

Programmes and Investment Committee



Date: 28 June 2017

Item: Euro VI Bus NOx Abatement

This paper will be considered in public.

1 Summary

ID: ST-PJ591C		Euro VI Bus NOx Abatement		
Existing Financial Authority	EFC	Existing Programme and Project Authority	Additional Authority Requested	Total Authority
£ 86.1 m	£ 94.3 m	£ 1.82 m	£ 25 m	£ 26.82 m

Authority Approval: The Committee is asked to approve additional budgeted Programme and Project Authority of £25m.

Outputs and Schedule: To ensure the entire bus fleet meets the Euro VI emissions standard by September 2020. This will primarily be achieved by retrofitting enhanced Selective Catalytic Reduction (SCR) systems on up to 4,920 buses. This authority submission covers the first 1,150 retrofits, which are expected to be delivered by spring 2018.

- 1.1 Delivery of the Low Emission Bus Zones (LEBZs) within the timescales targeted by TfL is dependent upon orders for Selective Catalytic Reduction (SCR) systems being placed in July, with fitment expected to commence in September 2017. The Committee is asked to approve additional budgeted Programme and Project Authority to facilitate this.

2 Recommendation

2.1 The Committee is asked to:

- (a) note the paper; and
- (b) approve additional budgeted Programme and Project Authority of £25m for the retrofitting of certain buses to meet emissions standards.

3 Background

- 3.1 London currently suffers from poor air quality, with many areas across London failing to meet the European Nitrogen Dioxide (NO₂) concentration standards. There is increasing evidence of the negative health impacts of poor air quality.
- 3.2 NO₂ and Nitrogen Oxide (NO) are collectively known as Oxides of Nitrogen (NO_x), and whilst NO is itself harmless, it easily reacts with air to form NO₂. Thus NO_x emissions are a key cause of high ambient NO₂ concentrations. All modes of

transport account for 63 per cent of the total NOx emissions in London, with TfL Buses accounting for 8 per cent of total NOx emissions.

- 3.3 The new Euro VI emissions standard has focused on the difficult urban driving conditions which are found across TfL's bus network. As a result, testing over the Millbrook test cycle, modelled on bus route 159, has shown that the Euro VI standard delivers a step change in emission performance compared to Euro V: an estimated 95 per cent reduction in NOx emissions and an 80 per cent reduction in Particulate Matter emissions (PM₁₀) per bus. Buses operating within both the Low Emissions Bus Zones (LEBZs) and the Ultra Low Emission Zone (ULEZ) are required to meet the Euro VI standard.
- 3.4 In recognition of the severity of the health issues caused by poor air quality, the Mayor has built upon the existing 'Air Quality Strategy' with 'A City for All Londoners', where he states that returning London's air quality to within safe limits is one of his major priorities. This project will help contribute towards delivering this priority by bringing all buses up to the Euro VI standard. In doing so, the project supports delivery of the LEBZs: buses travelling along these corridors will meet a Euro VI standard or better, thereby tackling the worst pollution hotspots. Additionally, the project delivers a ULEZ compliant bus fleet, whilst also supporting any future commitment to a London wide low emission zone.
- 3.5 The Putney High Street LEBZ was delivered in February 2017. A large scale trial of the enhanced SCR technology is currently in delivery as part of the separate Brixton-Streatham LEBZ project. The Brixton-Streatham corridor will be delivered at the end of October 2017. A total of 455 vehicles are used on that corridor, of which over 200 vehicles are being retrofitted to a Euro VI standard. Both LEBZs were funded within existing Programme and Project Authority.
- 3.6 This authority submission will fund approximately 1,150 retrofits, with fitment running through to spring 2018. A further authority request will be incorporated into the paper on the Contracted Services Programme which is due to be presented to the December 2017 meeting of the Committee.
- 3.7 The enhanced SCR unit costs secured under a competitive process for a framework of providers are at the upper end of the expected range. This has created a risk that the overall cost of the project may increase, and the Estimated Final Cost (EFC) for the project has been raised to reflect this risk. There are, however, also opportunities to bring costs back in line with expected values. As a result it is not proposed to increase the authorities of the project at this time. Instead, this first delivery tranche will be used to gain greater cost certainty ahead of a gate review planned for November 2017. Any changes in delivery approach or authorities required following this gate review will also be incorporated into the paper on the Contracted Services Programme which is due to be presented to the December 2017 meeting of the Committee.
- 3.8 Evidence of the significant air quality benefits delivered by the Euro VI standard has led TfL to propose an accelerated LEBZ delivery schedule, supported by the Mayor. As a result an additional £8.5m of costs are forecast to be brought forward from future financial years into this financial year. This acceleration will be balanced against savings and deferrals identified elsewhere within Surface Transport.

3.9 The project has passed through a Pathway stage gate 4 delivery review and has undergone an Independent Assurance Review. A further assurance review is planned as part of the gate review in November 2017 ahead of the project's next authority request.

4 Proposal

Preferred Option

- 4.1 There are currently approximately 6,900 buses in the fleet that do not meet Euro VI emission standards. Some of these buses will be replaced as part of contract re-lets by 2020. However, to upgrade the entire bus fleet to Euro VI standard through the natural churn of specifying new buses as contracts are re-let could take up to ten years. Without action, therefore, it is forecast that up to 4,920 buses in the fleet would not be Euro VI compliant in September 2020.
- 4.2 The scope of this project is to ensure that all Euro IV and V buses which will not be replaced through contractual mechanisms by September 2020 are brought up to the Euro VI standard. The preferred option for achieving this is retrofitting enhanced SCR systems. Enhanced SCR systems are an effective way of reducing heavy duty vehicle emissions at a fraction of the cost of purchasing new vehicles, by reducing the main air pollutants that are damaging to health. In the SCR process NO_x reacts with ammonia (NH₃), which is injected into the flue gas stream (typically in the form of urea) before the catalyst to convert nitrogen to water.

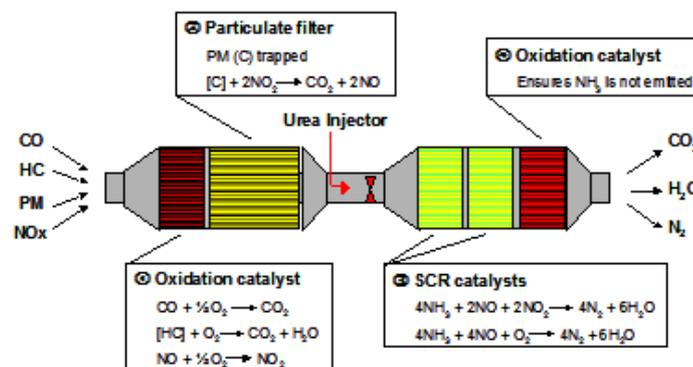


Figure 1 Diesel Particulate Filter and Selective Catalytic Reduction

- 4.3 SCR technology is already used on new Euro VI buses; retrofit suppliers will use the same technology and apply it to Euro IV and V vehicles to achieve emission reductions. The SCR units will need to be adapted to each engine type within the fleet to ensure effective performance. Similar earlier technology was used in 2013 when TfL, with match funding from the Department for Transport (DfT), undertook a programme to retrofit SCR technology to Euro III buses to bring them up to the Euro IV emission standard. 2,014 Euro III buses were retrofitted, achieving an 88 per cent reduction in NO_x emissions per bus.
- 4.4 Buses will need to be taken out of service for two to three days to retrofit SCR systems, however provision has been made within the project for replacement

buses to ensure there is no impact on the operational service delivered for customers.

- 4.5 No negative equality issues are expected to arise from this project. Research indicates that children are particularly vulnerable to air quality pollutants. Deprived groups and some ethnic groups are also more likely to be exposed to poor air quality. Thus any equality effects resulting from this project are expected to be positive.

Benefits (and Value)

Emission type	Average existing fleet emissions per km (over Millbrook test cycle)	Euro VI emissions per km (over Millbrook test cycle)	Emission reduction per km	Total annual emission reduction per bus pa (assuming an average of 60,000km per bus pa)	Social damage value per tonne	Monetised social benefit per bus pa
NOx	8.56g	0.5g	8.06g	486kg	£98,907	£48,068
PM	0.04g	0.01g	0.03	1.8kg	£273,193	£492

- 4.6 The EFC for the project is £94.3m including risk. The estimate used to calculate the project’s Financial Authority assumed the retrofit of up to 4,920 buses at £15,000 per SCR unit, with a further £2,500 per bus of project costs, at a total cost of £17,500 per bus. Following the contract award further risk analysis has led to an additional £1.66k of risk allowance per unit being included in the EFC.
- 4.7 The project costs and the introduction of benefits are phased over the delivery programme to 2020. The average remaining life of the buses in scope is six years, therefore benefits have been forecast to last for this period of time. This gives a BCR of 12.1:1, demonstrating that the project is a highly cost effective means of delivering air quality improvements.
- 4.8 The summary of the economic appraisal and benefits for the preferred option is tabulated below:

Economic Appraisal	
Estimated Final Cost, £k (at outturn prices)	(94,267)
Net Present Values ,£k	
Discounted NPV EFC	(86,611)
Optimism Bias	(8,661)
Net Financial Effect	(95,272)
Social Benefits	1,149,092
Total Benefit, £k	1,149,092
Benefit : Cost Ratio	12.1:1

4.9 Benefits Measured:

- (a) NO_x emissions – continuously measured through on board telematics data. The measure of success is a reduction of emissions to 0.5 g/km over the Millbrook test cycle. The emission performance of vehicles will be monitored using the telematics data to ensure equivalent performance to comparable Euro VI vehicles in real world conditions;
- (b) PM₁₀ emissions – random quality assurance testing at the Millbrook test facility will be used to measure reductions in PM₁₀ emissions. The measure of success is a reduction of emissions to 0.01 g/km over the Millbrook test cycle; and
- (c) NO₂ concentrations - the impact on ambient NO₂ concentrations will be measured by contracting an independent research group to conduct a benefits realisation exercise. This research will make use of the London Air Quality Network, which has sensors already in place. No measure of success has been set as changes in NO₂ concentrations are highly dependent upon other factors outside TfL's control such as meteorological conditions, however a reduction is expected. An allowance of £50k has been made within the project budget for any funding required for this additional research over and above existing programmes.

Options Analysis

4.10 Alternative options:

- (a) do nothing - the 'do nothing' option is to only replace buses as part of contract re-lets. This would require eight to ten years to bring the fleet up to Euro VI standard, leaving up to 4,920 buses below this standard by September 2020 and significantly delaying the introduction of major air quality benefits. Without this project the LEBZs will not be delivered to schedule and there will be an insufficient number of ULEZ compliant buses for effective operation within the central London zone;
- (b) upgrade engines - engine repowers to retrofit entire Euro VI engines deliver the same benefits as an SCR upgrade however they are significantly more expensive, at approximately £60k per bus, making it a less effective option on a value for money basis;
- (c) fleet replacement with Euro VI diesel buses - the cost of accelerating the update of new buses so that all buses are Euro VI compliant by 2020 varies according to the age of the bus and the length of its existing lease. The average cost of replacing a bus has been estimated at £94,427, however this varies significantly over the contract cycle. At this average cost fleet replacement is not a cost effective solution, however the variation in costs means there may be isolated instances where replacement of individual buses may offer value for money, and these will be considered on a case by case basis; and
- (d) fleet replacement with zero emission at tailpipe buses – electric drive buses are becoming increasingly available from the market, however hydrogen technology remains very expensive and battery technology is not yet able to power double-decker buses for the required range. As part of the central London ULEZ single-decker buses entering the zone from 2020 will be electric

(along with some hydrogen buses). However for this project the additional benefits delivered by an electric bus, completely eliminating NOx and PM emissions, reducing carbon emissions by 50 per cent and fuel savings, do not offset the significantly higher capital costs, giving a significantly lower BCR compared to SCR retrofits for the existing fleet.

- 4.11 The base 'do nothing' case is considered strategically unacceptable, as it would result in significant delays to the realisation of air quality benefits, failure to deliver the LEBZs within the proposed timescales, and leave TfL without sufficient compliant buses to operate an effective service within the ULEZ. Of the options available for delivering air quality improvements SCR retrofits deliver by far the best value for money and are therefore the preferred option.

Delivery of Preferred Option

- 4.12 Delivery of this overall project by 2020 (together with the intermediate LEBZ milestones) means an aggressive rate of installations in parallel with continued delivery of the bus network. This will require on-going prioritisation in terms of resources and support within TfL to ensure the Euro VI standard is achieved across the fleet by 2020.
- 4.13 The bus fleet is (with the exception of New Routemasters) not owned by TfL, and the Bus Operators are responsible for the continued maintenance and operation of the vehicles whilst contracted to TfL. Mid-contract changes to the vehicle specification (such as this project) are subject to negotiation. As a result the Bus Operators need to be able to choose their retrofit supplier rather than it being imposed upon them. The previous retrofit programme was successfully delivered this way.
- 4.14 TfL will agree with the operators which buses need to be retrofitted, the timescales, appropriate system(s) and thence the associated costs of the work. The Bus Operators should be no better and no worse off as a result of this programme, so there is no expectation that a margin will be added.
- 4.15 Project plans and formal agreements will be put in place with the Bus Operators to cover the ordering and installation, and Route Agreements (bus contracts) will be varied once the work is complete to reflect the enhanced vehicle emissions standard.
- 4.16 The actual installation will be delivered by specialist retrofit suppliers through installation and maintenance of NOx abatement modules. The Bus Operator will work with the agreed supplier to retrofit the buses in their fleet that require modification. The Bus Operator will make buses available for fitting and will manage their delivery through the fitting process. The TfL supplier framework will be for a period of three years with an option to extend for a further year.
- 4.17 The framework contract that TfL has put in place will enable the Bus Operators to place orders for their individual retrofit programmes. Operators will provide a safe space within their garage estate for suppliers to work, in order to carry out the retrofits. After the systems have been installed and tested by the supplier to ensure that the Euro VI standard is being met, the operators' engineers will sign off the work, triggering payment.

- 4.18 Operators have appointed Project Managers (PM), who will track and monitor the progress of their respective programmes. The PMs will have direct contact with TfL's project management team to provide weekly updates on programme, to flag any issues which they may be facing and to maintain programme governance.
- 4.19 TfL PMs will coordinate the programme to ensure the required average run rate of 33 buses per week across the 11 bus operators is being achieved, in order to ensure all 4,920 vehicles have been retrofitted by September 2020.
- 4.20 Failure to deliver this project would impact upon the ULEZ programme as we would have insufficient Euro VI buses to operate within the zone. Delays would result in a failure to deliver the LEBZs within the proposed timescales, delaying the realisation of air quality benefits.
- 4.21 There is one project milestone associated with this project is shown below:

Milestone description	Achievement criteria	Target date	Actual date
Bus Retrofit Contract Award (complete)	Contract Award recommendation endorsed at Surface Board confirmed by Surface Board minutes	15 May 2017	11 May 2017

- 4.22 The proposed timescales for LEBZ delivery are shown below, though these dates will be reviewed as the delivery programme progresses and are therefore subject to change:

Order	Low Emission Bus Zone	Proposed Implementation date
1	Putney High Street	February 2017
2	Brixton - Streatham	October 2017
3	A12 Eastern Avenue (Homerton Road)	December 2017
4	Lewisham - Catford	January 2018
5	Stratford	January 2018
6	High Road (Haringey) - Green Lanes	May 2018
7	Camberwell - New Cross	May 2018
8	Wandsworth - St. John's Hill	June 2018
9	Edgware Road (Kilburn-Maida Vale)	June 2018
10	Edmonton - Seven Sisters	December 2018
11	Uxbridge Road - Shepherds Bush	June 2019
12	Chiswick High Road - Kensington	July 2019

Note: Putney High Street is already in place and Brixton is currently being delivered as a separate project as part of a large scale trial of the enhanced SCR technology.

Risk and resources

- 4.23 As expressed on Active Risk Management (ARM) the P50 of the Quantitative Risk Assessment (QRA) for the project is currently £10.665m. The majority of the risk focuses on the uncertainty of the overall EFC until costs are fully understood.
- 4.24 The post-contract award risk review highlighted that the risk of the average installation costs exceeding £15k had grown significantly both in terms of possible impact and likelihood. This is a result of the average installation cost having increased above £15k. The variance in the suppliers' prices is also higher than expected, with a spread of over £6k per unit between different suppliers for the most popular engine types, making some units significantly more expensive than £15k. The likely impact of this risk to the project will be better understood once detailed negotiations with Bus Operators have been completed to review their proposed supplier partnerships. The increased exposure of the project to this risk has driven the need for an increased risk contingency, which in turn has increased the project's EFC above its Financial Authority.
- 4.25 It should be noted, however, that there are opportunities to reduce costs in other areas which are not included in the P50 risk contingency calculation, and which may allow the project EFC to be brought back within its Financial Authority. These opportunities include both the project management and ongoing operational costs for the SCR systems, which TfL will agree with the Bus Operators. There are also opportunities to support the Bus Operators in partnering with suppliers of cheaper solutions. Finally there is the possibility that fewer buses than originally estimated will require retrofits as a result of the bus contract re-let cycle, and this continues to be an area of focus.
- 4.26 These areas of cost uncertainty, both risks and opportunities, will become much clearer over the first few months of delivery. A gate review is planned for November 2017 to reassess the project in light of this greater cost certainty.
- 4.27 The top five risks are shown below:

Risk No	Risk Description	Mitigation Actions
ULEZ-Bus-034	Preferred suppliers have higher unit costs than has been forecast.	To closely engage with operators to understand their chosen framework suppliers for fitment and model costs to ensure overall affordability of programme.
ULEZ-Bus-008	Risk that abatement suppliers do not develop a solution for certain engines eg Mercedes, Scania, etc.	Developments costs have been factored into the tendered prices however there is a risk that if development is significantly more complex than anticipated the prices would need to be renegotiated. Bus engineering to work closely with suppliers to start work ASAP to commence work on developing system.
ULEZ-Bus-009	Bus Operators operational expenditure costs are not understood thoroughly and may be insufficient.	To engage with Bus Operator Project Managers to understand the delta in operational costs such as ad blue dosing and existing and future maintenance arrangements after a system has been selected.
ULEZ-Bus-035	The cost of bringing buses up to the Euro VI standard may rise due to operator project management costs still being unknown, with the potential to come in higher than expected.	Hold kick off meetings to understand the full make up of the project management costs to TfL and work with the Bus Operators throughout the project to ensure effective management of their costs.

ULEZ-Bus-033	If TfL mandate a particular solution on suppliers due to cost pressures and it fails there is a risk that the programme will fail to deliver and operators will seek redress.	There are concerns over the performance of some cheaper solutions by operators. TfL to monitor run rate and failure rates of different solutions to understand if cheaper solutions are able to be fitted quickly enough and are resilient.
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5 Financial Implications

- 5.1 Budget status: £86.1m is budgeted within Buses Contract Management (Air Quality) for this project. This leaves £8.2m of the project's current EFC unbudgeted. This increased EFC is a result of the increased risk resulting from the SCR costs secured through the Framework Agreement being at the upper end of the expected range. There are, however, good opportunities to bring the project EFC back within its Financial Authority. As a result it is proposed to proceed with this first tranche of installations and achieve cost certainty ahead of a gate review in November 2017. This review will identify any changes required either to the delivery approach or budget to align the project's EFC and Financial Authority.
- 5.2 It is proposed that an additional £8.5m of cost are brought into this financial year to accelerate air quality improvements, as shown in 5.5. The overall cash flow for this financial year will be kept broadly level by balancing the acceleration of this project with savings and deferrals identified elsewhere within Surface Transport.
- 5.3 The per unit costs are split into four areas:
- a) the supply and installation of the Selective Catalytic Reduction (SCR) modules – estimated at £15k per bus;
 - b) additional operating and maintenance costs of the equipment over the bus's remaining contracted life are included in the project. The additional costs of maintenance and ammonia are estimated to be £1k per bus over the remaining contracted life, though this will be agreed with each Bus Operator;
 - c) the project costs associated with the installation – project management costs including staff, premises and additional buses to back-fill, as well as risk and benefits realisation contingencies – estimated at £1.5k per bus. Again the Bus Operator components of these costs will be agreed with each Operator; and
 - d) an additional £1.66k per bus of risk contingency has been allowed as a result of the risk re-assessment following the contract award.
- 5.4 Initial benchmarking estimation was conducted against previous project costs in November 2016, shown in Appendix 1. Note opportunity savings are shown as a lump sum per unit at the bottom.

5.5 Summary of the costs and funding:

£,000

Capital cost breakdown	2017/18	2018/19	2019/20	2020/21	TOTAL
Equipment supply & Fit	14,160	26,955	27,045	5,640	73,800
Project management costs	925	1,761	1,767	368	4,822
Project Risk	1,567	3,238	4,288	1,583	10,676
Total Capital Cost	16,652	31,954	33,100	7,591	89,298

£,000

Operating cost breakdown	2017/18	2018/19	2019/20	2020/21	TOTAL
Additional operating & maintenance	944	1,797	1,803	376	4,920
Benefits realisation				49	49
Total Operating Cost	944	1,797	1,803	425	4,969

£,000

Project Summary	2017/18	2018/19	2019/20	2020/21	TOTAL
Capital Costs	16,652	31,954	33,100	7,591	89,298
Operating Costs	944	1,797	1,803	425	4,969
Total Project Cost	17,596	33,751	34,903	8,017	94,267
Included in Business Plan	9,100	31,500	31,500	14,000	86,100

£,000

Investment Funding	Previous Years	2017/18	2018/19	2019/20	2020/21	TOTAL
Total Project Cost		17,596	33,751	34,903	8,017	94,267
Budget/Plan		9,100	31,500	31,500	14,000	86,100
Plan Surplus/(Shortfall)		(8,496)	(2,251)	(3,403)	5,983	(8,167)
Current Authority	1,820					1,820
This Authority Request		27,000				27,000
Future Authority Requests		57,280				57,280

5.6 It is proposed that this Programme and Project Authority is valid until the end of the 2020/21 financial year. Future reporting to the Committee will be via the annual Contracted Services Programme submissions.

- 5.7 As part of fleet planning and bus service contract management, we will seek to optimise the number of buses that need to be retrofitted within the total costs of providing the bus network. We will also work to ensure best value for money when awarding routes which require buses to be retrofitted as part the contract.
- 5.8 Incremental operating and maintenance costs of the equipment (over that already on the bus) are included in the project, which are assumed to be an average of £1,000 over the contracted lifetime of the asset, though exact costs will be agreed with each Bus Operator. The main element of operating costs is ammonia, which is used in the NOx reduction process. The maintenance costs will be paid to the bus operators in a single up front lump sum to ensure clear responsibility for ongoing maintenance and minimise the financial administration required by an annualised payment to ensure adequate upkeep of the assets.

6 Assurance

- 6.1 A TfL Project Assurance and Independent Investment Programme Advisory Group (IIPAG) Assurance Review of the Programme has been completed and confirmed that there are no critical issues. Management responses have been provided and resulting actions are currently being implemented for the ten recommendations. A further assurance review is planned as part of the gate review in November 2017.

List of appendices to this paper:

Appendix 1: Comparative Cost Estimation

List of background papers:

Procurement Strategy for the NOx Abatement Programme
Contract Award Recommendation for the NOx Abatement Programme
IIPAG Report
IAR Report
Management response to IIPAG and IAR Reports

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Comparative cost estimation

Appendix 1

Item	Euro IV £ per bus	Euro VI £ per bus	Notes
Unit purchase and install	11,500	15,000	More complicated system, with integration into bus engine management system
Project costs	1,200	2,000	Installation takes longer, expect more PM resource from operators
Operating costs	2,200	1,750	Lower cost per annum, but buses in use for longer as they are newer
TfL Costs	0	50	Project staff
Sub total	14,900	18,750	
Risk	0	1,875	10% on new project
Initial Estimate		20,625	
Opportunities		-3,125 (15%)	£2.5k unit cost reduction for volume, balance in project costs and reduced risk
Final Estimated Cost	14,900	17,500	

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