1. **Purpose**

   The purpose of this document is to provide a brief overview of the in-tunnel air quality modelling undertaken and provide the key results.

2. **Background**

   The North East Link reference project consists of a twin tube tunnel of approximately 6.1 km in length. There are entrances to the tunnel at Blamey Road and the Eastern Freeway, with two underground interchanges, consisting of ramp and merge zones, at Lower Plenty Road and Manningham Road.

   As part of reference project development, a ventilation system has been designed for the purposes of controlling in-tunnel air quality, preventing portal emissions and controlling smoke in the event of a fire.

   As part of the development of the tunnel ventilation system, in-tunnel air modelling was undertaken. This document contains an overview of the air modelling conducted in relation to in-tunnel air quality and contains key modelling results.

3. **Design and performance criteria**

   The ventilation system has been designed to perform two primary functions:

   a) Provide acceptable in-tunnel air quality during normal operations.

   b) Provide smoke control in the event of a fire incident.

   These functions must be achieved with compliance to design performance criteria. The design performance criteria are outlined below. Further details can be found throughout the document.

   Normal operational conditions are defined as traffic flowing with an average speed of 20 km/h or greater. For normal operations, the design has considered the following emissions criteria:

   - The in-tunnel air quality criteria are based on the NSW NO₂ policy of 0.5 ppm based on a tunnel/route averaged value.
In-tunnel visibility criteria are based on PIARC 2012 recommendations. In-tunnel carbon monoxide, CO, is not a constraining pollutant for normal operations. Nevertheless, the following in-tunnel criteria are applied:

- Maximum of 150 ppm
- 15 minute average of 50 ppm
- Two hour average of 25 ppm

Under normal operations, the design has considered the following air speed and portal restrictions:

- The average longitudinal air velocity in any tunnel section does not exceed 10 m/s.
- The ventilation system is designed to have no null points, i.e. no stagnant or zero net velocity air.
- The tunnel ventilation system is designed to have zero net portal emissions.
- Vehicle and road tunnel emissions are to be discharged from a vertical structure that satisfies EPA Victoria design requirements and SEPP(AQM) design criteria.

Average vehicle speeds within the tunnel less than 20 km/h are considered to be abnormal operations for the purposes of this assessment. Under these scenarios, traffic management, such as lane closures, is to be implemented, with the objective to keep the average speed above 20 km/h. This design and operational constraint is consistent with other current tunnel design and construction in Australia, i.e. Westconnex in Sydney. In-tunnel pollution concentrations design limits cannot be achieved for average traffic speeds of less than 20 km/h (abnormal operating conditions).

Indefinite stationary vehicle scenarios have been examined and in-tunnel pollution limits cannot be achieved with the current design. Furthermore, due to the multiple interchanges and tunnel surface connectivity, a situation of 6 km of stationary traffic for any period of time is highly improbable.

In relation to fire incidents, smoke is to be controlled to prevent smoke ‘back layering’ and allow for emergency responders to approach an incident in a contra tunnel flow direction, utilising an overhead smoke duct for smoke capture. For locations other than all off ramps and within 100 m of portals, the smoke is to be discharged out of one of the main ventilation station outlets and the Manningham Road emergency ventilation station. The maximum design fire for the calculation of critical velocity is 50 MW.

4. Methodology

4.1 Software

IDA - RTV

The tunnel ventilation assessment utilised the tunnel ventilation analysis software IDA-RTV, as supplied by EQUA Simulation AB and purpose built for the analysis of road tunnel operations and emissions. This software has been used on a number of road tunnels in Australia, such as Westconnex.
The IDA-RTV model is a one dimensional computational fluid dynamics (CFD) model purpose built to model traffic induced airflows and emissions in tunnels. It can allow dynamic response and control of the tunnel ventilation system to be assessed. It has traffic flow models and heat transfer capabilities.

The IDA-RTV software package was used to model emissions for the projected traffic based on the EES reference project.

**ANSYS Fluent – CFD**

The computation fluid dynamics (CFD) modelling package, ANSYS Fluent 19.2, was used for the assessment of ventilation station design performance, jet fan installation factor estimation and smoke control in merge zones. The software allows for a CFD model of the proposed design to be analysed, in three dimensions, such that pressures, velocities, flow rates and numerous other factors affecting the tunnel ventilation system are simulated and assessed.

### 4.2 Tunnel ventilation system

The EES reference project includes two ventilation structures at the:

- Northern portal
- Southern portal.

Additionally, an emergency smoke discharge structure would be located at the Manningham Road Interchange – for emergency discharges only during fire events. This location was selected as it is in-between the two portal stations and located close to the Manningham Road interchange that was identified as having a higher risk of underground vehicle collisions and fires.

Overall the tunnel ventilation system for the EES reference project consists of the following components:

- Two ventilation structures, northern portal (Blamey Rd) and southern portal (Bulleen Rd) with expected discharge heights of 40 metres
- One emergency smoke discharge structure at Manningham Road Interchange, with a discharge height of at least 3 metres above local roof level, in compliance with AS 1668.2-2012 (The use of ventilation and air conditioning in buildings – Mechanical ventilation in buildings), clause 3.10.3.
- In-tunnel jet fans – likely number and power consumption are subject to change. Indicative number = 209 reversible jet fans (100 in the northbound tunnel and 109 in the southbound tunnel), each with an indicative power consumption of 45 kW
- Overhead smoke duct with dampers arranged in groups of four or more, spaced at 80 metres centres, with a connection to the Manningham Road emergency ventilation station.

### 4.3 Traffic

The traffic predictions prepared for NELP for 2026 and 2036 were used as the basis for the in-tunnel air quality modelling undertaken. The Victorian vehicle fleet composition was also taken into account.
The speed of the traffic through the tunnel determines the ventilation and the power requirements of a ventilation system. With free flowing traffic, travelling at 60 km/h or greater, the piston effect provides almost all of the required ventilation for the tunnel, with the prevention of portal emissions at the interchange off ramps being the primary design consideration.

Under abnormal operations, 20 km/h or less, the motion of the vehicles does not provide enough piston effect force to induce a large enough airflow to maintain acceptable in-tunnel air quality. Under congested traffic conditions, the piston effect needs to be augmented via the use of axial jet fans installed on the roof of the tunnel.

A range of traffic conditions were considered in the tunnel ventilation assessment including vehicle speeds from standstill (0 km/h) to 80 km/h. The tunnel has not been designed for traffic operations where the average traffic speed is less than 20 km/h as these are considered to be abnormal operations. Under slow traffic conditions (for example as a result of an incident), traffic management procedures will need to be implemented to restrict vehicles entering road tunnels.

4.4 Emissions factors

Emission factors were used to estimate the rate and quantity of pollutants emitted by road vehicles using the tunnels. PIARC 2012 emission factors were selected to be used for the in-tunnel modelling for NEL. This is consistent with all road tunnel projects undertaken in Australia over the last 25 years. PIARC provides emission factors for carbon monoxide (CO), oxides of nitrogen (NOx) and particulate matter (PM) as measured by the light extinction coefficient, k, which is a measure of tunnel visibility.

The PIARC (2012) design guideline was used as a basis of the assessment.

$\text{NO}_2: \text{NOx}$ emission ratio was estimated based on the difference vehicle classes and emission Standard, for example, Euro 3 diesel passenger cars were modelled as emitting 51 percent $\text{NO}_2$.

Exhaust PM emissions for petrol (gasoline) engines are not available in PIARC 2012 however, following a review of appropriate literature (Keogh et al, 2010; USEPA/Nam et al, 2008), PM exhaust emission factors from petrol vehicles were implemented, with tunnel grade and speed adjustments applied.

Road dust (PM) emissions were also included, based on recommended PIARC 2012 values.

1 Exhaust PM emissions for petrol (gasoline) engines are not available in PIARC 2012.
All PM emissions for all sources were assumed to be PM$_{2.5}$.

Age degradation factors were applied to all vehicle classes, where older vehicles were modelled as producing higher emissions.

5. Results

In-tunnel concentration profiles of assessed pollutants NO$_2$, CO and PM$_{2.5}$ (as turbidity/extinction coefficient, $k$) were calculated for a range of traffic scenarios. Jet fans and main ventilation fans were modelled and configured to prevent portal emissions. Tunnel flows were balanced using portals target inflows of between 0.5 and 1.0 m/s (0.75 m/s considered ideal).

The IDA-RTV software package was used to model the vehicle movements and emissions and the required number of jet fans based on inputs from the emissions model. The key results of the analysis are as follows:

- Compliance with visibility criteria was achieved for all assessed scenarios.
- Compliance with CO criteria was achieved for all assessed scenarios.
- Compliance with NO$_2$ criteria was achieved for normal operations, being average traffic speeds of 20 km/h or greater. For assessed average vehicle speeds of less than 20 km/h (abnormal operating conditions), compliance with the NO$_2$ 0.5 ppm (15-minute) tunnel/route average criteria was not achieved. Under these situations, traffic management, such as lane closures, is to be implemented, with the objective to keep the average speed above 20 km/h.

Graphical plots of in-tunnel concentrations are shown for the year 2026 in Figure 1 to Figure 4 for the southbound tunnel and Figure 5 to Figure 8 for the northbound tunnel. The graphical plots present the predicted instantaneous concentrations at points along the tunnel, however compliance with the design requirements is based on a 15-minute average concentration. Based on the instantaneous concentrations the averages have been used to assess compliance. Plots are only presented for year 2026 as pollutant levels are uniformly higher than they are for year 2036.
Figure 1  Southbound 2026 mainline in-tunnel NO₂ concentration (ppm) profiles

The above graph shows instantaneous concentrations at points along the tunnel, however compliance with the design requirements is based on a 15-minute average concentration.
Figure 2 Southbound 2026 mainline in-tunnel CO concentration (ppm) profiles

**Legend:**
- Blue dashed line: SB 2026 CO - 80km/h congested
- Orange dashed line: SB 2026 CO - 60km/h congested
- Black line: SB 2026 CO - 40km/h congested
- Red line: SB 2026 CO - 20km/h congested
- Light blue dashed line: SB 2026 CO - 10km/h congested
- Green line: SB 2026 CO - 0km/h congested
- Black dashed line: SB 2026 CO - 7am AWDT
- Yellow line: CO 15-min Avg Limit

**Axes:**
- Y-axis: CO (ppm)
- X-axis: Mainline Tunnel Position (m)
Figure 3  Southbound 2026 mainline in-tunnel visibility extinction coefficient, k (m-1) profiles
Figure 4: Southbound 2026 mainline in-tunnel PM$_{2.5}$ concentration ($\mu$g/m$^3$) profiles.
Figure 5  Northbound 2026 mainline in-tunnel NO2 concentration (ppm) profiles

The above graph shows instantaneous concentrations at points along the tunnel, however compliance with the design requirements is based on a 15-minute average concentration.
Figure 6 Northbound 2026 mainline in-tunnel CO concentration (ppm) profiles
Figure 7  Northbound 2026 mainline in-tunnel visibility extinction coefficient, k (m-1) profiles
Figure 8 Northbound 2026 mainline in-tunnel PM$_{2.5}$ concentration ($\mu$g/m$^3$) profiles
6. Conclusion

Compliance with all in-tunnel pollution performance criteria (specified in section 3) can be achieved between Blamey Road and the Eastern Freeway for normal operating conditions (average vehicle speeds greater than or equal to 20 km/h). For assessed average vehicle speeds of less than 20 km/h, compliance with the NO\textsubscript{2} 0.5 ppm (15-minute) average criteria was not achieved. The tunnel has not been designed for traffic operations where the average traffic speed is less than 20 km/h as these are considered to be abnormal operations. This is consistent with accepted design practice for other long Australian tunnels currently under construction. Under slow traffic conditions (for example as a result of an incident), traffic management procedures are required to be implemented to restrict vehicles entering the road tunnels and preference vehicles leaving the tunnels via the two interchanges.

The tunnel as a whole is designed around the prevention of portal emissions at the interchange ramps. In-tunnel pollution levels are low in relation to their target goals except for during low speed congested traffic conditions where the average traffic speed is less than 20 km/h, which are considered as incident conditions requiring traffic management. During these low speed traffic conditions, it is not possible to bring in enough fresh air from portals with an acceptable number of installed jet fans, without the risk of a portal emission occurring elsewhere.

This memorandum is prepared to inform the Inquiry and Advisory Committee and the public about the North East Link. This memorandum may be of assistance to you but the North East Link Project (a division of the Major Transport Infrastructure Authority) and its employees, contractors or consultants (including the issuer of this document) do not guarantee that the memorandum is without any defect, error or omission of any kind or is appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this memorandum.