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Dear Tony,

Assessment of Level 29 Pool Area with Operational CCTV Data

Further to your request, please find enclosed our additional analysis of Cross City Tunnel Vent (CCTV) emissions with consideration of the recent operational emission data provided by Transurban.

1 Background

ERM (formerly Pacific Environment) has previously assessed potential air quality impacts of the CCTV on the proposed Ribbon Sydney development (the Development), (PE, 2013, 2015, 2016a, 2016b, 2016c), due to commence operations in late 2019 – early 2020.

These studies involved the assessment of potential nitrogen dioxide (NO_2) impacts using conventional regulatory environmental atmospheric dispersion models (PE, 2013, 2015), with subsequent refinement using Computational Fluid Dynamic (CFD) modelling (PE, 2016a).

This work has followed a specific protocol (the Protocol) established for the Cross City Tunnel, which applies an incremental NO_2 criterion of 150 µg/m^3 for assessment in accordance with pre-defined emission scenarios.

More recently, Grocon has sought to understand the nature of potential air quality impacts for an open roof design. This design would feature an open-top deck and pool area within Level 29 and Level 30 of the development (the Level 29 pool area).

Accordingly, Pacific Environment was then commissioned to undertake a review of previous dispersion modelling and CFD analyses to understand potential air quality impacts in the vicinity of the Level 29 pool area (PE, 2016b), with subsequent refined assessment (2016c).

Since this time, it has been recommended that the analysis consider real-world operational data from the CCTV, which has since been made available to ERM by Transurban. This letter provides a summary of the methodology and findings of this additional scope of work.

2 Scope of Work

ERM has been commissioned by Grocon to conduct the following scope of works:

1. Review all data provided by Transurban related to NO_2 emissions from the Cross City Tunnel (CCT) ventilation outlet at Darling Harbour.

2. Provide a summary of the NO_2 emission data provided by Transurban, and compare this with previous modelling assumptions.

3. Use the NO_2 emission data provided by Transurban within a revised CCT ventilation outlet source within our dispersion model.

4. Request NSW EPA Air Technical Advisory Service Unit to confirm that the GRAL modelling system is fit for its current purpose.

5. Complete revised NO_2 dispersion modelling and impact predictions at the Ribbon development pool area.

Corresponding detail and analysis is provided in the following sections.

3 Review of CCTV Operational NO_2 Emission Data

ERM have been provided with 12 months of Continuous Emission Monitoring System (CEMS) reporting for the CCTV, as documented within Norditech monitoring reports (Norditech, 2017; 2018). Corresponding validated Microsoft Excel datasets have been provided for this period with the exception of November 2017.

ERM have conducted a review of these data including the following parameters:

- NO_2 emission concentration
- NO_2 emission rate
- Exhaust velocity
- Exhaust temperature.

Details of this analysis is provided in Appendix A. Summary statistics for these parameters are provided in Table 3.1 and Table 3.2.

Table 3.1: Summary statistics for CCTV operational in-stack NO_2 concentration and NO_2 emission rates

Statistic (7,599 valid hourly records)	In-Stack NO_2 Concentration ($\mu g/m^3$)	NO_2 Emission Rate (g/s)
Maximum	816	0.21
99.9th Percentile	519	0.13
99th Percentile	411	0.11
90th Percentile	300	0.07
Mean	183	0.04
Minimum	0	0.00

Table 3.2: Summary statistics for CCTV operational exhaust velocity and temperature

Statistic (7,990 valid hourly records)	Exhaust Velocity (m/s)	Temperature (°C)
Maximum	25.1	33
99th Percentile	11.3	30
90th Percentile	10.9	27
Mean	9.7	22
10th Percentile	6.4	16
1st Percentile	4.6	13
Minimum	1.4	11

Analysis of NO_2 measured inside the CCTV indicates that concentrations *are below the 1 hour average ambient air quality criterion (246 µg/m³) within the vent for 79% of the time*, and approximately 3 times higher than the ambient air quality criterion in the maximum of 7,599 valid hourly records reviewed. The 99.9th percentile concentration (the concentration exceeded approximately 1 in 1000 hours) is approximately twice the ambient air quality criterion.

Exhaust velocities varied between 1.4 m/s and 25.1 m/s, with 98% of readings falling between 4.6 m/s and 11.3 m/s.

Exhaust temperatures varied between 11°C and 33°C, and are more broadly distributed, with 80% of readings falling between 16°C and 27°C.

4 Comparison of Data with Previous Assumptions

Previous analyses have investigated a range of emission parameters (stack velocity and temperature) as relevant to the estimation of peak potential NO_2 impacts on the Level 29 pool area. Beyond these emission parameters, the mass emission rate (g/s of NO_2 emitted) is considered the key determinant of potential downwind concentrations. To provide context on the scale of operational NO_2 emissions against previous estimates, (as relevant to the interpretation of this and previous assessments), a comparison of various emission estimates has been made. Emission estimates collated for comparison include:

- Environmental Impact Statement (EIS) Estimates (Normal and Congested Operations)
- The Protocol (Low, Medium and High emission scenarios)
- PE (2017c) Independent Estimate (Peak Hour)
- Operational Emission Data.

A summary and visual representation of the data are provided in Table 4.1 and Figure 4.1 (respectively).

Table 4.1: Summary of current and historical CCTV NO_2 emission rates

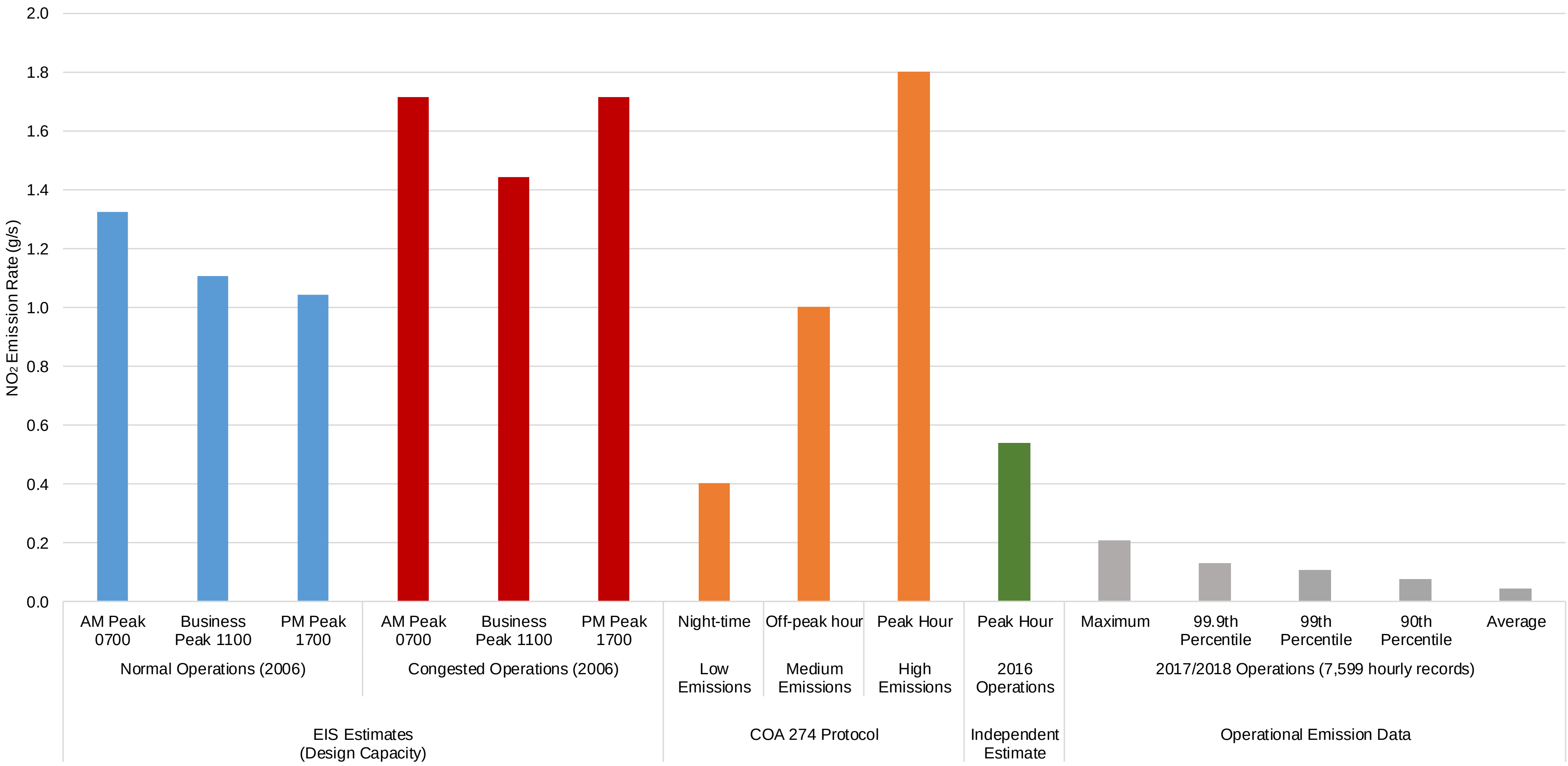
Basis	Scenario	Condition	NO_2 Emission Rate (g/s)	Notes
EIS Estimates	Normal Operations (2006)	AM Peak 0700	1.3*	(HAS, 2002) 1996 PIARC emission factors with correction to 2006 fleet. Design capacity
		Business Peak 1100	1.1*	
		PM Peak 1700	1.0*	
	Congested Operations (2006)	AM Peak 0700	1.7*	
		Business Peak 1100	1.4*	
		PM Peak 1700	1.7*	
COA 274 Protocol	Low Emissions	Night-time	0.4*	Assessment protocol estimates
	Medium Emissions	Off-peak hour	1.0*	
	High Emissions	Peak Hour	1.8*	
Independent Estimate	FY 2017 Volumes and Fleet	Peak Hour	0.54*	(PE, 2017c) Conservative assumptions around grade, vehicle fleet and emission factors.
Operational Emission Data	2017/2018 Operations	Maximum	0.21	Norditech (2017/2018) Aug 2017-Jul 2018 data** (7,599 hourly records)
		99.9th Percentile	0.13	
		99th Percentile	0.11	
		90th Percentile	0.07	
		Average	0.04	

Notes:

*Inclusive of the assumption that NO_2 emissions comprise 20% of total NO_x emissions.

**Statistics exclude November 2017 data for which hourly validated records were not provided.

Figure 4.1: Summary of current and CCTV NO_2 emission rate estimates



As shown in the dataset, operational emission data (7,599 hourly records) is approximately 5-9 times lower than the Protocol estimates, which have been applied in previous dispersion modelling analyses. It is noted that whilst the most recent modelling (PE, 2017c) included an operational estimate of 0.54 g/s, the higher Protocol estimates were applied in the quantitative element of the analysis.

5 GRAL Dispersion Modelling

The suitability of the GRAL model for such an application was discussed with the NSW EPA Air Technical Advisory Service Unit (ATASU). It was confirmed that the NSW EPA *Approved Methods for Modelling and Assessment of Air Quality in NSW* is now a somewhat historical document, however the intent of the document that certain more advanced computational models may be required that are not prescribed within this document as the need arises.

On this basis, ERM considers that the GRAL model is fit for its current purpose due to its ability to simulate flows around near-field structures (i.e. simulate the interaction of the CCTV plume with the Ribbon development structure) and has an established precedence of application in the modelling of air emissions dispersion from motorway tunnel ventilation outlets within NSW.

The existing GRAL dispersion model (PE, 2017c) has been updated to incorporate operational emission data. This has been compiled in the form of Scenarios 4, 5 and 6, which comprise a repeat of the analysis documented in PE (2017c) - Scenarios 1, 2 and 3, incorporating the operational emission data in accordance with the following:

- Use of the maximum measured NO_2 emission rate of 0.21 g/s.
- Use of a mean exhaust velocity of 9.7 m/s.
- Consideration of a higher temperature differential of -10°C (Scenario 6).

A summary of these modelling parameters is provided in Table 5.1

Table 5.1: CCT modelling parameters by scenario

Parameter	Scenario 4 / 4a / 4b	5 / 5a / 5b	6 / 6a / 6b / 6c
Time of Day	6am – 10am, 3pm – 7pm	10am – 3pm	10am – 3pm
NO_2 Emission Rate (g/s)		0.21	
Exit Velocity (m/s)		9.7	
In-Stack Temperature	Ambient	Ambient	Ambient - 10 °C
Wind Direction (°)		225	
Wind Speeds (m/s)	1.0 / 2.0 / 3.0	1.0 / 2.0 / 3.0	1.0 / 2.0 / 3.0 / 10.0
Ambient Temperature (°C)	15	20	20
Season	Winter	Spring	Summer
Stability Class	F / E / D	B / B / C	B / B / C / D
Mixing Height (m)	600	1000	500

6 Dispersion Modelling Results

Table 6.1 presents a summary of GRAL modelling results at discrete receptor locations. As shown in Table 6.1, all results are within the Protocol assessment criterion of 150 µg/m³.

Table 6.1: Summary of GRAL modelling results at discrete receptor locations.

Receptors	Maximum predicted 1-hour NO_2 concentration (µg/m³) at 95 m				
	R1	R2	R3	R4	R5
Scenario 4	0.0	0.0	0.0	0.0	0.0
Scenario 4a	0.0	0.0	0.0	0.0	0.0
Scenario 4b	0.0	0.0	0.0	0.0	0.0
Scenario 5	0.0	0.0	0.0	0.0	0.0
Scenario 5a	0.0	0.0	0.0	0.0	0.1
Scenario 5b	0.0	0.0	0.0	0.0	0.0
Scenario 6	0.0	0.0	0.0	0.0	0.0
Scenario 6a	0.2	0.2	0.2	0.2	0.2
Scenario 6b	0.0	0.0	0.0	0.0	0.0
Scenario 6c	2.4	2.7	1.3	1.3	1.2

When allowance for the five to tenfold reduction in emission rates is made, these results are broadly consistent with those documented in PE (2017c).

Conclusions

ERM has conducted a review of operational emission data for the CCTV with subsequent update of the existing dispersion modelling analysis for the Ribbon project. Based on this work, the following is noted:

- Analysis of CCTV NO_2 concentration data indicates that *in-stack concentrations are below the 1 hour average ambient air quality criterion (246 µg/m³) within the vent for 79% of the time*, and approximately 3 times higher than the ambient air quality criterion in the maximum of 7,599 valid hourly records reviewed.
- The 99.9th percentile in-stack concentration (the concentration exceeded in 1 in 1000 hours) is approximately twice the ambient air quality criterion. This is indicative of a low risk of potential NO_2 exceedances at locations away from the CCTV (after which significant dilution will occur).
- A review of modelled emission rates against operational emission data indicates that *modelling assumptions previously applied to data are conservative against operational data*, with peak operational NO_2 emission rates being 5 – 10 times lower than those previously applied
- Based on peak operational emission rates, maximum downwind concentrations at the Level 29 pool area are predicted to be approximately 2 µg/m³, which is *approximately two orders of magnitude below the impact assessment criterion* of 150 µg/m³. This is consistent with measured in-stack concentrations, and anticipated levels of dilution between the CCTV and the Level 29 pool area.
- The operational data reflects the current level of tunnel usage. Whilst an increase in traffic may occur in future years, fleet emission performance improvements would likely produce significant reductions in emissions per vehicle movement.

  PE (2017) estimated a 46% reduction in emissions due to modernisation of the vehicle fleet between 2017 and 2030. This reduction would be anticipated to largely counter increases in NO_2 emissions associated with increases vehicle movements, should growth toward the design capacity of the tunnel occur in the future.

Accordingly, as consistent with previous investigations (PE, 2017c), it is considered that *the risk of exceedances of the NSW EPA ambient air quality criteria (using NO_2 as a marker) associated with operation of the Level 29 pool area is minor*.

Should you have any questions relating to this analysis, please do not hesitate to contact the undersigned.

Yours sincerely,

James Grieve	Damon Roddis
Senior Consultant	Partner

References

- HAS 2002 *Proposed alteration to the Modified Activity as outlined in the Supplementary Environmental Impact Statement for the Cross City Tunnel*, Holmes Air Sciences, 31 October 2002.
- Norditech 2017a *Cross City Tunnel – Stack Emissions Monitoring Report, August 2017*, Norditech Pty Ltd, 8 September 2017.
- Norditech 2017b *Cross City Tunnel – Stack Emissions Monitoring Report, September 2017*, Norditech Pty Ltd, 6 October 2017.
- Norditech 2017c *Cross City Tunnel – Stack Emissions Monitoring Report, October 2017*, Norditech Pty Ltd, 8 November 2017.
- Norditech 2017d *Cross City Tunnel – Stack Emissions Monitoring Report, November 2017,* Norditech Pty Ltd, 8 December 2017.
- Norditech 2018a *Cross City Tunnel – Stack Emissions Monitoring Report, December 2017,* Norditech Pty Ltd, 9 January 2018.
- Norditech 2018b *Cross City Tunnel – Stack Emissions Monitoring Report, January 2018,* Norditech Pty Ltd, 7 February 2018.
- Norditech 2018c *Cross City Tunnel – Stack Emissions Monitoring Report, February 2018,* Norditech Pty Ltd, 7 March 2018.
- Norditech 2018d *Cross City Tunnel – Stack Emissions Monitoring Report, March 2018,* Norditech Pty Ltd, 5 April 2018.
- Norditech 2018e *Cross City Tunnel – Stack Emissions Monitoring Report, April 2018,* Norditech Pty Ltd, 4 May 2018.
- Norditech 2018f *Cross City Tunnel – Stack Emissions Monitoring Report, May 2018,* Norditech Pty Ltd, 6 June 2018.
- Norditech 2018g *Cross City Tunnel – Stack Emissions Monitoring Report, June 2018,* Norditech Pty Ltd, 6 July 2018.
- Norditech 2018h *Cross City Tunnel – Stack Emissions Monitoring Report, July 2018,* Norditech Pty Ltd, 7 August 2018.
- PE 2013 *Air Quality Impacts for Redevelopment of 31 Wheat Rd Revised Design*, Pacific Environment, August 2013.
- PE 2015 *The Ribbon Air Quality Assessment 2015 Revised Design*, Pacific Environment, November 2015.
- PE 2016a *The Ribbon – Air Quality Assessment, Final Report*, Pacific Environment, 11 October 2016.

- PE 2016b *The Ribbon – Level 29 Pool Area Assessment*, Pacific Environment, 23 December 2016.
- PE 2016c *The Ribbon – Refined Assessment of Level 29 Pool Area*, Pacific Environment, 12 August 2017.

Appendix A – Review of CCTV Emission Data

A1.1 CCTV Exhaust NO_2 Concentration

Table A.1 presents a summary of NO_2 concentrations measured in air vented from the CCTV, whilst Figure A.1 provides a summary of the diurnal variation in these data.

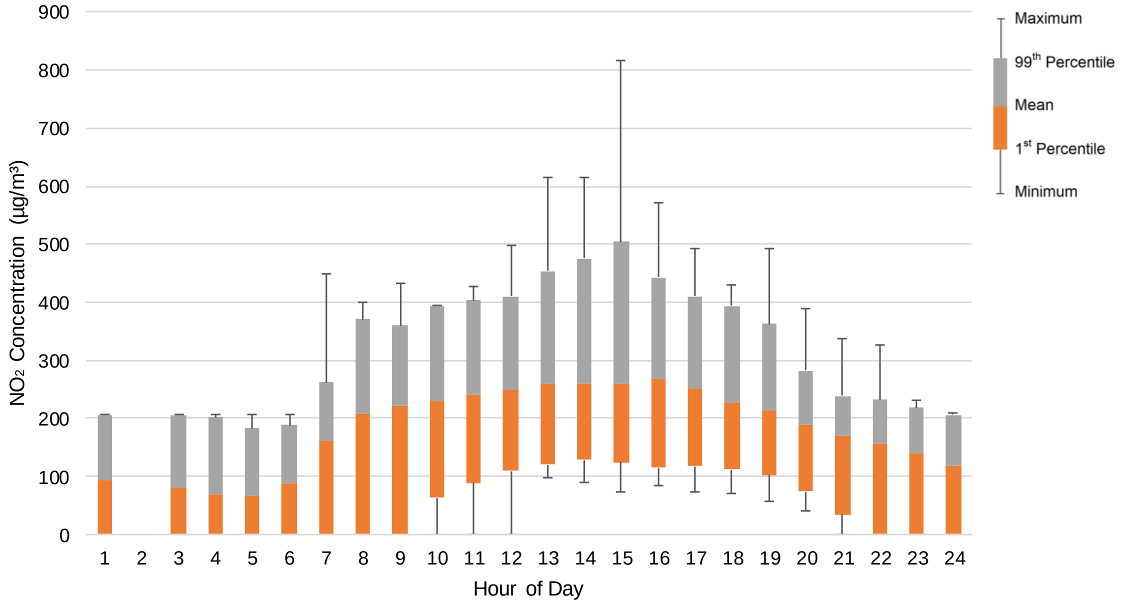
Table A.1: CCTV NO_2 emission concentration – summary statistics

Statistic (7,599 valid hourly records)	NO_2 Concentration (µg/m³)
Maximum	816
99.9th Percentile	519
99th Percentile	411
90th Percentile	300
Mean	183
Minimum	0

Notes:

- With the exception of the maximum, statistics presented exclude November 2017.
- Concentrations presented at reference conditions of 0°C and 1 atmosphere.

Figure A.1: CCTV NO_2 emission concentration – diurnal variation



Notes:

- Hour 2 missing due to daily automated calibration checks.
- Data presented exclude November 2017.
- Concentrations presented at reference conditions of 0°C and 1 atmosphere.

A1.2 CCTV NO_2 Emission Rate

NO_2 emission rates have been calculated as the product of the normalised volumetric flow rate and normalised concentration.

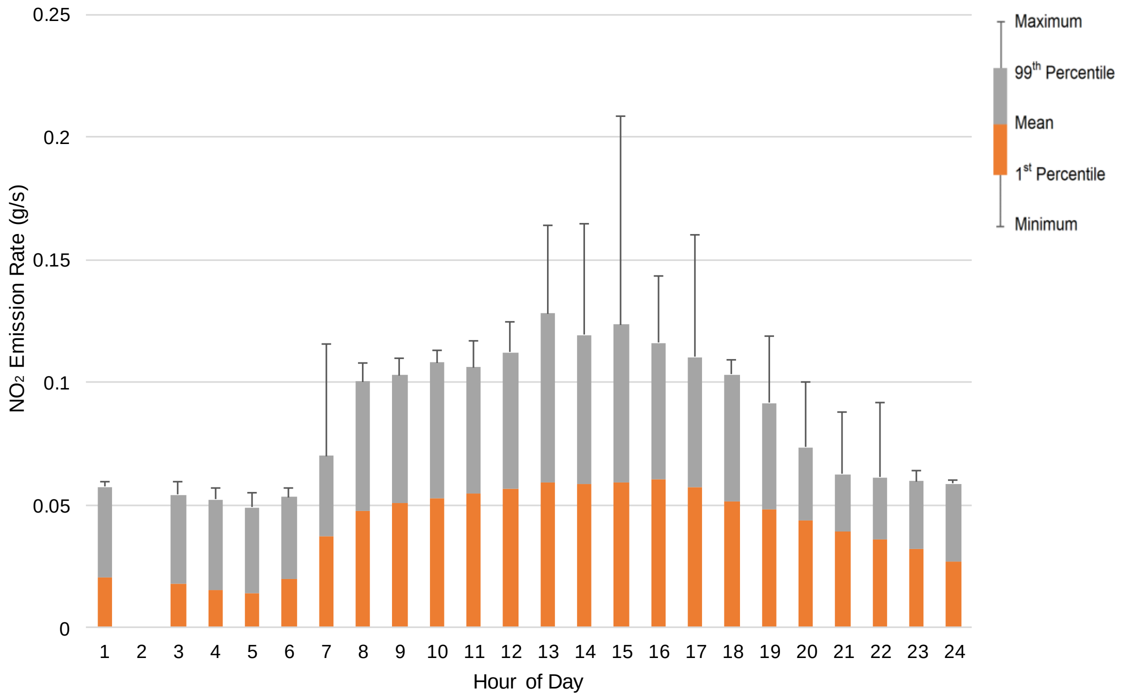
Table A.2 presents a summary of NO_2 emission rates for the CCTV, whilst Figure A.1 provides a summary of the diurnal variation in these data.

Table A.2: CCTV NO_2 emission rate – summary statistics

Statistic (7,599 hourly values)	NO_2 Emission Rate (g/s)
Maximum	0.21
99.9th Percentile	0.13
99th Percentile	0.11
90th Percentile	0.07
Mean	0.04
Minimum	0.00

Notes: Statistics presented exclude November 2017.

Figure A.2: CCTV NO_2 emission rate – diurnal variation



Notes:

- Hour 2 missing due to overnight automated calibration checks.
- Data presented exclude November 2017.

A1.3 CCTV Exhaust Temperature

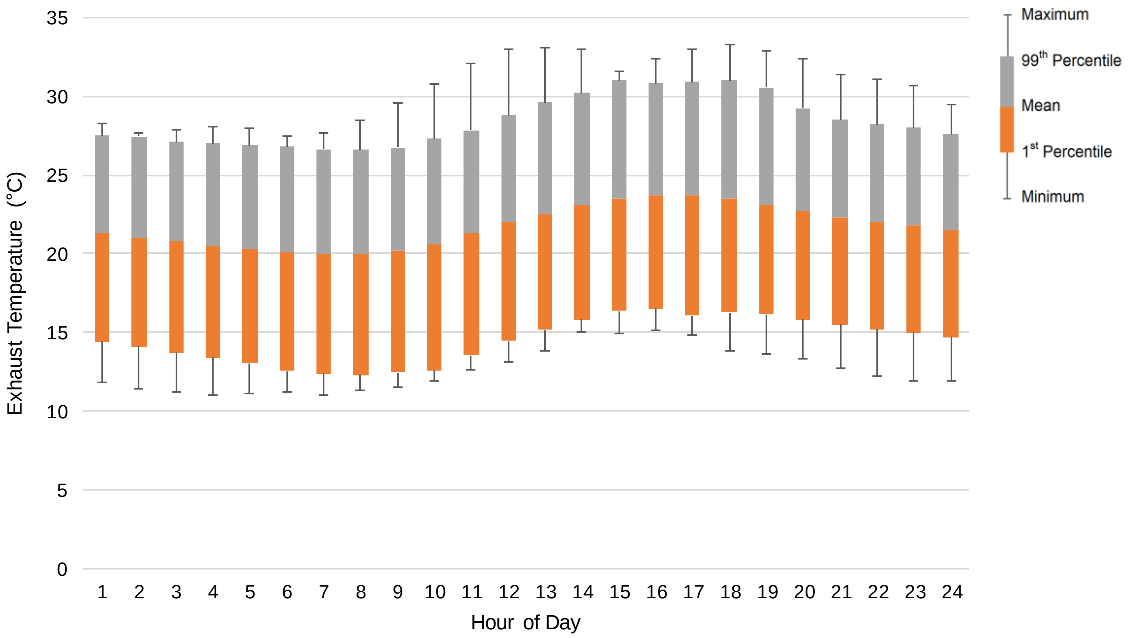
Table A.3 presents a summary of exhaust temperature for the CCTV, whilst Figure A.3 provides a summary of the diurnal variation in these data.

Table A.3: CCTV exhaust temperature – summary statistics

Statistic (7,990 valid hourly records)	Temperature (°C)
Maximum	33
99th Percentile	30
90th Percentile	27
Mean	22
10th Percentile	16
1st Percentile	13
Minimum	11

Notes: Statistics presented exclude November 2017.

Figure A.3: CCTV exhaust temperature – diurnal variation



Note: Data presented exclude November 2017.

A1.4 CCTV Exhaust Velocity

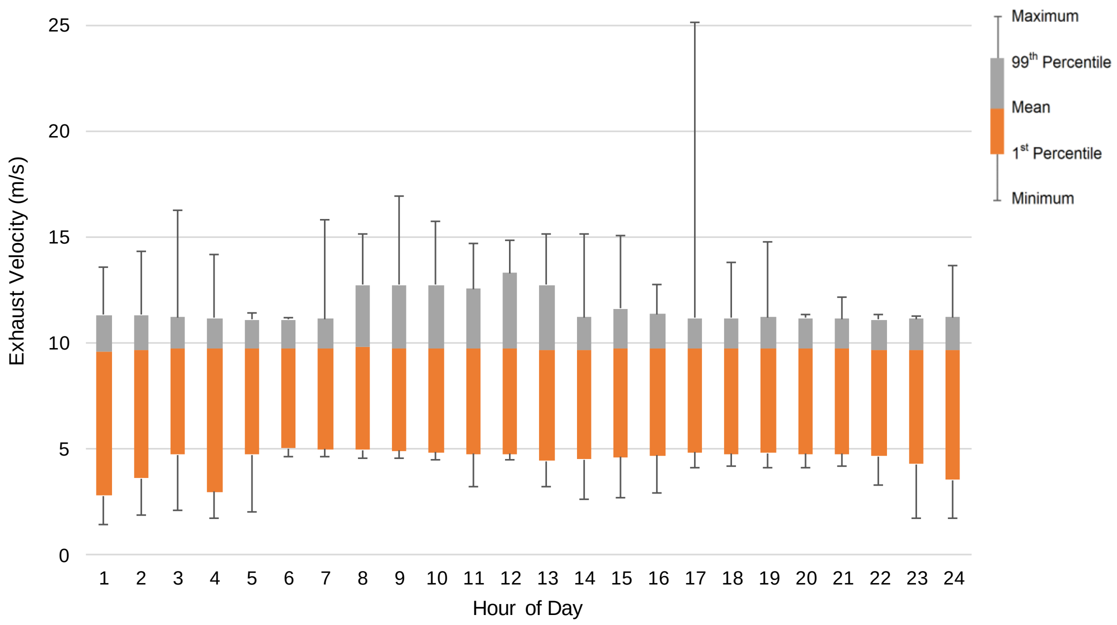
Table A.4 presents a summary of NO_2 emissions from the CCTV, whilst Figure A.4 provides a summary of the diurnal variation in these data.

Table A.4: CCTV exhaust velocity – summary statistics

Statistic (7,990 valid hourly records)	Exhaust Velocity (m/s)
Maximum	25.1
99th Percentile	11.3
90th Percentile	10.9
Mean	9.7
10th Percentile	6.4
1st Percentile	4.6
Minimum	1.4

Notes: Statistics presented exclude November 2017.

Figure A.4: CCTV exhaust velocity – diurnal variation



Note: Data presented exclude November 2017.