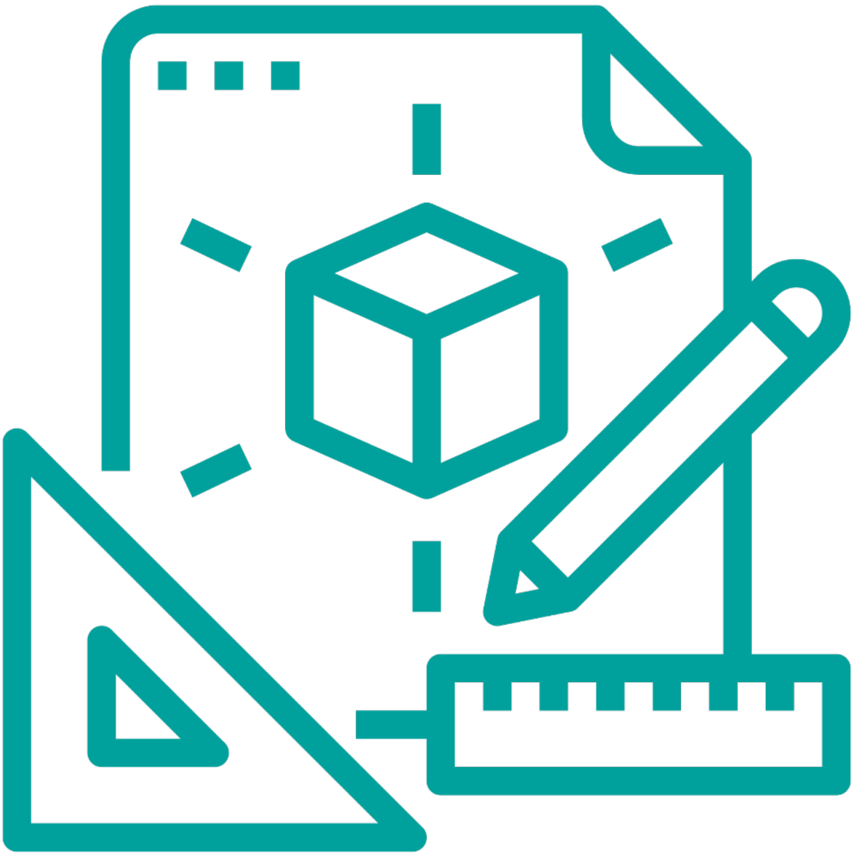
OPENAIR

Operational Network of
Air quality Impact Resources

Best Practice Guide

BP210 | Develop

Sensing device deployment planning: detailed design



Introduction

To establish a smart sensing network, a deployment planning process is required to establish where to locate devices, how to mount and install them, and how to secure approvals.

There are two stages to this sensing device deployment planning: high-level design, and detailed design (see Table 1). This OPENAIR Best Practice Guide chapter covers the ***detailed design*** process, with discussion of factors such as micro-siting (choosing the height and orientation of devices), device labelling, and how to document device deployment to support well-managed network operations.

It is recommended that you refer to the Best Practice Guide chapter *Sensing device deployment planning: high-level design* before engaging with this chapter.

*Table 1. Overview of **high-level design** and **detailed design** of sensing device deployment planning*

High-level design (not covered in this chapter)	**Detailed design** (the focus of this chapter)

This chapter does ***not*** **address the following *high-level* design topics:**
• General deployment locations
• General mounting infrastructure
• Power supply strategy
• General mounting solution(s)
• Access planning
	This chapter addresses the following ***detailed*** **design topics:**
	• Planning detailed deployment options:
	  - Identifying *specific potential locations and mounting infrastructure options*
	  - Confirming *specific mounting solutions*
	  - Conducting *communications checks*
	  - Considering *micro-siting of devices*
	• Documenting detailed deployment options for approval
	• Securing approvals
	• Labelling devices

Who is this resource for?

This resource is intended to assist people working within local governments tasked with the practical delivery of an air quality monitoring project using smart low-cost sensing devices.

How to use this resource

This Best Practice Guide chapter builds on high-level design activities, and provides more detailed guidance on planning and documenting sensing device deployment. As noted, use this chapter after completing the high-level design process (refer to the OPENAIR Best Practice Guide chapter *Sensing device deployment planning: high-level design*).

Before you begin

1. Be clear about the practical criteria for mounting and operating devices, as defined by the devices themselves

You should have a clear idea of the devices that you intend to procure (refer to the OPENAIR Best Practice Guide chapter *Sensing device procurement* for guidance). The specifics of the design and operation of your chosen devices will help to define a set of practical criteria for a viable deployment location.

For example:

- a solar-powered device requires adequate solar exposure
- a larger device, or a device with a large solar panel, requires a pole of a suitable size and strength to ensure that it is stable and secure
- a device that requires mains power will be limited to mounting infrastructure with mains access
- a device that uses a custom smart pole mounting bracket may be limited to mounting on one particular type of smart pole design.

2. Ensure that your budget is comprehensive

Detailed planning and deployment of a smart sensing network may carry a range of hidden and unanticipated costs. Aim to familiarise yourself with the detailed design process as early as possible to ensure that your project budget can cover all these costs.

Some of the potentially hidden or unanticipated costs may include:

- additional hardware purchases (e.g. non-standard mounting equipment; survey equipment)
- labour associated with planning (e.g. engineering assessments; design of custom brackets)
- labour and overheads associated with installation (e.g. assembly and fabrication; crane/tele-lift hire; high-voltage-certified electrical contractor)
- device labelling (e.g. graphic design; printing)
- administration (e.g. to support a prolonged and complex approvals process).

3. Review key stakeholders relevant to detailed deployment planning

There are several groups of stakeholders referred to in this document. It is helpful to identify your own network of relevant project stakeholders, including specific organisations, departments, and individuals (and to confirm their contact details) before you begin detailed planning.

Key stakeholder groups may include:

- land owners (e.g. local government; state government; private developers)
- internal teams with jurisdiction over public space (e.g. parks; sports facilities; street infrastructure)
- mounting asset owners (e.g. state government)
- mounting asset contractors (e.g. smart pole vendor with maintenance contract)
- regulatory authorities that may need to provide approval (e.g. Transport for NSW)
- service providers (e.g. energy utility; communications network provider)
- preferred installers (e.g. local government street infrastructure team; preferred electrician)
- internal public engagement and communications teams (with respect to interpretive labelling).

CASE STUDY: the complexity of stakeholders in the City of Sydney

Image source: UTS

This image of an intersection in Sydney helps to illustrate the complex stakeholder relationships that need to be considered during the detailed deployment planning phase of a smart sensing network.

Smart poles in this image were initially owned by the NSW Government's transport authority, but then handed over to the City of Sydney. The City has jurisdiction over side streets, but not over main roads. The State transport authority manages main roads and the light rail, and must approve devices mounted on poles within these corridors, even if the poles are owned by the City. Smart poles are all managed through a contract with a single vendor, who must approve any devices mounted on the poles, and must also design any custom brackets. Devices mounted on the poles make use of mains power delivered by the City's energy utility provider, and communications are provided by a local area network that is managed by the University of Technology Sydney (UTS).

Planning detailed deployment options

Start by planning specific detailed deployment options for your sensing device network that can be submitted for approval (see Figure 1).

1.	**Identify specific locations and mounting infrastructure**	**Aim:** In each of the general locations selected for your sensing device network, identify a set of possible deployment locations and mounting infrastructure[1] options that can be considered for approval.
2.	**Confirm specific mounting solutions**	**Aim:** Confirm a detailed, practical approach for physically connecting a device (and associated components) to a chosen piece of mounting infrastructure.
3.	**Conduct communications checks**	**Aim:** Confirm a detailed, practical approach for physically connecting a device (and associated components) to a chosen piece of mounting infrastructure.
4.	**Consider micro-siting details of devices**	**Aim:** Confirm micro-siting specifics for each potential deployment location.

Figure 1. Four key steps to take in preparing for the deployment of your project's sensing devices

[1] Mounting infrastructure is the physical, fixed infrastructure on which sensing devices are mounted (most commonly, a pole).

1. Identify specific locations and mounting infrastructure

Aim: In each of the general locations selected for your sensing device network, identify a set of possible deployment locations and mounting infrastructure options that can be considered for approval.

Conduct site visits and assess options

It is important to spend time getting to know and understand a possible device deployment location first-hand. Take lots of photographs, and try to think broadly about potential options.

In the high-level design process, you would have identified one or more generic options for mounting infrastructure (e.g. local government-owned steel light poles). It is now time to find *individual* examples of mounting infrastructure in situ, and to assess their suitability on a case-by-case basis.

You should consider the suitability of each specific mounting infrastructure option using the following criteria:

- **Is it methodologically appropriate?** Can the chosen piece of mounting infrastructure meet your methodological requirements for correct installation of a sensing device, in order to support your chosen data use case?
- **Is it practically appropriate?** Does the chosen piece of mounting infrastructure meet practical needs in terms of power, communications, and structural security?

TIP: DEVELOP BACKUP DEPLOYMENT LOCATIONS

For any sensing network larger than a few devices, it is advisable to develop backup deployment location proposals equal to 20% of your total locations (i.e. 2 backup locations for every 10 devices in your network). Gain approval for these as part of your initial planning and approvals process.

The reasoning for this is that once your network is deployed, a troubleshooting process will begin. It is normal for some device deployments to run into challenges, despite the best possible planning. The communications signal might be too weak, or the solar exposure might be too low. In these cases, a device will need to be moved. You can streamline that process (and save time) by having some pre-approved backup locations ready to go.

3. Confirm specific mounting solutions

Aim: Confirm a detailed, practical approach for physically connecting a device (and associated components) to a chosen piece of mounting infrastructure.

During your high-level deployment planning, you will have identified one or more *general* mounting solutions for your chosen devices and mounting infrastructure. You now need to consider *specific* mounting solutions for each of your potential deployment locations.

For each location, consider these factors:

- the out-of-the-box mounting solution for devices and whether this will suffice; if not, design custom solutions (e.g. a translation bracket and/or extension pole) as required
- mounting solutions for *all* hardware, including devices and power supply equipment (such as solar panels or external batteries)
- the impact of wind loading, and ensuring any solutions meet engineering requirements (you may need to engage an engineer to assess and advise on this).

A complete mounting solution will generally include:

- A bracket or combination of brackets connecting the device to the mounting infrastructure (this may include a custom connector that bridges the gap between existing standard brackets; see Figure 2)
- Any extension poles/masts required (e.g. to achieve the required height off the ground)
- Fixings (e.g. screws, bolts, bands, and clamps).

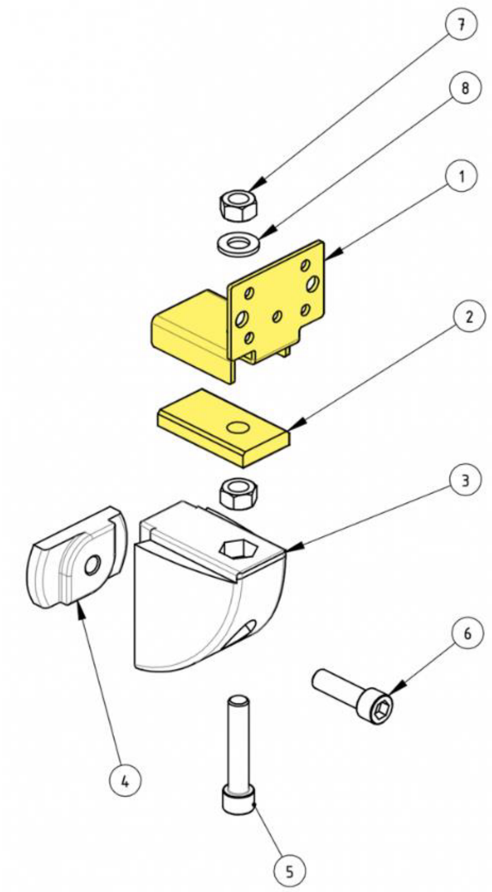


Figure 2. An example of a custom bracket (yellow) created to connect an existing smart pole connection bracket with the out-of-the-box brackets for a sensing device. Parts 3 and 4 connect to the channel of a smart pole. Plate 1 connects to the out-of-the-box bracket of two different sensing devices.

Figure source: UTS

Custom poles and tree-mounted devices

As you search for mounting infrastructure in a target location, you may find yourself struggling to identify a suitable option. There are two suggested approaches to ensure that a device can be deployed in a place that lacks existing fixed mounting infrastructure: using custom poles, or tree-mounted devices.

Custom poles

You can install a custom pole designed specifically for mounting a chosen sensing device in a particular location. Many local governments already have street infrastructure teams, which means that the work to fabricate and install a custom solution may be low-cost and uncomplicated.

Variations on custom poles include:

- a free-standing pole
- a J-pole that elevates and extends a device above a building or roofline
- an extension arm that holds a device away from a large pole to ensure better airflow and avoid thermal radiation.

A J-pole extension installed in Sutherland Shire (NSW) for the purpose of mounting a Clarity air quality sensing device.

Image source: Sutherland Shire Council

Tree-mounted devices

It is possible to mount devices on trees. However, there are several factors to consider, depending on your project or data use case, including:

- ambient temperature under a tree canopy may be slightly lower than the surrounding area
- trees can generate biogenic emissions that will show up in air quality measurements, potentially interfering with sensing device readings
- tree-mounted devices are more likely to experience fouling associated with insects and spiders
- drilling or screwing into the trunk is often undesirable, as it may cause disease in the tree
- trees grow, so any straps used to install a device may dig into a tree and damage it over longer periods (wind can also cause friction damage)
- trees move in the wind, which may result in damage to a device (e.g. if a branch falls on it).

A tree-mounting solution that uses a hangboard. Straps are loose to accommodate tree growth, and are covered with rubber tube to protect the tree. The board is heavy hardwood that will not move in the wind, and blends in visually with the tree.

Image source: UTS

3. Conduct communications checks

Aim: Confirm that each potential deployment location and mounting infrastructure option has viable communications.

Is this something that you need to do?

The strength and reliability of wireless communications used for smart sensing can vary, even across small distances. A general deployment area may have good signal coverage, but specific locations within that area may not. Tall buildings, trees, or undulating topology can all block or attenuate signal, causing highly localised black spots.

By conducting communications checks for each proposed location during the planning stage, you can avoid deploying devices in locations with marginal or unviable signal coverage. This prevents future complications, and the extra time and effort required upfront tends to pay off in the long run.

The relative importance of conducting detailed, on-the-ground communications checks depends on the communications technology being used (see Table 2).

Table 2.The relative importance of conducting on-the-ground communications checks (for different types of communications technology)

Less important to conduct on-the-ground communications checks	More important to conduct on-the-ground communications checks
4G, NBIoT	LoRaWAN, Sigfox, Wi-Fi
Widespread infrastructure with comprehensive geographical coverage Good signal penetration	More likely to have sparse or patchy geographical coverage Poorer signal penetration

Equipment for conducting communications checks

The viability of communications coverage at a given location is determined through a combination of signal strength (RSSI), and signal-to-noise ratio (SNR).

RSSI is impacted by distance from a communications gateway, as well as by line of sight. Depending on the technology used, certain radio frequencies can also bounce off (or pass through) buildings and trees, though all are blocked entirely by topology.

SNR relates to the volume (or ‘loudness’) of the communications signal relative to the radio background noise, which tends to be higher in urban areas. Some locations have background noise that drowns out weaker communications signals.

To conduct signal checks, you will need a handheld device capable of checking RSSI and SNR. There are three approaches you can take, as follows:

1. **Purchase a specialist device.** You can purchase a specialist device designed for conducting signal checks for your chosen communications technology. This is the more expensive approach. It streamlines workflow and scales easily, so it tends to make sense for larger network deployments, but not so much for smaller pilot deployments (due to the cost of the device).
2. **Use one of the sensing devices that will be deployed.** Take a pre-configured sensing device of the type that will be deployed, and activate it at the test location. You need to have access to reported telemetry for RSSI and SNR, but most device types should supply this. Ideally, you want real-time access to this data on a mobile phone or tablet in the field. This enables you to review and respond to the location, and update your plans based on the signal viability data (e.g. rule out location option A and select location option B). This approach is simpler and more cost-effective than using a specialist device, and it may also provide a more accurate assessment of how a particular device type (with custom communications settings) will perform. However, it tends to be more manually intensive and time-consuming to work in this way, and is not a good method for scaling.
3. **Use a smartphone app.** A variety of apps are available for checking Wi-Fi and 4G/LTE signals using a smartphone. It is not possible, however, to use these kinds of apps to check LPWAN signal.

Methodology for conducting communications checks

Regardless of the signal testing device used, the method for conducting communications checks is the same.

In the field:

1. Hold the signal testing device as close as you can to the actual physical location in which you plan to deploy your sensing device.
2. Activate the device to obtain a reading for RSSI and SNR.
3. Repeat to collect a minimum of three repeat readings for each location (and ideally more).
4. Record all readings for each location, for future reference.

Back at your desk:

5. Calculate an average RSSI and SNR value for each location, based off multiple readings. The average is your guide. A large range may be a concern, in which case you may choose to discount the average and treat the 'worst' values as your reference.
6. For each potential location, use your collected RSSI and SNR values to rank the communications as either: good, fair, marginal, or unviable.
7. Discount all locations that are unviable; and favour locations with good and fair coverage.

TIP: HOW TO INTERPRET COMMUNICATIONS CHECKS

'Viable' RSSI and SNR readings are entirely relative to particular communications technologies and specific device types, so it is not possible to offer any sort of universal reference for viability in this chapter. It is recommended that you engage with your device vendor and/or communications service provider to understand what good, fair, marginal, and unviable signal readings look like (based on the specifics of your project devices and communications options).

What if a location is a high priority but has marginal communications?

Sometimes, a particular location might be identified as being a high priority for a project (e.g. a road intersection near a school), but may turn out to have marginal communications. Generally, it is advisable to avoid deploying devices in locations with marginal communications, as they will be at high risk of connection loss during poor weather, which will create gaps in the data record.

Fortunately, there are some measures that can be taken to improve communications for specific devices:

- **Check the orientation of a device relative to the nearest gateway.** The pole that a device is mounted on can block communications if it lies between the device and the gateway. Consider shifting the orientation to a different side of the pole.
- **Check for other highly localised physical obstructions.** A tree branch or sign mounted on the same street pole can be enough to attenuate signal. You may be able to position a device higher or lower than your planned standard height, to avoid such blockages.
- **Optimise device communication settings.** Most Internet of Things (IoT) devices should have configurable communication settings that allow them to operate more reliably in locations with marginal communications (e.g. spreading factor and transmission power). Speak with your device vendor about what is possible. Be mindful that optimising a device's communication settings often increases its power consumption. This can have implications for battery life, or the ability of a solar panel to provide reliable power supply.
- **Install an extra gateway nearby.** This may significantly improve RSSI and SNR at your target location. It can also support 'stereo' connectivity (i.e. two or more gateway connections), which helps to reduce the risk of connectivity loss during poor weather.

4. Consider micro-siting details of devices

Aim: Confirm micro-siting specifics for each potential deployment location.

Micro-siting refers to the specific decisions made about how to install a device at a particular location. Each context will have its own micro-siting considerations, but there are five main variables:

1. **Height above the ground**
2. **Orientation**
3. **Nearby pollution sources**
4. **Nearby objects and surfaces**
5. **Shading**

1. Height above the ground

This refers to the height that a sensing device is deployed above the ground that is immediately beneath it. Height above ground matters because air quality and heat change as you move up through the air column: conditions at 1 metre above ground will be different to conditions at 3 metres, or 6 metres. It is therefore desirable to standardise height above ground for all devices in one network (though this is not always possible, as discussed in Figure 3). Recording height above ground is also critical for data interpretation, including the ability to compare data from two different devices.

This urban heat sensing device at Sydney Olympic Park is installed on a wayfinding sign beside a cycle path, at a height of 3m. To achieve this height, the existing pole was extended (as part of the device installation). While 3m is well above head height (and may be fractionally cooler than the air that people are moving through closer to the dark-coloured asphalt), it was important to decrease the risk of vandalism, tampering, and theft. In this case, a compromise was made between a methodological ideal and a practical constraint. Image source: UTS.

Find a balance between the methodological ideal and practical constraints

There is no fixed standard for height above ground when it comes to the deployment of smart low-cost air quality and urban heat sensing devices. The choice made for any given device deployment is a pragmatic balance between the methodological ideal and practical constraints (see Figure 3).

The methodological ideal		Practical constraints
A well-designed data use case should determine a methodological ideal for data collection. For example, if the study is focused on human exposure to poor air quality on public streets, then the ideal height above ground would be average human head height (sometimes called 'the breathing zone'). If the focus is on exposure of residents on apartment balconies, then a different and more flexible approach to height above ground would be needed. You should be clear about what your methodological ideal is because it will form the primary reference for a preferred height.	**VS**	Practical constraints are factors that prevent deployment of a device at the preferred height. Common practical constraints include: • risk of vandalism, tampering, or theft (if a device is within reach, it is at higher risk) • risk of vehicle collision (the best way to mitigate this risk is to deploy a device above the height of most vehicles) • other infrastructure in the way (e.g. a sign or traffic light is already installed at the preferred height) • solar exposure (e.g. the preferred height may impact the amount of direct sunlight received by a solar panel, which may rule out certain options).

Figure 3. Balancing a methodological ideal and practical constraints

A device should be deployed as close as possible to the methodologically ideal height, with necessary adaptations to any practical constraints presented by the location.

Decide on a network standard height (and deviations)

The ideal approach is to decide on a 'network standard height' (the preferred deployment height for all devices in a network) that is based on a compromise between the methodological ideal and the key practical constraints. For example, a common choice is to deploy devices at 3 metres above the ground. This is close to human head height, but mostly out of reach in terms of vandalism, tampering, and theft.

Record height above ground for each device deployment

Due to deviations from network standard height, each device deployment in a network may have its own unique height above the ground. It is important to record this information accurately (specifying height to the nearest 0.1m) for inclusion in installation instructions, and for later inclusion in metadata.

2. Orientation

Orientation refers to the position of a device relative to its mounting infrastructure. This could mean stipulating whether a device is mounted on the north, south, east, or west side of a pole.

A large, solid street pole can block communications between a device and a nearby gateway. By considering orientation, this problem can be avoided. Image source: Lake Macquarie City Council

Orientation matters because it can impact:

- device communications (mounting infrastructure can physically block signal)
- solar power supply (solar panels must point north in the southern hemisphere)
- ambient temperature (solar exposure/shading will impact ambient temperature)
- risk of damage to the device caused by vehicle collision (avoid orientating devices that face the road on roadside poles)
- access (orientation towards a busy road may create challenges for installation and maintenance).

Orientation is both a practical concern *and* a data quality concern. Its impact on data quality may be subtle, but is nevertheless important. For example, marginal communications caused by obstruction from a pole may result in an intermittent data record that corresponds with poor weather events; or a small bias in ambient temperature may prevent accurate comparison between two sites in an urban heat study.

Stipulate a network standard orientation (and deviations)

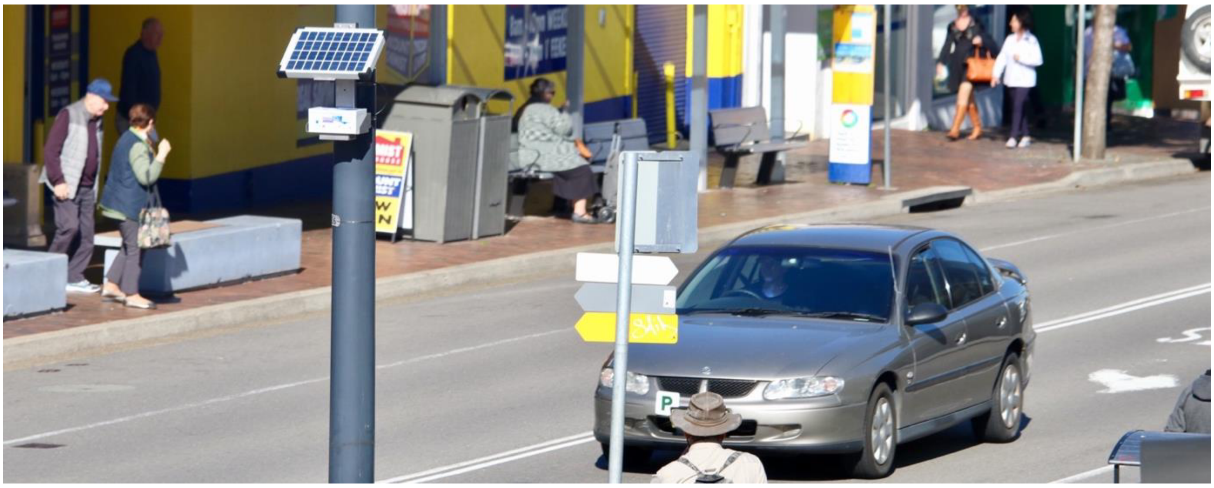
You may choose to stipulate a 'network standard orientation'. For example, if you are deploying solar-powered devices, you would likely stipulate 'north' as your network standard. Various practical constraints might cause deviation from that standard at specific sites (e.g. a sign that is already deployed at the preferred orientation and height). In such cases, the deviation should be recorded as part of the installation instructions.

Record orientation for each device deployment

Each device deployment in a network may have its own unique orientation. It is important to record this information accurately for inclusion in installation instructions (and for later inclusion in metadata). Aim to specify orientation to the nearest cardinal and inter-cardinal points of a compass (e.g. N, NW, W, SW, S, SE, E, NE).

3. Nearby pollution sources

One of the main benefits of smart low-cost smart air quality sensing devices is that they can be used to measure air quality in places that are traditionally unmeasured by regulatory monitoring. For example, the urban canopy layer (UCL) is the zone of air between the ground and the tops of buildings and trees within towns and cities. Within this zone, air is not well-mixed, and multiple, localised pollution sources can lead to uneven distribution of air pollution over very short distances. The variability of the UCL is straegically avoided by regulatory monitoring stations to obtain representative data for a wider surrounding area.



Smart low-cost sensing devices enable the study of urban microclimates. Image source: Lake Macquarie City Council

Smart low-cost sensing devices can be used to study air quality *within* the UCL, so that localised air quality or urban microclimates can be measured. These microclimates result from the intersection of multiple factors, one of which is nearby pollution sources.

Nearby pollution sources (and their interplay with the surrounding environment) are a micro-siting factor to be considered when planning the detailed deployment of a sensing device.

Common pollution sources in urban/suburban settings include:

- roads (particularly intersections with idling traffic)
- air conditioning outlets
- ventilation outlets from commercial kitchens
- chimneys (e.g. in residences with a wood stove).

The airflow in the immediate vicinity of the sensing device is another critical dimension to consider. Small variations in the micro-siting of a device, relative to the surrounding environment, can impact the exposure of that device to highly localised pockets of air pollution.

Align your approach to nearby pollution sources with the needs of your data use case

Contrary to established methodology for regulatory air quality monitoring, smart low-cost sensing devices may sometimes be positioned close to nearby pollution sources, if this is what your data use case requires.

The OPENAIR supplementary resource *A framework for categorising air quality sensing devices* defines four tiers for how air quality data can be used. Tiers 1, 2, and 3 all relate to the use of smart low-cost sensing devices, and describe data use cases where proximity to a nearby pollution source may actually be the intention and focus of a study, rather than something to be avoided.

EXAMPLE OF A PROJECT THAT INTENTIONALLY POSITIONS DEVICES CLOSE TO LOCALISED POLLUTION SOURCES

A project seeks to understand the exposure of people to diesel emissions while they wait in bus shelters. Particulate matter sensing devices are deployed inside bus shelters to capture highly localised diesel emissions that are trapped inside. Data shows that peak particulate concentrations are many times higher than the surrounding average, and regularly exceed recommended healthy levels.

Avoid the complexity of multiple nearby pollution sources (and unwanted interference)

Another micro-siting consideration is unwanted interference. The urban canopy layer is complex and extremely variable, and there may be multiple localised pollution sources. If your aim is to study only one of these sources, you should try to avoid the others to get a ‘clean’ set of data that is easy to interpret.

This may become challenging when the chemical relationship between different types of air pollution is considered. For example, if you are studying ozone around roads, the presence or absence of street trees may impact your data. This is because trees can be sources of biogenic emissions that react with ozone. You may therefore choose to deploy sensing devices in roadside locations with no street trees, to avoid this additional complexity. It is important to have a good grasp of the science behind your air quality issue, as that knowledge may well be critical to making informed deployment decisions.

Stipulate a network standard for nearby pollution sources (and deviations)

You may choose to stipulate a ‘network standard for nearby pollution sources’. This should be dictated by the specifics of your data use case, and may include multiple requirements. For example, a study of particulate pollution in inner-city street canyons might stipulate that devices should be deployed at least 5 metres from any air conditioning vents, *and* that devices should be deployed no more than 2 metres from the roadside.

Compared with height and orientation, deviation from network standard requirements for nearby pollution sources may have significant and unacceptable effects on data quality. Deviations should therefore be avoided as much as possible.

Record nearby pollution sources for each device deployment

Installation instructions for a device should define a location and micro-siting scenario that aligns with the needs of your data use case, and ideally adheres to a defined network standard. However, each device deployment in a network will likely still have its own unique set of nearby pollution sources, and it is important to capture this information to help with future data interpretation. The information may be difficult to quantify or standardise, so it is best to capture it qualitatively as a deployment 'note' (using an open text field).

4. Nearby objects and surfaces

Objects and surfaces in close proximity to a sensing device can impact its operation and data quality.

Communications signal obstruction

Solid objects can physically obstruct wireless signal between a device and a gateway, resulting in marginal or unviable connectivity (this effect is also associated with device orientation). Signal obstruction can extend in a wide radius around a particular deployment site, with trees, signs, buildings, and other infrastructure all being potential barriers. In complex environments, variations in micro-siting of less than 1 metre can mean the difference between a good or marginal signal. These micro-siting effects on communications strength are most pronounced with LPWAN and Wi-Fi.

Thermal interference

An object with thermal mass (the ability to absorb and retain heat) can radiate stored heat back out into the surrounding environment, warming the air around it. During and after warm or sunny periods, where an object with thermal mass is exposed to heat, any sensing devices located in close proximity to that object will experience higher ambient temperatures. For data use cases that require accurate ambient air temperature readings, or accurate gas readings, it is advisable to avoid nearby thermal interference.

Common examples of objects that cause thermal interference issues for sensing devices include:

- **Larger diameter steel and concrete poles.** These poles can heat up on a hot day, and may elevate ambient temperature close to their surface, impacting devices mounted on them. To avoid thermal interference, use an extension arm that holds a sensing device well away from the pole's surface (generally around 0.5m is enough to make a difference).
- **Walls and rooftops.** Walls and rooftops can be large thermal masses that also create their own microclimatic effects (such as updraughts). As a general rule, it is best to avoid having them in close proximity to a sensing device. Where devices must be deployed on (or near) a wall or rooftop, aim to hold them at least a metre away from these surfaces, using an extension pole or mast. Walls or rooftops that are permanently shaded (e.g. south-facing, or beneath a tree canopy) are of less concern.

Airflow obstructions

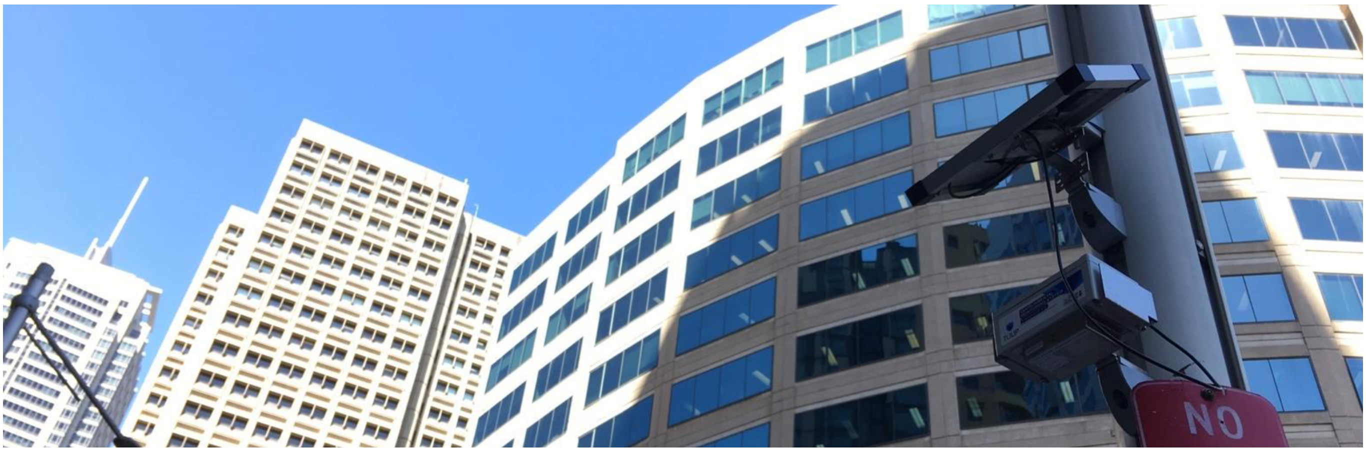
Nearby objects and surfaces can affect airflow around a device. This impacts the mixing of air, and can result in polluted air being trapped near a device for an extended period (or conversely, a device being sheltered from polluted air just around a corner).

This effect predominantly relates to the built environment, and can occur at various scales:

- **At larger scales**, a device located in the corner of a sheltered square or courtyard will have reduced airflow relative to a device located on an open street with crosswinds.
- **At smaller scales**, variations in airflow can be significant over spaces of only a metre or two, making this a micro-siting concern. An example is a street pole in a retail precinct, located next to a solid awning. A device located below the level of the awning would experience markedly different airflow to a device located on the same pole, but above the level of the awning.

5. Shading

Buildings, trees, and topology create shade. The amount of shade versus direct sunlight that a device is exposed to can vary over short distances. Shade and sun exposure can impact the operation and data quality of a device, making shading a micro-siting consideration.



An example of building shadow impacting a solar-powered sensing device in Sydney. Image source: UTS

Implications of shading for device operations

- **The ability of a solar panel to provide adequate power to a device.** If a panel receives less sunlight than it requires to meet the power demand of a device, the device will lose power.

Implications of shading for data quality

- **The impact of shading on ambient temperature.** Variations in solar exposure can impact the ambient temperature of a device. Shading can also vary on daily or seasonal cycles, or over short distances, creating notable differences in data output between devices deployed close to each other (e.g. on opposite sides of a street).

Shade and micro-siting considerations for a given location

- **Consider the implications of seasonal extremes**. How shaded will the chosen deployment location be in mid-winter? How exposed to direct sun will it be in mid-summer?
- **Consider the implications of prolonged overcast weather**. This is a particular concern for a site that is already partially shaded, where the amount of direct sun received may be sufficient during fair weather, but insufficient during poor weather.
- **Consider nearby vegetation growth**. Will summer leaf growth shade a device? Will nearby plants grow to permanently shade a device over the course of a season?
- **Consider optimising solar exposure by altering orientation.** You may choose to orientate a solar panel to optimise solar collection during periods of sun exposure. For example, for a location that receives morning sunlight but is shaded in the afternoon, you can orientate the panel to the north-east and collect more morning sun.

An example of pole clutter in Prague (the Czech Republic). Image source: Creative Commons

POLE CLUTTER

Pole clutter is the proliferation of hardware mounted on street poles, which can lead to unsightly outcomes in public spaces.

There are several ways to reduce pole clutter:

- **Establish a technology procurement policy**. Pole clutter tends to result from poor planning and ad hoc purchases.
- **Ensure that you have a well-defined data use case**, and that each device in the network is necessary for serving that use case. There is no point in adding to pole clutter with a device that is not actually needed.
- **Procure devices that are as compact as possible**, while remaining fit-for-purpose.
- **Consider using mains power supply**. Solar panels increase options for deployment locations, but they add to pole clutter and may also be unviable in shaded inner-city locations.
- **Put devices inside a pole**. Several commercial smart pole suppliers offer air quality sensing devices that can be mounted inside the pole. While this approach can resolve pole clutter concerns, caution should be exercised for the following reasons:
    - Your device procurement choices will be limited to a narrow range provided by the pole manufacturer, which may not provide fit-for-purpose data.
    - Data-as-a-service models are common in this scenario. This means that you would not own devices, and may not even own the data, which could have wider implications.
    - Airflow in and out of a pole can be restricted, impacting the accuracy of air quality measurements. It is best practice to mount devices away from a pole on an arm, ideally with a Stevenson screen that allows for 360° airflow.
    - Poles can heat up on hot days, and internal temperatures may rise well above ambient levels, interfering with the accuracy of measurements.

Document detailed deployment options for approval

The formal approvals you need for your sensing device deployments will be based on the assessment of detailed documentation that captures precisely what is being proposed. There are three key steps to putting together the necessary approval documentation:

1. Develop annotated site-by-site deployment proposals
2. Develop a master list and map detailing all proposed deployments
3. Develop detailed installation instructions.

1. Develop annotated site-by-site deployment proposals

Aim: To develop a specific proposal for mounting and installing devices at each potential deployment location.

Now that you have planned the options for site-by-site deployment of all devices in your network, you should have a collection of photographs of the various locations, and a clear idea of mounting infrastructure, power supply, micro-siting specifics, and a mounting solution for each one (see Figure 4 as an example). Collate this information into a visual proposal document, including *all* potential deployment sites (as well as backups).

Railway Square, main crossing, south

-33.882998, 151.204203

Mounting infrastructure: Smart pole

Owner: City of Sydney

Pole ID: [*XXX*]

Site access: Public

Device type: Smart sensing device X

Height: 4.5-5m

Orientation: North-east

Power: Solar

Signal strength: Strong

Figure 4. An example of an annotated site installation proposal.
Image source: UTS

2. Develop a master list and map detailing all proposed deployments

Aim: To develop a list of all proposed deployment locations (including key locational metadata), and to enter this information into a shareable digital map.

Develop a master list of all proposed deployments to accompany your annotated site-by-site installation proposals. Create a spreadsheet from this list. This is the first draft of what will become your master metadata record (see the OPENAIR Best Practice Guide chapter *Data labelling for smart air quality monitoring* for further guidance on the creation of a master metadata record). Capture the information for each annotated site proposal as metadata columns, with each site as a new row in the spreadsheet. You may wish to add additional details (such as a name and contact details for approvals, a preferred installation contractor, or a proposed installation date).

Once your master list of proposed sites is finalised, upload it to Google Maps to create an interactive map of all proposed deployments. Google Maps is a simple, free online tool accessible to anyone, on any device. It supports the creation of custom maps (using a spreadsheet with longitude and latitude coordinates as input), and can capture a range of associated metadata fields from the same sheet.

3. Develop detailed installation instructions

Aim: To develop detailed, step-by-step instructions for the installation of all sensing devices, for use by installers.

Installation instructions should accommodate variations between different locations and the mounting infrastructure options that you have chosen. For example, you might be deploying some of your devices on new smart poles, some on older light poles in parks, and one on the side of a building. In this case, generic installation instructions would relate to the three different types of installation (installation types A, B, and C).

Installation instructions for each installation type should include the following information:

1. **A schematic diagram.** A schematic diagram illustrates how the device (and any external power supply) is attached to the mounting infrastructure. It visually confirms the spatial relationship of all components. Ideally, a schematic diagram should include a close-up of the device and mounting assembly, and a contextual overview that shows the device relative to the ground and mounting infrastructure (see Figure 5).
2. **A list of components for assembly.**
   This should include:
   - the device
   - external power supply (if used) and cables
   - mounting bracket(s) (all components)
   - all fixings (screws, bolts, bands, clamps).

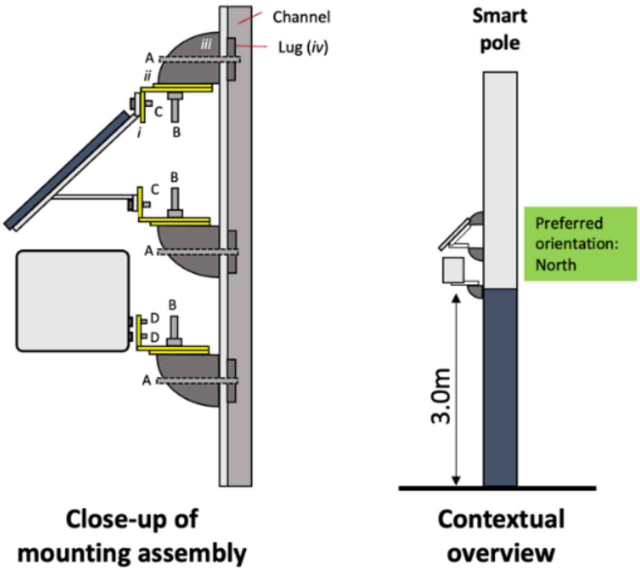


Figure 5. Example of a schematic diagram. Figure source: UTS

A step-by-step list of instructions for the complete installation process

This should include:

- Checks to ensure that the correct location/device has been selected
- Instructions for the physical installation of the device
- Workplace health and safety notes
- Capture of installation photographs
- Capture of other installation metadata.

A form for installation metadata capture

It is important that a small amount of critical metadata is captured when a device is installed. Create a form that installers can complete. Installation metadata should include:

- Date and time of installation
- Installer details (name, organisation)
- Actual GPS coordinates
- Actual height off ground
- Actual orientation
- Installation notes

Installation of an air quality sensing device and solar panel in Tweed Heads, NSW. Image source: Tweed Shire Council

INSTALLATION PHOTOGRAPHS

An example of a photograph that shows a device ID number relative to its deployment context. Image source: UTS

There are three types of photographs that should be captured for each installation:

1. **Unique device identification number/code.** Ensure that the photograph includes the external label with the device identifier *and* some context references that identify the location. This photograph can be used to help verify that each device was installed in the correct place.
2. **Close-up of device and mounting assembly.** Ensure that this photograph captures the close-up details of the device as it was installed, including external power supply (e.g. solar panel), mounting brackets, and mounting infrastructure (e.g. tree or pole). This photograph can be used to support device management and maintenance.
3. **Context shot.** Ensure that this photograph captures the complete deployment context. Include the ground beneath the device, and key surrounding physical elements (such as buildings and trees). This photograph can be used to help interpret sensing device data.

Secure approvals

The approvals process

There are three stages to the approvals process for device deployment (see Figure 6).

Approval of HIGH-LEVEL deployment plans

High-level deployment plans identify general intent, including general locations and types of mounting infrastructure, as well as general requirements for things like mains power and access.

Approvals at this stage are usually in principle only, pending further details. Approval may be required from the landowner, the mounting asset owner (if different), service suppliers (e.g. power utility; smart pole contractor), and the relevant roads and traffic authority.

Refer to the OPENAIR Best Practice Guide chapter *Sensing device deployment planning: high-level design* for more guidance.

Approval of DETAILED deployment plans

Detailed deployment plans specify all of the details for each proposed device deployment, which should be captured in documentation (as already outlined). Documents should be presented to all relevant authorities.

Ensure that you allow sufficient time for this stage of the approvals process. Many of the authorities in question may wish to conduct their own site visits to ensure that they are comfortable with what is being proposed, and this can increase the amount of time required.

Post-installation sign-off

Following installation, there may be a process of gaining final sign-off approval. This is likely restricted to the landowner and owner of the mounting infrastructure. At a minimum, this will generally require installation photographs and the final list of as-deployed devices being sent to the relevant authorities. However, it may also involve physical inspection of some or all of the installations by one of the approving authorities.

Figure 6. The three stages of the approvals process

Detailed deployment approvals

There are several things that need to be approved as part of the detailed deployment approvals process. These are:

1. Approval of locations and mounting infrastructure
2. Approval of detailed installation proposals
3. Approval of service connections
4. Approval of agreed period of deployment and removal.

Approval of locations and mounting infrastructure

Approving authorities

Mounting infrastructure owner; landowner (if different).

Aim

To gain approval for the installation of a device on a specified piece of mounting infrastructure.

This includes approval from the owner of that infrastructure. In many cases, the landowner is a separate authority that will also need to provide approval (e.g. a street pole owned by a utility company, located on local government land).

Practical considerations

- **Engage with specific departments.** You may need to engage with specific departments, either within your organisation, or within external authorities. Take the time to identify key contacts and to cultivate a relationship with them early on in your project. Examples include:
  - A device deployed in a park might require approval from a parkland manager
  - A device deployed on a street might require approval from a street infrastructure manager
  - A device deployed in a tree in a protected natural area might require approval from a specific natural areas team that manages conservation and compliance.
- **Consider future plans for the location.** A chosen location or piece of mounting infrastructure may have plans in place that will disrupt it during the planned period of device operation. These scenarios can present additional challenges to gaining approval, and should be factored into discussions and/or avoided if a more streamlined process is preferred. Examples include:
  - **Handover of a piece of mounting infrastructure or location from one owner to another.** This tends to occur with new developments, where there is an initial owner (e.g. a private developer) and a recipient authority (e.g. a local government) that takes over ownership upon completion of the site.
  - **Planned works, such as public space redevelopment.** This may involve the movement or replacement of mounting infrastructure, such as street poles. An area due for redevelopment is best avoided entirely; or you could make plans to deploy devices as part of the redevelopment, if timing allows.

Approval of detailed installation proposals

Approving authorities

Mounting infrastructure owner; landowner (if different); engineer (if requested)

Aim

To gain approval for the specific details of each device installation, including the mounting solution and micro-siting details.

Practical considerations

Relevant authorities should be presented with detailed information that describes how a device (and associated equipment) will be mounted. This includes information relating to:

- **Specifications.** The dimensions and weight of all equipment to be mounted.
- **Extensions.** Extension poles and masts designed to achieve desired micro-siting conditions (e.g. additional height), including precise details of how they will be installed.
- **Mounting assembly.** The complete assembly of brackets and fixings used to secure a device to the mounting infrastructure (or to an extension pole or mast).
- **Micro-siting.** The overall micro-siting of the device relative to the mounting infrastructure and location. This should be in the form of a schematic diagram that indicates height, orientation, and the device's position relative to existing hardware/infrastructure in the vicinity (e.g. a sign or traffic light).

A detailed installation proposal will be assessed in terms of:

- **Engineering compliance.** This involves assessment of the complete device installation assembly, to confirm that it is safe and secure. The assessment includes consideration of weight and wind loading relative to the strength of the mounting assembly and mounting infrastructure. Engineering compliance can require an engineer to assess and sign-off on the proposal.
- **Aesthetic impact.** This is of particular concern in busier public spaces, such as town centres and retail precincts. Assessors may consider the contribution of the installation to pole clutter, and the degree to which it fits (or clashes) with a general aesthetic standard or theme for the precinct.
- **Access, disruption, and risk.** This includes accessibility for the initial installation, as well as for ongoing maintenance. Approvals may require defined terms and conditions relating to access. Key considerations include:
    - **Site access**. Are special permissions required to access a restricted site?
    - **Personnel accreditation**. Do installers require specific access accreditation (e.g. working at heights)?
    - **Disruption to standard operations.** This can include the need for road closures; obstruction of a cycle path; temporary loss of services to a pole; or the temporary shutdown of mains power or overhead high-voltage lines.

- **Workplace health and safety (WHS) risk assessment.** Do the expected activities required for installation and maintenance comply with organisational WHS policy?

Approval of service connections

Approving authorities

Mounting infrastructure owner; and/or specific service provider

Aim

To gain approval for the physical connection of a device to critical services.

A device may require physical connection to mains power and/or data connectivity (e.g. ethernet connection in a smart pole). In such cases, the service provider will need to be engaged.

Practical considerations

- For mains power connection, a detailed electrical diagram may be required as an additional form of documentation.
- It is worth confirming whether the service provider requires installers to hold any specific accreditations.
- Mains power connection may require negotiation of a power supply agreement. It is best to formalise this during the approvals process. Even if no charge will be made for power consumption, this should be formally established. The same goes for connection to a private data network; you should formalise annual data usage, and clarify any recurring charges.

Approval of agreed period of deployment and removal

Approving authorities

Mounting infrastructure owner; landowner (if different)

Aim

To formalise how long each device will be deployed at a proposed location, and who is responsible for its removal.

The period of deployment for a device will be determined by whichever of the following three factors equates to the shortest period of time:

1. The operational lifetime of hardware, determined by the component with the shortest lifetime
2. The requirements of the data use case (e.g. at least one year of sensing device data is required)
3. The operational budget (e.g. operations might only be confirmed for one year).

Practical considerations

- **Plan for staff turnover.** Consider that the personnel responsible for decommissioning a device may not have been present within the organisation when the devices were originally installed. With this in mind, ensure that detailed and accurate installation documentation is created, with accompanying details of all approvals and associated agreements. Ensure that all of this information is stored in a centrally accessible database, and is easily discoverable.

- **Set a renewal date.** If the plan is to deploy devices indefinitely (assuming a hardware maintenance schedule is in place to ensure continued operation), it is still good practice to set a review and renewal date. For example, review the deployment in three years, and provide stakeholders with an opportunity to renegotiate terms.

Label devices

Operational labelling of devices

Deployed sensing devices should be physically labelled for the following operational reasons:

- The device needs to be uniquely identifiable for operational and management purposes.
- Staff or contractors who come across the deployed device need to understand what it is, who owns it, and who to contact for more information.

For example:

A new road sign is being installed on a pole that is hosting a sensing device. The road sign takes priority in terms of positioning, so the contractor responsible needs the sensing device to be relocated. Effective device labelling (see Table 3) can help to ensure that the device is treated with care, and that the contractor knows who to contact to discuss the issue, and to oversee the relocation of this device to ensure it still meets methodological requirements for sensing.

Table 3. An example of operational labelling for a device

	Field description	Example
Device serial number (or name)	An assigned unique reference	WEATHER013
Short description	A short description of the device	Air quality monitoring device
Instruction	A short instruction aimed at a third party	Should this device require moving or attention, please contact the organisation below.

	Field description	Example
Device owner	The organisation that owns the device (and department, if relevant)	City of Parramatta (Future City team)
Contact details	A generic phone number and/or email address	General enquiries 1300 617 058
Deployment date	DD/MM/YYYY	01/01/2023

TIP: AVOID USING A DEVICE'S UNIQUE IDENTIFIER ON LABELS

A 'unique identifier' is a critical piece of information associated with any smart device. It is an alphanumerical code that tends to be a fixed and unchanging reference for a device, often printed onto its internal circuitry or chip. This makes it possible to identify the device even if the device's assigned serial number or name changes.

A unique identifier is the key to accessing and controlling a device. As such, it should never be included on an externally visible device label, as this would constitute a security risk. Instead, assign a serial number or name that is associated with the unique identifier in your database, and use that on the external label.

Labelling for public interpretation and digital trust

Digital technologies are increasingly present in public spaces, but the public's trust in those technologies is not always high. When a member of the public sees a smart device, how can they be helped to feel confident about what it is, what data it is collecting, who is managing it, and whose interests it serves? An emerging approach to the labelling of devices seeks to address this challenge.

Digital trust is defined as "individuals' expectation that digital technologies and services – and the organizations providing them – will protect all stakeholders' interests and uphold societal expectations and values" (World Economic Forum, n.d.).

Poor digital trust is a challenge facing organisations that run smart sensing networks because:

- it significantly reduces the potential for newly collected data to support positive social impact
- it may threaten an organisation's social licence to operate a sensing network in public spaces
- it may increase the risk of vandalism associated with misconceptions about a device's purpose.

Digital Trust for Places & Routines (DTPR)

Digital Trust for Places & Routines (DTPR) is an open-source communication standard to increase the transparency, legibility, and accountability of digital technology in the built environment.

The core of the DTPR communication standard is a taxonomy of concepts around digital technology and data practices, and a set of icons to quickly and clearly communicate those concepts. All of the DTPR tools and resources can be accessed here for free.

These DTPR-approved icons can be used to label smart sensing devices deployed in the public realm. There is an increase in their uptake around the world, and the hope is that they will become established as a universally recognised standard.

CASE STUDY: DTPR pilot at Sydney Olympic Park, NSW

In 2023, the Sydney Olympic Park Authority (SOPA) began piloting the use of DTPR icons to communicate with the public about three digital technologies deployed throughout public spaces:

1. Closed Circuit Television (CCTV)
2. Dynamic Crowd Measurement (DCM)
3. Smart Irrigation Management for Parks and Cool Towns (SIMPaCT).

SOPA's aim is to be more transparent around the use of digital technology and data capture, and to improve the organisation's understanding of community attitudes towards digital technologies in public spaces.

The pilot project has co-located signs with visible digital technologies across Sydney Olympic Park. Signs feature DTPR icons, and contain information about what the technology does, and who implements it. A QR code links to a web page with more detailed information that is structured using the extended DTPR information taxonomy (classification). The web page features a quick survey to capture how people feel about the technology, and to gather feedback about how effective the icons are in communicating the purpose of the technology (see Figure 7).

Figure 7. The SIMPaCT project features a network of 13 smart weather stations. This sign, featuring DTPR icons, has been deployed on poles at head height to interpret this technology for the public.

References

World Economic Forum. (n.d.). https://initiatives.weforum.org/digital-trust/about

Additional resources

United States EPA* | *A Guide to Siting and Installing Air Sensors

The United States Environmental Protection Agency has produced a guide to the siting and installation of smart low-cost air quality sensing devices. The guide covers much of the same content included in this OPENAIR Best Practice Guide chapter and is broadly aligned, though geared towards a U.S. -based audience.

Tracking California (and partners)* | *Guidebook for Developing a Community Air Monitoring Network

This comprehensive practical guide to community-led air quality monitoring contains a section on *Network design and implementation* (Chapters 12, 13, and 14), covering some of the same topics addressed in this OPENAIR Best Practice Guide chapter. The full guide is worth consulting on all aspects of a smart low-cost sensing network project.

Environmental Defense Fund* | *Making the Invisible Visible: A guide for mapping hyperlocal air pollution to drive clean air action

This guide is a comprehensive overview of many different aspects of designing and delivering a smart low-cost air quality monitoring network.

Greater London Authority* | *Guide for monitoring air quality in London

This guide contains some basic guidance for planning an air quality monitoring network.

The Things Network* | *A guide to RSSI and SNR

A simple guide to RSSI and SNR (which are measures of data communications viability for a planned deployment location). This guide is written specifically to be relevant to LoRaWAN, but the same principles roughly apply to all LPWAN and wireless technologies.

Digital Trust for Places & Routines (DTPR)

DTPR is an open-source communication standard to increase the transparency, legibility, and accountability of digital technology in the built environment. It provides icons and a design guide that can be used as the basis for public interpretation signage for smart devices deployed in public places.

Associated OPENAIR resources

Best Practice Guide chapters

Sensing device procurement

This Best Practice Guide chapter provides guidance on the selection and procurement of smart low-cost air quality sensing devices. It explores critical considerations relating to the design and functionality of devices and the quality of the data they produce, supporting procurement choices that are appropriate to the needs of a project and organisation.

Sensing device deployment planning: high-level design

This Best Practice Guide chapter explores the high-level design of a smart air quality monitoring network. It provides general guidance for selecting where to deploy devices, what to mount them on, how to mount them, and how to support their operation.

Air quality sensing device activation and deployment

This Best Practice Guide chapter provides guidance for activating and deploying smart low-cost air quality sensing devices.

Data labelling for smart air quality monitoring

This Best Practice Guide chapter provides guidance on data labelling for smart air quality monitoring. It provides advice on developing and implementing a project data schema (which defines all of the telemetry and metadata that will be used in a project).

Supplementary resources

Sensing device deployment planning: high-level design template

This resource is a practical, step-by-step template for undertaking the high-level design of a smart air quality monitoring network. It covers how to identify general device deployment locations; identify suitable device mounting infrastructure; identify power supply options; develop device mounting solutions; and plan access and permissions.

A process and checklist for deploying devices

This resource provides a detailed, practical guide to activating and deploying smart low-cost air quality sensing devices.

A framework for categorising air quality sensing devices

This resource presents a new framework for categorising air quality sensing devices in an Australian context. It identifies four tiers of device types, separated in terms of functionality, and the quality and usability of their data output. It is designed to assist with the selection of devices that are appropriate to meeting the needs of a project and an intended data use case.

Further information

For more information about this project please contact:

Peter Runcie
Project Lead, NSW Smart Sensing Network (NSSN)
Email: peter@natirar.com.au

This Best Practice Guide chapter is part of a suite of resources designed to support local government action on air quality through the use of smart low-cost sensing technologies. It is the first Australian project of its kind. Visit www.openair.org.au for more information.

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