3.2 Identifying Impacting Factors and Emissions

Throughout this paper it has been discussed that there are several impacting factors which affect both the levels of pollutants produced and the ability of the AQ sensor networks to detect the pollutants. Therefore, if AQ levels are to be modelled it would be desirable to also measure the levels of these impacting factors to identify the sources to then decrease the uncertainties formed by these factors .
This section will seek to find methods to identify the levels of these impacting factors from available data sets. By utilising GitHub many open codes could be utilised to measure the impacting factors on AQ levels, which in turn could be used to predict and extrapolate the air quality in an area.

3.2.1 Traffic and Road Vehicle Emissions

One of the main impacting factors for NO_2, $PM_{2.5}$ and PM_{10} is the amount of traffic in the area. Chen et al [29] have created an open software code which computes the emission levels due to road vehicles and maps the level of emission for a given area. This software could be implemented into a model for emission levels as the traffic related sources of emission could be identified for the desired area. The volume traffic has the largest correlation to air pollution levels although many other features impact air pollution levels. The type of vehicle is a large feature along with its speed and style of driving. These are difficult to gain dataset of but with the usage of traffic cameras and computer vision technique these can be extracted. This is further to added to if ANPR camera are allowed to be applied to determine vehicle license plates. The additional usage of road structure of sharp corners, traffic lights, braking zone and accelerating zones these can be attributed to causing emissions. Another feature is the age of the vehicle and type that determines the emission levels. Large amount research has been done on this and a commercial option is provided by emission analytics of a database of vehicles, ages and emission levels.

https://www.emissionsanalytics.com/about

There are many methods to model traffic emission levels from individual vehicles to plume from many vehicles. Whether the analysis that is done on the plume is to model the expected traffic flow on transport networks or to identify individual vehicles motion from traffic cameras a large amount of high resolution, real time and accurate features about traffic is beginning to become available.

There is unfortunately a large difference in regions from the most innovate and often most congested have large amount of dataset to rural or less innovative regions have to apply limited data to modelling to gain uncertain results. The figure below identifies the feature of interest of this factor and possible method of extraction with accuracy levels.

Feature	Dataset	Extraction Method	Uncertainty or accuracy	Real time ability	Resolution factors
Traffic Volume	Google Maps	API	Medium	Yes	Low
Traffic Density	Traffic cameras	Computer vision	High	Yes	Spatial resolution
Vehicle type	Traffic cameras	Vivastreet and computer vision	High	Yes	Individual vehicle or ratio of volume
Vehicle emission	Traffic cameras	Vivastreet and	High	Yes	Exact or estimate

levels		emission analytics computer vision			
Vehicle speed	Traffic cameras	Computer vision	High	Yes	At location or on average over route
Vehicle acceleration	Traffic Cameras	Computer vision	Medium	Yes	At location or on average over route
Vehicle Age	ANPR	National Authority or DVLA API	Medium	No	Exact or estimation
Vehicle braking	Traffic cameras	Computer Vision	Medium	Yes	At location or on average over route
Vehicle load weight	Traffic cameras	Computer Vision	Low	Yes	Individual vehicle or estimate

Vehicle mileage	ANPR	National Authority or DVLA	Medium	Yes	Exact or estimate
Vehicle modifications	ANPR	National Authority or DVLA	Medium	Yes	Exact or estimate
Vehicle braking	Traffic cameras	Computer Vision	Medium	Yes	At location or on average over route
Vehicle Cold starts	Traffic cameras	Computer Vision	Medium	Yes	At location or on average over route
Vehicle parked	Traffic cameras	Computer Vision	Medium	Yes	At location or on average over route
Vehicle idling	Traffic cameras	Computer Vision	Medium	Yes	At location or on average over route

Vehicle waiting in congestion	Traffic cameras	Computer Vision	Medium	Yes	At location or on average over route
Road structure	openstreetmap	API and machine learning	Medium	Yes	At location or on average over route
Vehicle obstruction and accident	Traffic cameras, WAZE	API and Computer Vision	Medium	Yes	At location or on average over route
Road furniture	Satellite imagery , street imagery	Computer Vision	Medium	Yes	At location or on average over route
Road Signage	Street imagery	Computer Vision	Medium	Yes	At location or on average over route

Some the features used in air quality modelling and analysis can been in the figure below.

Table 3.1: Metadata information selected with focus on sampling point location and classification. References to the EU AQ legislation which requires the metadata to be reported are given in parentheses.

Mandatory - All	Mandatory - Traffic	Mandatory, where available	Voluntary
Inlet height (AAQD, Annex III. C.and 2011/850/EC II. D ii.19)	**Building distance** (AAQD, Annex III.C and 2011/850/EC, II. D.ii.20) .	**Station information** (2011/850/EC, II. D.ii.27)	**Dispersion local** (IPR Guidance, XML user guide D5.2.11.1 pp 199)
Altitude (2011/850/EC,II.D.ii.26)	**Kerb distance** (AAQD Annex III.C and 2011/850/EC, II.D.ii.21)	**Main sources** (2011/850/EC,II.D.ii.23)	**Dispersion regional** (IPR Guidance, XML user guide D5.2.11.8 pp 203)
Latitude, Longitude (2011/850/EC,II.D.ii.26)	**Distance to major junction** (AAQD Annex III.C and 2011/850/EC, II.D.ii.29),	**Spatial extent of representative area** (2011/850/EC,II.D.ii.16).	**Traffic emissions** (IPR Guidance, XML user guide D5.1.5.3. pp 127)
Classification of the area (2011/850/EC,II.D.ii.28)	**Traffic volume** (2011/850/EC,II.D.ii.30)	**Mandatory, where available - Traffic**	
Station classification (2011/850/EC,II.D.ii.22) .	**Mandatory - Industrial**	**Heavy duty fraction** (2011/850/EC, II.D.ii.31)	
	Distance from source (AAQD, Annex III.B.1.b and 2011/850/EC, II.D.ii.24)	**Traffic speed** (2011/850/EC, II.D.ii.32)	
	Industrial emissions (IPR Guidance, XML user guide D5.1.5.5. pp 128)	**Street-canyon - Width of street** (2011/850/EC,II.D.ii.33)	
		Street canyon - Height of building facades (2011/850/EC, II.D.ii.34)	

The availability of these features can be seen for the EU from 2018 in the figure below that were reported.

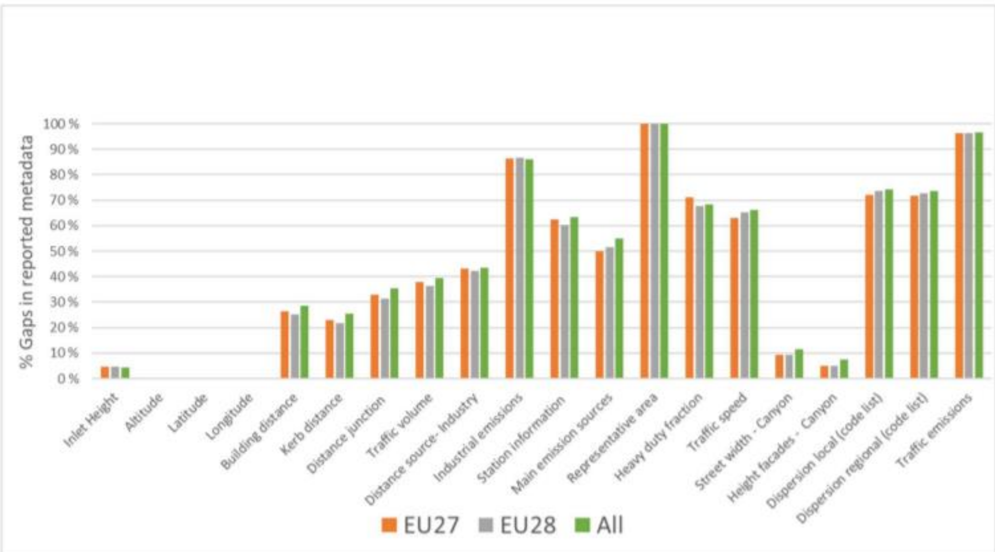

Figure 6.1. Summary of the metadata analysis showing the percentage of missing or not reported metadata

3.2.2 Wind, Relative Humidity, Precipitation, Air Pressure, Solar Radiation and Other Meteorological Factors

Another key factor on the emissions in an area is wind and humidity. This especially impacts particle matter pollution with PM and wind being negatively correlated and PM and humidity being positively correlated. Kulshresth has created a code [30] which predicts the levels of $PM_{2.5}$ in a city due to the wind and humidity at that time, which has been tested in Dehli with relative accuracy as the predicted versus the actual $PM_{2.5}$ values having an R^2 value of 0.80 [30]. This software could be implemented into a model for emission levels as wind and humidity are both already calculated by almost all low cost sensors, as mentioned in section 2.2, and therefore the levels of $PM_{2.5}$ could be predicted. Similar to most meteorological features there are accurate predictions at sparse spatial domain.

The most severe pollution episodes are usually associated with calm or very low wind speed conditions. Vignati et al. have shown that differences in prevailing wind speed conditions seem to explain much of the differences in urban pollution concentrations.

In urban areas, the wind direction is rarely constant over short periods of an hour or less. This is particularly true for low wind speeds, less than 1 m s−1. The dependence of concentration on fluctuations, when averaged over a period of an hour, is smoothed significantly. In order to account for this effect an averaging interval with respect to the wind direction is often applied Berkowicz and Hertel .

There is a lack of knowledge, analysis and prediction of wind or other meteorological prediction at the street level. One option is to just use machine learning method to predict from meteorological stations and interpolate the measurements although this has large inaccuracies. This is because of the complexity of the meteorological features. Another option is wind or meteorological modelling techniques either using gaussian methods or computational fluid dynamics methods. This can only be done for small zone and has its own sensitivities or uncertainties. There is still a lack of meteorological prediction at the street levels that can only be solved modelling.

Feature	Dataset	Extraction Method	Uncertainty or accuracy	Real time ability	Resolution factors	
Wind Speed at top of canyon or building rooftop	ECMWF	API	High	Yes	Metres	
Wind Speed at street level						
Wind Direction at top of canyon or building rooftop	ECMWF	API	High	Yes	Metres	
Wind Direction at street level						
Wind acceleration at top of canyon or building rooftop	ECMWF	API	High	Yes	Metres	
Wind acceleration						

at street level						
Wind turbulence at top of canyon or building rooftop	ECMWF	API	High	Yes	Metres	
Wind turbulence at street level						
Air pressure	ECMWF	API	High	Yes	Metres	
Wind temperature	ECMWF	API	High	Yes	Metres	
Solar Radiation	ECMWF	API	High	Yes	Metres	
Cloud cover	ECMWF	API	High	Yes	Metres	
Precipitation	ECMWF	API	High	Yes	Metres	
Relative Humidity	ECMWF	API	High	Yes	Metres	
Due	ECMWF	API	High	Yes	Metres	
Snow	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	

	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	
	ECMWF	API	High	Yes	Metres	

3.2.3 Atmospheric Turbulence

At very low wind speeds, the wind vortex in the canyon vanishes and turbulence created by the traffic flow will become significant in determining the highest pollution levels in a street canyon. In a street canyon, the flow of vehicles is generally dense and thus the turbulence field cannot be considered as a simple superposition of non-interacting vehicle wakes. For this reason, the vehicles in a canyon are considered as moving roughness elements. In Berkowicz et al.[39] it is shown that traffic-induced turbulence increases with the square root of the traffic flow and decreases with increasing canyon width. Apart from these parameters, knowledge of the number of vehicles passing the street per unit time and the average driving speeds of cars and heavy vehicles are needed. The flow regime within a street canyon is primarily determined by its geometry (e.g. height-to-width, (H/W), and length-to-height, (L/H) ratios). For wind flow across the street axis, Oke (1988)[40] distinguishes between 'skimming flow' with a characteristic vortex occurring for a relatively large H/W, 'wake intermediate flow' for intermediate H/W, and 'isolated roughness flow' for smaller H/W. As OSPM is a model designed for street canyons of aspect ratio close to 1.0 the model assumes an isolated roughness flow regime. As already explained, the Gaussian plume from local traffic within a street canyon of an aspect ratio of 1.0 is directly advected to the leeward side while on the windward side the impact is only from the air that has recirculated in the street for wind speeds greater than 2 m s−1.

3.2.4 Temperature Prediction.

As previously mentioned, temperature is the key impacting factor on the levels of ozone O_3 with the ozone pollution levels showing great seasonality due to temperature. This code by Handford uses historical data to predict the temperature for a specific location in the UK. This code could be implemented to predict general seasonality in temperature and therefore be utilised to predict any potential ozone spikes due to high temperatures. This a highly advanced domain with many accurate predictions produced in real time by European Centre for Medium Range Weather Forecasting, Met Office and other over a large area and within urban domains. The highly resolution prediction to street level are highly uncertain. There is a lack of measurement of temperature in a dense spatial domain. One option is to apply costly temperature modelling techniques either using gaussian methods or computational fluid dynamics methods. This can only be done for small zone and has its own sensitivities or uncertainties. This makes the heat island affect in urban zones difficult to analyse and therefor is lack of understanding and predictions of temperature at street levels in most cases.

3.2.5 Urban density

This is large impacting factor in how the air flows through an urban domain and how air pollution disperses. This is often why complex air quality modelling is required when urban density is complex and there is no available AQ sensors measurements to calibrate against. It is quite basic to measure with advent of GIS techniques and openstreetmap.org availability of urban density. There are still features about urban density that are of interest. Some of these are façade material of buildings, obstructions in transport routes, attachment to buildings, telephone cables, transport route signage and furniture. Many of these features are possible to extract through streetmap images and satellite imagery with computer vision techniques. The only limitation is the real time requirement from the analysis and sometimes the lack of high resolution imagery in real time.

Urban density						
Building heights	https://www.wudapt.org/, google, openstreetmap					
Aspect ratio of urban canyons						
Width of urban canyons						
Height of urban canyons						
Façade of buildings						
Pavement width						
Attachments to buildings	Street imagery	Computer Vision			Yes	
Road width						
Building morphology						

Road morphology						

3.2.6 Green Spaces

The green spaces have large benefits and impact on those in urban domain and the urban domain itself. There is large impact of green space on air pollution levels. Initially they reduce the emission because they limit traffic usage and promote non emission sources. They can also add chemical, biological and physical impacts on air pollution. The dynamics of the green space impact on air pollution is highly uncertain although it has been shown to be an overall positive to reduction in air pollution. In the majority the amount of green space needed to mitigation is often much larger than expected and feasible to implement. It main benefits and impact are to encourage reduction in emission. This is more affective as the main air quality experts state that the most effect reduction in air pollution is to erase the emission source not to mitigated air pollution. The majority of research is to identify the type of vegetation that positively impacts reduction in air pollution. Some sparse vegetation like some types of individual trees have been shown to allow air pollutant like PM to depose on the leave meaning it restricts the flow of the air pollution out of the urban zone. This then allow the air pollutant to recirculate and cause increased air pollution levels. So the main limitation is to determine the vegetation that benefits reduction in air pollution. The majority of these are hedges, parks and gardens.

3.2.7 Population usage

The usage of the domain impacts the exposure levels but can hinder air flows, increase CO2 emissions and cause more air pollution. It is often an indicator to more urbanisation which increases air pollution levels.

3.2.8 Land usage

The land usage is a factor in the type of emission and amount of emission along with potential for other impacting factors or green space, urban density etc… It is also the occupancy, social level and type of usage.

Social levels	https://data.unhabitat.org/pages/datasets, https://ghsl.jrc.ec.europa.eu/ucdb2018Overview.php				
Zone type	https://ourworldindata.org/urbanization				
Permanent or temporary residents					

3.2.9 Long range air pollutants

There are longer range air pollutants which occasionally can have a significant impact. These are dust storms, sand storm from sahara or desert regions. There are forest fires which have PM, NOx and Ozone impacts.