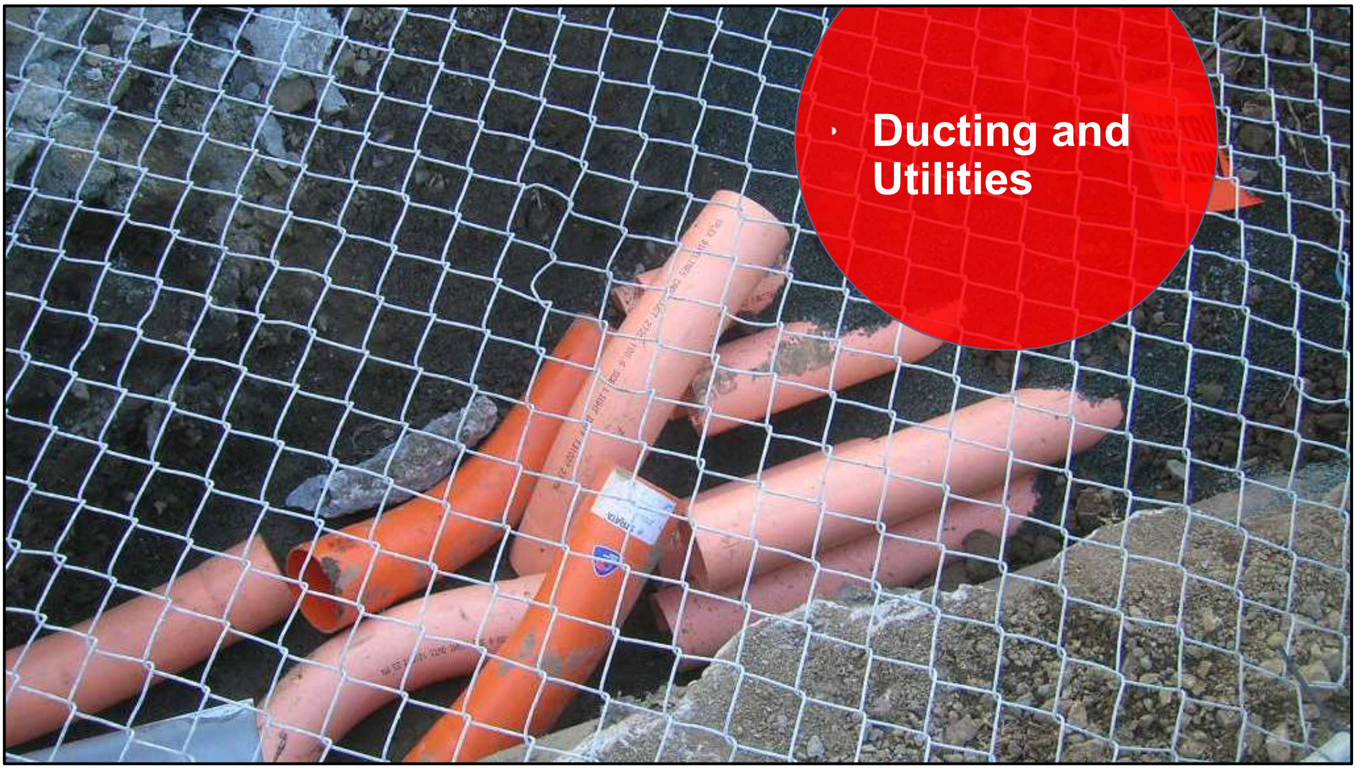
If your carriageway does not provide the required clearance envelope you will need to look at where your poles and equipment are installed and whether they need to be socketed or hinged to allow them to be removed or lowered for overdimension vehicles. If you are planning to use hinged poles you need to consider in your design what direction the poles will fold, what infrastructure may be in the way, where the equipment needed to lower the poles will be able to sit and how the equipment will be protected when it is lowered and raised.

Hinged poles are old technology and have the following potential issues:

1. Manufacturers can supply hinged joint use poles, however they may not recommend using them due to the equipment needed to lower the poles, the requirement for counterweights, the potential for damage to the signals infrastructure on the pole and the potential for the pole to rust at the hinge.
2. All poles with signalised displays power cables entering the poles from the underside. When the poles are lowered and raised extreme care needs to be taken to manage the electrical hazard.
3. The hinges which the brackets for the fold down poles sit on need to be robust as

failure of the hinges is a significant safety issue.

4. Lanterns can twist as a consequence of lowering, resulting in displays facing the opposite direction giving a false signal to vehicles and creating conflicts.
5. Visors can fall off the lanterns, which are there to prevent opposing vehicles seeing the displays.
6. Bolts not being re-tightened correctly after lowering and re-raising could lead to poles failing over time.
7. During lowering, backing boards or lantern visors could striking surrounding street furniture and prevent the full lowering of the pole.



- Signals, detector and electrical cabling all go through ducts that are buried in the carriageway and berms.
- Typically, 100mm ducts are used for connections between the controller and signals poles and 32 or 50mm ducts between the inductance detector loop cable connections in the kerbside junction boxes and adjacent chambers.
- Redundancy can be built into the system by running multiple ducts under the carriageway (usually two) and closing the loop around an intersection by providing ducts on all legs even if cables are not installed in them.
- Ducting will likely be installed on all legs of the intersection, which should be considered in utilities investigations.
- Chambers will be required on each corner of the intersection and in medians. Space should be available in areas not trafficked by pedestrians or cyclists for the chambers. If this is not possible, chamber lids should have non-slip surfacing.
- Ducting will be installed to each kerbside junction box, which could be 50m+ upstream of the intersection for advance detectors.

The New Zealand Electrical Code of Practice for Electrical Safe Distances (NZECP 34) sets out minimum safe electrical clearance distance requirements for overhead electric lines and for building and excavation near overhead electric line support structures.

The proximity of electric lines and support structures to the signals equipment needs to be considered and identified in the design to ensure site constraints in terms of height and location of signal poles and equipment can be confirmed prior to designs. Mast arms can have an outreach up to 7m long and CCTV and streetlighting can extend the height of the poles up to 12 metres with an outreach of up to 4 metres.

Traffic signal poles, signal heads and mast arms can sway significantly in high winds, so clearances to overhead electric lines need to take this into account.

Identify during the geometric design where overhead power lines or above ground structures may conflict with signals equipment.

A suitable location should be included for the signals controller cabinet. It will have ducting running to it from the intersection which will include power supply to the poles, signal cabling and loop feeder cable from the detectors. It may also have communications cables. The location needs to consider all these underground connections in terms of utilities conflicts and power supply and the requirement for safe maintenance access.

A signals engineer will need the controller to be in a safe location to work – where they are on level ground and they can open the cabinet door and also see the signals displays in operation. They will also need a safe location to park their vehicle and walk to the controller while carrying tools.

The cabinet will be installed on a plinth and include equipment sensitive to water and to attack by insects/rodents. It should not be in a drainage path or an area likely to flood.

The cabinet is also a roadside hazard that could be struck by vehicles, so should be out of the likely path of errant vehicles and not conflict with the location of pedestrian or cycle facilities.

The controller location is the reference point from which some signals design details are determined, i.e. signal groups, pole numbers, detector numbers, cabling and ducting plans. Changing the controller location will require redesign of all these design components, so confirming a safe location during the geometric design is essential.

Identify a safe location in your intersection layout to place the controller where utilities conflicts are minimised, the site can be safely accessed and worked in, the signals are visible, the area is not prone to flooding and the controller is unlikely to be struck by vehicles.

And finally, re-designing signalised intersections can include trying to re-use existing signals equipment. The signals designer should be involved early in the design process to ensure all the geometric design requirements are considered but also to manage the expectation that existing signals equipment can be re-used or relocated.

Existing signals infrastructure may become redundant through geometric changes to an intersection (i.e. kerbline changes, lane allocation changes, island changes, crosswalk changes), however it may also become redundant through changes required to the signals operation.
The place to start when considering modifying an existing intersection and keeping existing equipment, is a review of the as built drawings, the controller information sheets (and/or SCATS intersection graphics if CIS are not available) and a condition survey of the signals equipment, chambers and ducting to confirm the type and condition of existing equipment. If as built drawings are not available a topographic survey will be required to confirm equipment locations.

In Ground Detectors

Inductance loops used for vehicle and cycle detection cannot be re-used -

generally they are 40mm to 100mm beneath the road surface. If limit line locations are changed, loop locations will need to change. If the road surface is being disturbed, they will need to be replaced. They are also difficult to re-cut without resurfacing as the pavement integrity is damaged with multiple sawcuts.

Using an existing Controller

Typically, controllers are not installed with significant spare capacity for additional inputs. If additional detectors are part of the re-design of an existing intersection there is the potential the existing controller may need to be replaced due to inability to manage the additional inputs. The controller may also be redundant technology.

Using existing poles and signal displays

Pole foundations are concreted in. Unless poles are socket or flange mounted relocating existing signal poles may not be possible.

Existing signal heads may be able to be re-used if they are in good condition and existing lanterns may be able to be re-used only if they are LED. Reusing old Tungsten Halogen lamps is false economy as they need to be replaced every 6 months to avoid premature failures.

Using existing ducting and chambers

Signal cables are pulled through ducts between the controller, chambers and the poles. Over time ducts can be compressed or damaged due to vehicle loads. Existing ducts may need to be abandoned rather than re-used unless they can be inspected and confirmed are suitable for re-use and cables can be re-drawn through them without damage.

In addition, the size of ducts in place at an existing intersection may not be suitable for new installations or cables may have previously been direct buried and no ducts were installed.

Any questions or comments?