

Date: 8 March 2017

Item: London Underground Rolling Stock Renewals Programme

This paper will be considered in public

1 Summary

London Underground (LU) Rolling Stock Renewals Programme				
Existing Financial Authority	Estimated Final Cost (EFC)	Existing Programme and Project Authority	Additional Authority Requested	Total Programme and Project Authority
£ 703.09m	£ 703.09m	£ 250.09m	£ 199.23m	£ 449.32m

- 1.1 A paper is included on Part 2 of the agenda, which contains exempt supplementary information. The information is exempt by virtue of paragraph 3 of Schedule 12A of the Local Government Act 1972 in that it contains information relating to the business affairs of TfL. Any discussion of that exempt information must take place after the press and public have been excluded from this meeting.

2 Recommendations

- 2.1 **The Committee is asked to note the paper and the supplementary paper on Part 2 of the agenda and:**

- (a) **approve additional Programme and Project Authority of £199.23m (outturn including risk) for the London Underground Rolling Stock Renewals Programme, giving a total of £449.32m; and**
- (b) **approve Procurement Authority, in the sums set out in the paper on Part 2 of the agenda, for the award of a design, manufacture and supply contract for a replacement propulsion system for the Central line fleet.**

3 Background

- 3.1 In 'A City for all Londoners' (October 2016), the Mayor stated his intent to improve the transport system to ensure a world-class experience. The LU Rolling Stock Renewals Programme has been established to deliver:
- (a) modifications to passenger rolling stock to improve safety, accessibility, reliability and customer satisfaction, whilst reducing maintenance costs; and
 - (b) modifications to existing engineering vehicles (eg equipment that supports the maintenance of track) and the procurement of replacement vehicles to reduce the cost of infrastructure renewals and minimise line closure requirements.

- 3.2 The LU Rolling Stock Renewals Programme brings together projects that, although they have differing strategic objectives, share common resource requirements for their delivery. The Rolling Stock Renewals team within LU's Renewals and Enhancements Directorate is responsible for the delivery of this Programme and possesses the project management and engineering competencies required to ensure the work is completed successfully.
- 3.3 The TfL Business Plan includes the latest estimated costs for the projects that will be delivered within the Programme.
- 3.4 Future investment in the passenger rolling stock and engineering vehicles will be required as the newer assets age and requirements evolve. The annual business planning process will provide the Financial Authority to meet these requirements and new projects will be initiated within the Programme. Additional Programme and Project Authority and Procurement Authority will be sought as appropriate in accordance with TfL's Standing Orders.

4 Strategic Case

LU Rolling Stock Renewals Programme objectives

- 4.1 The individual projects in the Programme contribute towards one or more of the Programme's objectives. A number of these projects satisfy mandatory requirements or deliver essential maintenance to ensure the safety of customers and improve asset performance. Other projects are discretionary but are aligned with the Programme's objectives. Business cases need to demonstrate each project's contribution to the objectives in order to secure Programme and Project Authority.
- 4.2 The table below presents the Programme's objectives and the specific policy goal from the Mayor's Transport Strategy that they support.

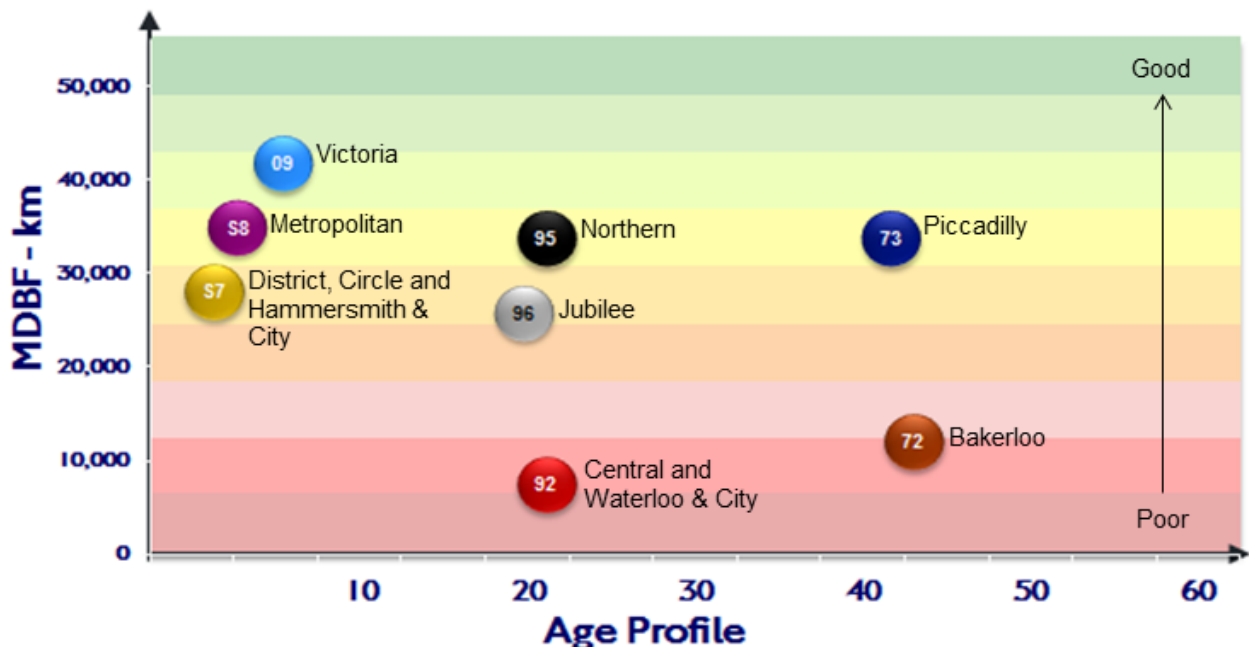
Mayor's Transport Strategy Policy Goals	Rolling Stock Renewals Programme Objectives
Support economic development and population growth	<ol style="list-style-type: none"> 1. Reduced operating costs 2. Reduced cost of infrastructure upgrades and renewals 3. Increased capacity 4. Improved reliability 5. Reduced journey times
Enhance the quality of life for all Londoners	<ol style="list-style-type: none"> 6. Improved customer satisfaction
Improve the safety and security of all Londoners	<ol style="list-style-type: none"> 7. Improved customer safety 8. Greater sense of personal security amongst LU's customers
Improve transport opportunities for all Londoners	<ol style="list-style-type: none"> 9. Improved accessibility across the LU network
Reduce transport's contribution to climate change, and improve its resilience	<ol style="list-style-type: none"> 10. Improved energy efficiency 11. Maximised recycling of energy 12. Increased resilience

Passenger Rolling stock

- 4.3 There are eight types of passenger rolling stock in use on the LU network, comprising 619 trains made up of 4,316 cars. These vehicles operate on 11 lines and are maintained across 14 fleet depots. LU's passenger rolling stock types are:

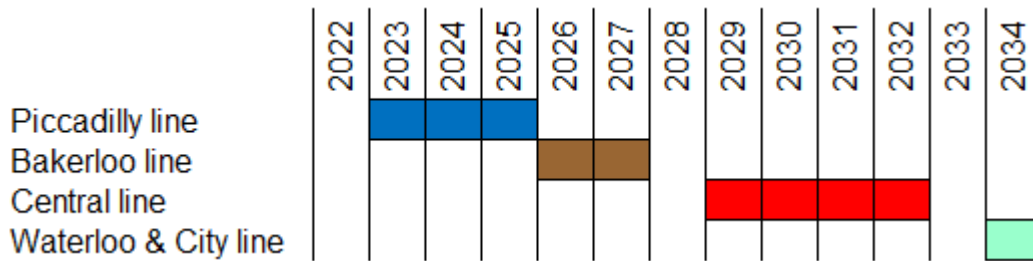
Line	Stock	Fleet Size and Configuration
Bakerloo	1972 Tube Stock (72TS)	36 x 7-car trains
Piccadilly	1973 Tube Stock (73TS)	86 x 6-car trains
Central	1992 Tube Stock (92TS)	85 x 8-car trains
Waterloo & City	1992 Tube Stock (92TS)	5 x 4-car trains
Northern	1995 Tube Stock (95TS)	106 x 6-car trains
Jubilee	1996 Tube Stock (96TS)	63 x 7-car trains
Victoria	2009 Tube Stock (09TS)	47 x 8-car trains
District, Circle and Hammersmith & City	S7 Stock	133 x 7-car trains
Metropolitan	S8 Stock	59 x 8-car trains

- 4.4 The assets typically account for approximately 40 per cent of LU's maintenance costs and 30 per cent of its Renewals and Enhancements capital costs.
- 4.5 Over the last 12 years the average reliability of LU passenger rolling stock has improved significantly from 5,000km to 24,000km Mean Distance Between Failure (MDBF). The assets span a broad spectrum of age, technology and performance and, as such, bring different requirements and challenges. The figure below illustrates the relative age and performance of each type of passenger rolling stock:



- 4.6 The variation in performance is largely due to design robustness, simplicity and the historical level of investment. LU's objective is to reduce this variation and improve reliability, capacity and customer satisfaction, whilst reducing whole life costs.

4.7 The rolling stock operated on the Piccadilly, Bakerloo, Central and Waterloo & City lines will be replaced through the Deep Tube Upgrade Programme. The indicative phasing of the fleet replacements is shown in the figure below:



4.8 From the diagrams above, it can be seen that the rolling stock operated on the Central and Waterloo & City lines are LU's worst performing trains and need to remain in service until the 2030s. Significant investment, representing almost half of the Programme's budget, is required to address the known issues with these fleets. This will ensure their continued safe and reliable operation until they are withdrawn from service.

4.9 The Programme is undertaking works to extend the life of the Bakerloo line trains to enable them to remain safe and fit for purpose until their planned replacement in the late 2020s. No further capital investment in the Piccadilly line fleet is planned before the trains are replaced but a regime of enhanced maintenance is being undertaken and a project has been initiated to mitigate the effect of leaf-fall on the line.

4.10 The mid-life refurbishment and modification of the Northern line's trains to improve customer experience and accessibility was completed in April 2015. An equivalent project for the Jubilee line's trains has commenced and is due to be completed in 2019.

4.11 No Programme investment is anticipated within the Business Plan horizon on the newer rolling stock types that are operated on the Metropolitan, District, Circle, Hammersmith & City and Victoria lines.

4.12 The scope of the Programme includes depot renewal projects to support the safe, efficient and cost-effective delivery of passenger rolling stock and engineering vehicle projects and maintenance. The Business Plan makes provision for the design and construction of a new workshop at Acton Works to replace life-expired facilities.

Engineering vehicles

4.13 Engineering vehicles are essential to the delivery of track maintenance and renewals. LU's fleet of engineering vehicles operates across the entire LU network and comprises:

- (a) electric and diesel locomotives (43 in total);
- (b) 11 types of wagon (197 in total) for hauling materials and waste;
- (c) 13 types of plant equipment (eg cranes) (27 units); and

- (d) a Track Recording Vehicle which measures the geometry of the track to ensure that it is safe and compliant with the standard.

4.14 Until the development of the current engineering vehicle work-stream in 2012, minimal investment had been provided in the engineering vehicles. The last significant investment took place in the 1970s and early 1980s. Many of the vehicles (particularly the wagons) came from Network Rail (and its predecessors) and are not optimised for the LU network.

4.15 The Programme supports a reduction in the cost of track maintenance and renewals, principally by enabling more activities to be mechanised (automated), and ensures that the engineering vehicles will remain safe and fit for purpose until their scheduled replacement.

4.16 The engineering vehicle work-stream has the following specific goals:

- (a) to extend the life of the existing battery-powered locomotives, which provide a critical haulage capability for the wagons and plant equipment, until a new heavy haulage capability is provided in the mid 2020s;
- (b) to replace LU's life-expired wagons to preserve capability, reduce maintenance costs and provide more efficient delivery through optimised design;
- (c) to support the adoption of a modern modular approach to the installation of rail junctions (points and crossings) to reduce costs and increase asset life;
- (d) to introduce a Mechanised Renewal Vehicle to reduce the cost of track renewal in deep tube tunnels and improve safety;
- (e) to introduce an Overnight Ballasted Track Renewal capability to reduce the cost of replacing life expired ballast and enable the activity to be carried out in engineering hours to reduce line closure requirements; and
- (f) to introduce an internal rail profiling capability to operate in areas of the network that are inaccessible to external hire market equipment.

5 Proposal

5.1 The LU Rolling Stock Renewals Programme currently comprises the following projects (all figures include risk and inflation):

Description	Financial Authority (£m)	Estimated Final Cost (EFC) (£m)	Existing Programme and Project Authority (£m)	This Authority Request (£m)	Future Requests (£m)
<p>Central Line Improvement Programme. Established to bring together the planned rolling stock investments to ensure that the trains operated on the Central and Waterloo & City lines remain safe and fit for purpose until they are replaced through the Deep Tube Upgrade Programme in the 2030s. The scope of work includes the replacement of the propulsion system and train computer, modifications to comply with accessibility regulations and structural repairs. Further details are at Appendix 1.</p>	314.30	314.30	32.22 (includes 3.05m prior authority for feasibility studies)	172.41 and Procurement Authority for award of propulsion system contract.	109.51
<p>Bakerloo Line Life Extension. Essential structural repairs, accessibility modifications and reliability improvement works to extend the life of the Bakerloo line trains until they are replaced through the Deep Tube Upgrade Programme in the late 2020s. Further details are at Appendix 2.</p>	115.28	115.28	65.59	0	53.56
<p>Jubilee Line Mid-life Refurbishment. Refurbishment of the Jubilee line saloon cars, modifications to comply with accessibility regulations and reliability improvements for the propulsion system. Further details are at Appendix 3.</p>	28.52	28.52	28.22	0	0.3
<p>Rail Adhesion Trains. Renewal of the Metropolitan line's Rail Adhesion Trains, which mitigate the effect of leaf-fall on the rail-head, and the provision of this capability on the Piccadilly line. Further details are at Appendix 4.</p>	8.17	8.17	8.38	0	0

Description	Financial Authority (£m)	Estimated Final Cost (EFC) (£m)	Existing Programme and Project Authority (£m)	This Authority Request (£m)	Future Requests (£m)
Remote Track Monitoring. A series of work packages to deliver LU's track condition monitoring requirements. These include: the design, manufacture and installation of automated track recording systems on a number of passenger trains for the Bakerloo, Victoria, District, Circle, Hammersmith & City and Metropolitan lines; stabilising LU's primary track recording capability; and determining the future remote track monitoring solution. Further details are at Appendix 5.	23.97	23.97	15.64	1.41	7.00
Mechanisation of Track Maintenance and Renewals. The design and manufacture of specialised vehicles to mechanise (automate) the maintenance and renewal of track assets. Further details are at Appendix 6.	85.83	85.83	5.71	2.00	78.54
Engineering Vehicle Life Extension and Replacement. Life extension and overhaul of engineering vehicles to enable them to remain in service until their planned replacement date. Procurement of 71 general purpose wagons to support track renewal and maintenance activities. Design and manufacture of a replacement to the battery-powered locomotive fleet. Further details are at Appendix 7.	59.04	59.04	40.44	1.34	22.71
Trains Modification Unit Workshop. The design and construction of a new facility at Acton Works for the delivery of rolling stock and engineering vehicle projects and heavy maintenance. Further details are at Appendix 8.	22.62	22.62	0.55	22.07	0
Miscellaneous rolling stock and engineering vehicle projects that will be closed in FY17/18; remaining costs for FY17/18 total £0.42m.	45.36	45.36	53.33	0	0
Totals (£m)	703.09	703.09	250.09*	199.23	271.62

* Note that savings and efficiencies have enabled the EFC of some projects that are in the delivery stage to be reduced below their authorised Programme and Project Authority. As a result, the total Financial Authority and EFC for the Programme are less than the sum of the existing Programme and Project Authority, this authority request and future requests.

6 Authorities sought

- 6.1 This paper is seeking additional Programme and Project Authority of £199.23m comprising £172.41m for the Central line Improvement Programme, £4.75m for four engineering vehicle projects and £22.07m for the design and build of a new workshop for the Trains Modification Unit, giving a total of £449.32m. The benefits that will be achieved from the proposed investment are summarised in the appendices.
- 6.2 The requested authority of £172.41m for the Central line Improvement Programme (Appendix 1) will fund the following principal outputs:
- (a) design, manufacture, supply and installation of a replacement propulsion system for the Central line fleet;
 - (b) design, manufacture and supply of a passenger information system and saloon CCTV for the Central line fleet;
 - (c) design, manufacture and supply of replacement energy efficient saloon lighting for the Central and Waterloo & City line fleets; and
 - (d) manufacture and supply of replacement car body panels for the Central line fleet.
- 6.3 As part of the Central line Improvement Programme, this paper requests Procurement Authority for the award of a design, manufacture and supply contract for a replacement propulsion system for the Central line fleet.
- 6.4 The release of the requested additional authority of £4.75m for the following engineering vehicle projects will be subject to the endorsement of individual investment submissions to the LU Board, planned for later in 2017:
- (a) Remote Track Monitoring (Appendix 5)
Additional scope to extend the life of LU's existing Track Recording Vehicle and determine the future remote track monitoring solution (£1.41m).
 - (b) Mechanisation of Track Maintenance and Renewals (Appendix 6)
Additional scope for works at Ruislip Depot as part of a project to mechanise the renewal of points and crossings (£0.5m); and
the design stage of the Mechanised Renewals Vehicle project, which is currently at the feasibility stage (£1.5m).
 - (c) Engineering Vehicle Life Extension and Replacement (Appendix 7)
Additional scope to overhaul 17 engineering vehicles in 2017/18 (£1.34m).
- 6.5 The release of the additional requested authority for the Trains Modification Unit Workshop project (Appendix 8) will be subject to the endorsement of an investment submission to the LU Board planned for May 2017. The Central line Improvement Programme will be delivered within the new facility. The facility provides long term benefit to other LU activities, including the delivery of maintenance and future improvements to passenger fleets.

Financial implications

6.6 Summary of the Programme costs and funding to 31 March 2024:

Costs and Funding (£m)	Prior Years	2016/17	2017/18	2018/19	2019/20	2020/21 to 2023/24	Total
Cost (Outturn)							
Estimated Final Cost	91.714	32.620	64.115	77.657	119.355	317.624	703.084

Forecast Budget/Plan	91.714	32.620	64.115	77.657	119.355	317.624	703.084
Third Party Funding	0	0	0	0	0	0	0
Plan Surplus/(Shortfall)	0	0	0	0	0	0	0
EFC of Approved Projects	91.714	32.620	45.055	38.389	13.617	10.838	232.233
This Authority Request	0	0	19.060	22.979	19.269	137.922	199.230
Future Requests	0	0	0	16.289	86.469	168.864	271.622

7 Assurance

- 7.1 A TfL Project Assurance (PA) and Independent Investment Programme Advisory Group (IIPAG) Assurance Review of the Programme took place in February 2017. A separate Assurance Review of the contract award recommendation for the replacement propulsion system for the Central line fleet took place in October 2016. The recommendations from the reviews are being addressed.
- 7.2 An Integrated Assurance Plan for the Programme has been agreed with TfL PA and this plan details the project-level reviews that will take place over the course of the year. Included within the plan are the following:
- Assurance Reviews of the contract award recommendations within the Central line Improvement Programme which will be held in support of the individual Commercial Procurement Steering Group meetings; and
 - Assurance Reviews of the engineering vehicle projects listed at paragraph 6.4 and the Trains Modification Unit Workshop project will be conducted in support of the respective submissions to the LU Board.

List of appendices to this paper:

- Appendix 1 Central Line Improvement Programme
- Appendix 2 Bakerloo Line Life Extension
- Appendix 3 Jubilee Line Mid-life Refurbishment
- Appendix 4 Rail Adhesion Trains
- Appendix 5 Remote Track Monitoring
- Appendix 6 Mechanisation of Track Maintenance and Renewals
- Appendix 7 Engineering Vehicle Life Extension and Replacement
- Appendix 8 Trains Modification Unit Workshop

Exempt supplementary information is included in a paper on Part 2 of the agenda.

List of background papers:

None.

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Appendix 1 – Central Line Improvement Programme

1 Background

- 1.1 The trains operated on the Central and Waterloo & City lines entered service between 1993 and 1995 and are halfway through their 40 year nominal design life. The Central line fleet performs worse than any other fleet and scores consistently lowest in customer satisfaction surveys. The problems experienced with the trains have their origins either in poor design, poor manufacture or obsolescence.
- 1.2 The trains contain technology that was innovative at the time but which is now superseded and difficult to maintain. They are the last trains procured by LU to use 'direct current' motors and the first to use electronic rather than electro-mechanical control systems. Almost £8m per year is spent repairing and overhauling the motors and containing the frequency of motor damage, known as 'flashovers', to below 200 per year. Photographs of the damage and burning that result from motor 'flashovers' are at the end of this Appendix.
- 1.3 The Central line Improvement Programme (CLIP) has been established to deliver essential works to ensure that the trains operated on the Central and Waterloo & City lines remain safe and fit for purpose until they are replaced through the Deep Tube Upgrade Programme in the 2030s.
- 1.4 The scope of CLIP is to:
 - a. replace the unreliable and costly-to-maintain 'direct current' propulsion system with a modern 'alternating current' propulsion system;
 - b. replace the unreliable and obsolete on-board train computer (known as the Data Transmission System);
 - c. repair floor corrosion damage and resolve door pillar cracking and water ingress concerns;
 - d. achieve an acceptable level of compliance with the Rail Vehicle Accessibility Regulations (RVAR), including wheelchair access and a visual and audible passenger information system; and
 - e. install CCTV and replacement energy efficient lighting in the carriages.
- 1.5 Initial Project Authority of £29.17m was awarded by the TfL Board on 19 July 2016 for the definition stage of CLIP. This authority funds:
 - a. the procurement of a replacement train computer for the Central line fleet;
 - b. the design and prototyping of rolling stock modifications and repairs to deliver the scope outlined at paragraphs 1.4c, 1.4d and 1.4e; and
 - c. programme management and production planning activities.

2 Proposal

2.1 Programme and Project Authority and Procurement Authority are sought for the design, manufacture and supply of a replacement propulsion system for the Central line fleet. The scope of the proposed contract includes the supply of:

- a. motors;
- b. propulsion system electronics;
- c. power supplies for the train's auxiliary system, such as the carriage lighting; and
- d. maintenance-free standby batteries which provide power for emergency ventilation, lighting and communication.

2.2 Programme and Project Authority is also sought for the:

- a. installation of the replacement propulsion system and on-board train computer;
- b. design, manufacture and supply of a modern Passenger Information System (PIS) and saloon CCTV for the Central line trains;
- c. design, manufacture and supply of energy efficient LED lighting for both the Central and Waterloo & City line trains;
- d. manufacture and supply of replacement car body ends for the Central line fleet to prevent water ingress; and
- e. repair of two defective Central line cabs and signalling modifications to enable a shuttle service to be introduced between Hainault and Woodford to partially mitigate the effect on train availability during the delivery stage of CLIP.

2.3 The current EFC of CLIP is £321.6m which exceeds the Financial Authority of £314.3m. The estimate will be refined as the design work is completed, as tenders are received from suppliers and through the application of lean production methods to the delivery stage. As necessary, scope management and prioritisation of the work will ensure that the EFC remains within the Financial Authority. This will be resolved prior to the request for the remaining Programme and Project Authority for CLIP in the next annual submission to the Committee for the LU Rolling Stock Renewals Programme.

Benefits of propulsion system upgrade

2.4 The primary means by which CLIP will improve fleet reliability and reduce operating costs is the replacement of the unreliable, obsolete and costly-to-maintain propulsion system with a modern 'alternating current' propulsion system.

2.5 The replacement propulsion system will reduce customer affecting failures attributed to the Central line fleet by 14 per cent. In addition, a quarter of cancellations due to trains being unavailable will be avoided.

- 2.6 There is a financially positive business case for the replacement of the existing propulsion system.
- 2.7 The fleet is expected to be replaced by 2033 and, by then, the propulsion system upgrade will produce a net financial saving of £32m (present value); the payback period from contract placement is 11 years (2028).
- 2.8 The table below shows the incremental financial effect of the propulsion upgrade compared with extending the life of the existing system:

Economic Appraisal	Propulsion system upgrade
Estimated Final Cost, £m (at outturn prices, including risk)	(159.728)
Incremental Net Present Values, £m (preferred option minus base case)	
Discounted NPV EFC (including risk)	(92.485)
Other costs	0
OPEX (+ or -)	86.268
Third Party	0
Revenue	23.149
Other Income (recoverable costs)	15.161
Net Financial Effect	32.093
Payback Period	11 years
Customer Benefits	86.299
Total Benefit	
Benefit : Cost Ratio	Financially Positive (no net cost)

- 2.9 The main benefits that the propulsion system upgrade will deliver are summarised in the table below:

Title	Description	Expected benefits (current prices) and measure
Reliability	Replacement of the unreliable propulsion system, static converters and batteries will improve train reliability and reduce service cancellations.	An annual reduction of 428 service affecting failures, avoiding 326,000 lost customer hours valued at £2.8m.
Fleet maintenance costs	Improved reliability will reduce casualty maintenance costs. Motor flashover mitigation costs will be avoided.	An average annual reduction of £7.3m in fleet maintenance costs.
Energy consumption	The replacement motors will be more energy efficient than the legacy equipment and the upgraded system will recycle more energy.	A 6.9 per cent reduction in energy consumption, saving £0.83m per year, and an annual reduction in CO ₂ emissions of 4,000 tonnes.

Title	Description	Expected benefits (current prices) and measure
Journey quality	Reduced energy consumption will reduce peak tunnel temperatures.	A 0.8°C reduction in peak tunnel temperature delivering annual ambience benefits valued at £1.6m and safety benefits valued at £0.4m.
Journey time	The propulsion upgrade will improve the rate of acceleration of heavily laden trains.	Interstation runtime improvements with an annual benefit worth £4.38m.

Alternative option to propulsion system upgrade

- 2.10 Retaining the existing propulsion system is feasible but this would limit the Central line's ability to achieve higher levels of reliability and would subject LU to ongoing maintenance costs averaging £8m (current prices) per year. The wider benefits identified at paragraph 2.9 would not be realised.
- 2.11 If the existing propulsion system is retained, the electronics and fibre-optic connectors would need to be overhauled. The estimated cost of this work to address obsolescence concerns and mitigate the risk of a further deterioration in reliability is £33.8m (outturn).

Benefits of PIS, saloon CCTV and LED lighting

- 2.12 Passenger information, such as the next destination of the train, must be visually displayed in every carriage to comply with accessibility regulations. In addition to satisfying this requirement, the installation of a modern passenger information system on the Central line trains will deliver customer benefits valued at £12.3m per year, giving a financially positive business case for the work. A passenger information system is not needed on the Waterloo & City line because it operates between two stations.
- 2.13 The installation of saloon CCTV on the Central line will produce annual customer security benefits valued at £16.6m. The Waterloo & City line trains already have saloon CCTV fitted.
- 2.14 The ambience benefit of replacing the fluorescent saloon lighting on the Central and Waterloo & City lines with LED lighting is estimated to be £0.46m per year. The energy saved by the switch to LED technology will offset the energy consumed by the PIS and saloon CCTV equipment.

Enhanced Capital Allowances

- 2.15 The procurement of motors and LED lighting is eligible for a Government rebate through the Enhanced Capital Allowance scheme whereby up to 19 per cent of costs are recoverable.
- 2.16 The rebate would be worth up to £30m if HM Revenue & Customs accepts that the full project costs qualify. The rebate does not contribute to the funding of CLIP.

Delivery

- 2.17 Analysis has determined that the CLIP rolling stock works, including the propulsion system upgrade, should be combined into a single installation package. This achieves the best balance between early benefits realisation and protecting train availability and timetables. The indicative schedule has the installation taking place between April 2019 and December 2022. Each train will be in work for 32 days, with a maximum of five trains in work at any given time.
- 2.18 In line with LU's strategic intent to develop and retain key internal capabilities and competencies, the Trains Modification Unit will deliver CLIP from a new workshop that will be constructed at Acton Works by December 2018. This investment is detailed at Appendix 8.
- 2.19 No increase in TfL headcount is needed for the procurement activities funded from the requested Programme and Project Authority but additional staff will be required for the delivery stage. These resource requirements will be detailed in the next Programme Authority Submission.

2.20 Key milestones for the Programme are:

Milestone	Target Date
Propulsion system contract award	March 2017
Train works commence	April 2019
Train works complete	December 2022

2.21 The top risks are:

Risk No	Risk Description	Mitigation Actions
1	LU liable for interface issues that are identified between the train computer and the new propulsion system, PIS and CCTV.	Equipment suppliers to agree interface control documents. Regular design reviews with equipment suppliers, rig testing and prototype testing.
2	Train condition (wiring, structure and re-used equipment) worse than predicted.	Carry out train condition surveys. Conduct prototype testing of modification schemes.
3	New-build facilities at Acton Works not ready for planned start of rolling stock works.	Identify alternate facilities in which to deliver the ramp-up phase of CLIP.
4	Trains Modification Unit unable to recruit, train and retain sufficient maintenance staff to deliver CLIP at the planned rate. This has been compounded by the implications of IR35 status for public sector contractors.	Plan recruitment and training campaign aligned to CLIP ramp-up schedule. Contracting arrangements for non-permanent staff to be reviewed.

2.22 The current EFC for CLIP includes a risk value of £22.2m of which £9.74m is included in this authority request. The majority of the requested risk value is based on a quantitative risk analysis of the recommended supplier's project plans for the design and manufacture of the replacement propulsion system.

3 Financial implications

3.1 CLIP will be delivered within the Financial Authority of £314.3m. The EFC will be updated as tender prices are received from suppliers and the delivery plan is refined.

3.2 Summary of the costs and funding:

Costs and Funding (£m)	Prior Years	2016/17	2017/18	2018/19	2019/20	2020/21 to 2023/24	Total
Cost (Outturn)							
Estimated Final Cost	1.652	3.550	9.544	19.358	80.699	199.493	314.296
Investment Funding							
Forecast Budget/Plan	1.652	3.550	9.544	19.358	80.699	199.493	314.296
Feasibility study outturn cost	1.652	1.557	0	0	0	0	3.209
Current Authority	0	1.993	7.793	4.744	3.799	10.838	29.167
This Authority Request	0	0	1.751	13.465	19.269	137.922	172.407
Future Requests	0	0	0	1.149	57.631	50.733	109.513

Commercial

3.3 A manufacture and supply agreement suitable for the procurement of complex plant and equipment has been developed. This contract has been used for the propulsion system and train computer procurements and will ensure that LU has access to the technical information needed to maintain and reconfigure the systems for the remaining life of the Central line fleet.

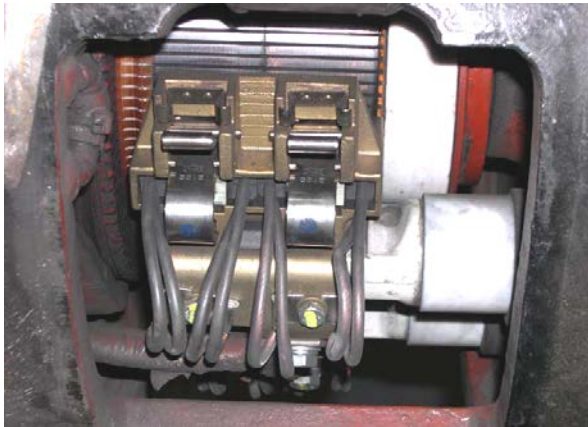
3.4 The contract for the replacement of the train computer was awarded in December 2016. The cost is contained within the previously awarded Programme and Project Authority.

3.5 Milestone payments for the design, development and test stages of the propulsion system contract are aligned with the approval of design reviews and completion of prototype testing. Subsequent milestone payments, coupled with liquidated damage provisions, will incentivise the supplier to meet the agreed equipment delivery schedules and the reliability performance targets.

3.6 The supplier is also incentivised to work with LU to maximise the Enhanced Capital Allowance rebate. Post-delivery, a long-term support services agreement will commence with the equipment supplier.

3.7 The procurement strategy for the competitive tendering of contracts for the design, manufacture and supply of the PIS, saloon CCTV and LED lighting has been approved. The invitation-to-tender for the PIS was issued in September 2016 and it is planned that the contract will be awarded in May 2017. Competitions for the saloon CCTV and LED lighting contracts are due to be completed by January 2018.

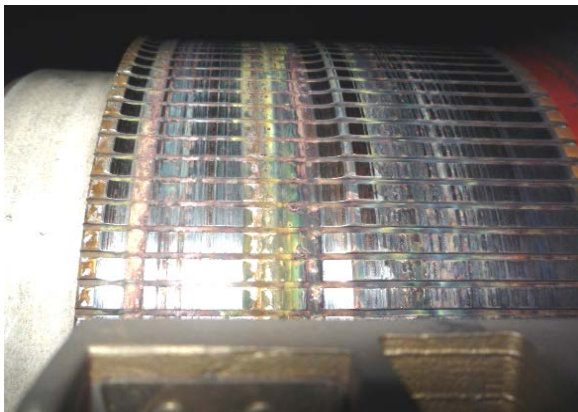
Photographs of the existing propulsion system



Existing motor, showing the brush-gear and commutator before a flashover



Existing motor as a result of a flashover



Damaged commutator from a flash over



Propulsion system electronic card - damaged beyond repair

Appendix 2 – Bakerloo Line Life Extension

1 Background

- 1.1 The Bakerloo line fleet comprises 36 trains of 1972 Tube Stock (72TS) and has a nominal design life of 40 years. The fleet was originally planned to be replaced in 2018 as part of the Deep Tube Upgrade Programme. Due to business priorities this has now been deferred until the late 2020s. The fleet is now 45 years old and suffers from age related failures which impair its structural integrity.
- 1.2 The Bakerloo line fleet has one of the lowest Mean Distance Between Failure (MBDF) performances of LU's passenger rolling stock. It is substantially out-performed by the Piccadilly line which is of a similar age and design.
- 1.3 Due to the deferred replacement date of the Bakerloo line fleet, budget has been prioritised to fund essential maintenance works and reliability improvements.
- 1.4 LU published a condition study report in June 2013 which identified that substantial repairs were needed to ensure that the trains meet relevant safety standards regarding performance in a collision or derailment until the fleet's replacement. Photographs of typical damage and the repairs are at the end of this Appendix.
- 1.5 In addition, it is necessary to modify the trains to comply with the Rail Vehicle Accessibility Regulations (RVAR) legislation and fulfil the Mayor's commitment to ensure London's transport system is accessible to all users.

2 Proposal

- 2.1 To rectify the reliability and structural issues of the Bakerloo line fleet and improve accessibility, three work streams are being progressed:

Weld repairs

- 2.2 The scope of this project, which is fully authorised and underway, includes weld repairs and corrosion repairs to structural elements of the carriages and the fitment of an RVAR compliant floor covering. To date, nine trains have been repaired and 43 per cent (£24m) of the EFC will have been incurred by 31 March 17.
- 2.3 The delivery of the project will ramp up from repairing a single train at a time to the concurrent repair of two trains from March 2017. This acceleration of the project will reduce the overall cost and complete the repair work by the end of 2018/19, in line with engineering recommendations.

Reliability improvements

- 2.4 It is proposed to undertake a range of essential reliability improvement and overhaul works to keep the fleet in operation until the late 2020s.
- 2.5 The items within scope include work on the propulsion and braking systems as well as an overhaul of the saloon doors and ambience works to improve the interior and exterior of the train. Engineering assessments of the rolling stock will take place during 2017 to verify the final scope and costs. Programme and Project Authority for the works will be sought in 2018.

RVAR compliance

- 2.6 The following train modifications must be implemented to improve accessibility:
- a. two wheelchair bays located in a single car of each seven-car train;
 - b. palm-operable passenger emergency alarms located adjacent to the wheelchair bays providing direct communication with the driver;
 - c. audible and visual Passenger Information Systems (PIS);
 - d. handrails on either side of the saloon double doors and a single handrail at the single doors;
 - e. external signage indicating the car in which the wheelchair bays are located and internal signage identifying the wheelchair bays within the car; and
 - f. LED lighting to reduce the demand on the power supply and thereby accommodate the additional load from the PIS.
- 2.7 Programme and Project Authority of £5.6m has been awarded for the design and prototyping of the RVAR modifications and the procurement and installation of LED lighting. Additional authority to implement the RVAR works will be sought in 2018.

Benefits

- 2.8 The benefits of the Bakerloo line projects, over the remaining life of the fleet, are:

Benefit	Description (all values are outturn)
PIS	The provision of a PIS gives customer benefits worth £51.193m.
Multi-purpose areas (MPA)	Wheelchair bays can be used as a MPA when not occupied by wheelchair users. The benefit to customers is valued at £1.237m.
Reduction in the energy costs	Saloon LED lighting will reduce power consumption, producing a net cost saving of £0.5m once the power requirements of PIS are taken into account.
Improved ambience	There will be an improvement in ambience scores for lighting and saloon temperature with a customer benefit of £5.745m.
Improved safety	The work will enable a number of Cases for Continued Safe Operation relating to car body structural integrity and condition and saloon lighting diffusers to be closed.
Enhanced Capital Allowance	LED lighting is eligible for Enhanced Capital Allowances, providing a 19 per cent tax rebate. The rebate is estimated to be £0.41m.
Improved reliability	The expected improvement in fleet availability and reduction in lost customer hours will be confirmed in future investment submissions.

2.9 The economic appraisal and benefits of the weld repairs and RVAR projects, compared with the base case options of carrying out the weld repairs on a single train at a time and not modifying the trains, is shown below:

Economic Appraisal	Life extension works
Estimated Final Cost, £m (at outturn prices, including risk)	(88.665)
Incremental Net Present Values ,£m (preferred option minus base case)	
Discounted NPV EFC (including risk)	(22.311)
Enhanced Capital Allowance rebate	0.379
OPEX (+ or -)	(0.294)
Revenue	8.621
Net Financial Effect	(13.605)
Customer Benefits	32.277
Total Benefit	
Benefit : Cost Ratio	2.37:1

Delivery

- 2.10 The Bakerloo line projects are managed by the Rolling Stock Renewals team. LU's Trains Modification Unit is delivering the weld repairs project and will implement the accessibility modifications once the design work has been completed.
- 2.11 The wheelchair bay and handrail design work will be delivered through external design companies and supported and assured by LU engineers. The PIS will be procured from an external supplier who can provide the design and materials for the implementation phase.
- 2.12 Reliability improvement works will be delivered through fleet maintenance teams and project teams. Where the work is simple, and can be readily integrated into routine maintenance work, then the fleet maintenance team will include it within their annual work schedules. If the work is more involved, the delivery of the reliability improvements will be aligned with the accessibility modifications.

Photographs of typical structural damage and repairs



Car body corrosion



Repaired structure

Appendix 3 - Jubilee Line Mid-life Refurbishment

1 Background

- 1.1 The Jubilee line fleet was first introduced into service in 1997 with additional rolling stock procured in 2005 to add a seventh car to each train. The fleet now comprises 63 seven-car trains of 1996 Tube Stock.
- 1.2 The design life of the trains is 40 years. By 2017/18, the fleet, with the exception of those cars added in 2005, will be 20 years old and requires refurbishment to keep the interior and exterior in an acceptable condition.
- 1.3 It is necessary to modify the trains to comply with the Rail Vehicle Accessibility Regulations (RVAR) legislation and fulfil the Mayor's commitment to ensure London's transport system is accessible to all users.
- 1.4 Work is also proposed to improve the reliability of the train's propulsion system. The system accounts for 11.6 per cent of service affecting failures attributed to the Jubilee line rolling stock.

2 Proposal

- 2.1 The proposal comprises two projects:

Mid-life refurbishment

- 2.2 The mid-life refurbishment project, which is fully authorised, will refurbish the saloon cars, enhance ambience levels and achieve RVAR compliance. Work on the first train has been completed and, by 31 March 2017, 19 per cent (£5.35m) of the project's EFC will have been incurred.

- 2.3 The proposed scope of work includes:

- a. refurbishment of saloon and cab interiors, including grab-poles and handles;
- b. refurbishment of the train exterior;
- c. prevention of water ingress by resealing and filling gaps between the body panels and the car ends;
- d. replacement of the saloon glass;
- e. replacement of the cab and saloon flooring with a new flooring system that enables individual sections to be lifted without the need to remove and replace all of the floor covering; and
- f. modification of existing multi-purpose areas to provide RVAR compliant wheelchair spaces with palm-operable passenger emergency alarms.

Propulsion system reliability

- 2.4 Modifications to the propulsion system have been proposed that are expected to improve the reliability of the fleet and reduce maintenance costs. These

modifications have been developed through engineering analysis which has identified the electronic components responsible for past failures.

- 2.5 Programme and Project Authority will be sought in 2018 to undertake the necessary testing to prove that the proposed modifications improve reliability. If the testing is successful, the modifications will be carried out by the Fleet maintenance team during the repair of failed electronics modules. This approach will avoid the cost of an implementation project.

Benefits

- 2.6 These projects will deliver the following benefits:
- a. RVAR compliance to the equivalent level achieved on the Northern line and agreed with the Department for Transport;
 - b. an improvement in train ambience scores;
 - c. improved train reliability and availability achieved by preventing water ingress and installing a modular floor that will enable quicker access to repair train wiring and controls; and
 - d. a reduction in propulsion system service affecting failures to an average of 1.3 per period. This would return the performance of the propulsion system to its best historical performance, improving reliability and reducing maintenance costs.
- 2.7 The table below shows the incremental financial effect of the agreed scope of mid-life refurbishment work, compared to the base case of carrying out only the minimum scope of work to achieve RVAR compliance, plus the expected benefits from the propulsion system reliability modifications:

Economic Appraisal	
Estimated Final Cost, £m (at outturn prices)	(28.525)
Incremental Net Present Values ,£m (preferred option minus base case)	
Discounted NPV EFC (including risk)	(8.077)
OPEX (+ or -)	1.779
Revenue	10.768
Net Financial Effect	4.470
Payback Period	20 years
Customer Benefits	39.810
Total Benefit	
Benefit : Cost Ratio	Financially Positive (no net cost)

Delivery

- 2.8 The Jubilee line mid-life refurbishment will be managed by the Rolling Stock Renewals team and delivered by a Fleet project team. The Fleet maintenance team will carry out the propulsion system reliability trials.

Appendix 4 - Rail Adhesion Trains

1 Background

- 1.1 Poor adhesion conditions are mitigated on the Metropolitan line by one specially converted train, known as a Rail Adhesion Train (RAT). The RAT treats the rail head in the autumn (through the application of Sandite, a composite material of sand and aluminium in the form of an adhesive paste) to maintain the minimum required level of adhesion during leaf fall conditions. Without this mitigation, speed restrictions must be applied to maintain braking performance and to run a safe service.
- 1.2 The demand for RAT coverage will increase when the Four Lines Modernisation Programme introduces Automatic Train Control (ATC) on the Metropolitan line. Scenario analysis has confirmed that two RATs will be required to support ATC operation from circa 2021.
- 1.3 The Piccadilly line fleet is vulnerable to wheel damage caused by low adhesion conditions but the line is currently not supported by any means to improve rail adhesion and protect against wheel slide.
- 1.4 The Piccadilly line fleet has experienced abnormally high levels of wheel damage during the last two leaf-fall seasons. Almost half of the fleet was stopped as a result of damaged wheels in November 2016, resulting in severe delays on the line for nearly three weeks, whilst the trains were repaired.
- 1.5 The driving style and techniques employed by train operators play an important role in avoiding wheel slide. However, instances of wheel slide in the 2016 leaf-fall season, despite the application of the defined defensive driving technique, have highlighted the need for improvements to the existing mitigation measures.

2 Proposal

- 2.1 The proposal for these projects, both of which are fully authorised, is as follows:

Metropolitan line Rail Adhesion Train

- 2.2 By September 2017, the project will replace the Metropolitan line's single, life-expired, RAT with two new RATs converted from redundant D-Stock trains taken from the District line. The project will modify the Sandite filling platform at Neasden Depot to support the introduction of the new RATs and provide operator and maintainer training. The project will have incurred costs of £4.65m (67 per cent of the current EFC of £6.93m) by 31 March 2017.

Piccadilly line Rail Adhesion Trains

- 2.3 Funding of £1.24m was approved in December 2016 to provide a Piccadilly line RAT capability by September 2017.
- 2.4 The proposal is to take one Piccadilly line passenger train out of service for up to six months each year and convert it to create two 3-car RATs. The temporary conversion will entail Fleet maintenance staff fitting and removing a pallet-mounted

Sandite dispensing module in each RAT. The modules will be based upon equipment already designed for the Central and Metropolitan line RATs.

- 2.5 One RAT will be used to treat the rail between Cockfosters and Arnos Grove and the second RAT will operate between Northfields and Osterley. The Rayners Lane branch of the line will be supported by the Metropolitan line RATs.
- 2.6 In low adhesion conditions, a reduced brake rate is selected to reduce the risk of wheel slip. Reducing the brake rate to a lower level would further reduce the likelihood of wheel slip.
- 2.7 A leaf-fall season timetable will need to be introduced on the Piccadilly line to incorporate the operation of RATs and to accommodate the modified brake rate and any temporary speed restrictions.

Benefits

- 2.8 The following table is an economic appraisal of the two RAT proposals. The Metropolitan line project is compared to the base case of retiring the existing RAT and installing a large number of track-side Sandite applicators. The Piccadilly line project is compared with the dis-benefits incurred in 2016.

Economic Appraisal	
Estimated Final Cost, £m (at outturn prices, including risk)	(8.164)
Incremental Net Present Values, £m (preferred option minus base case)	
Discounted NPV EFC (including risk)	1.496
OPEX (+ or -)	(2.374)
Revenue	12.839
Net Financial Effect	11.961
Customer Benefits	191.936
Total Benefit	
Benefit : Cost Ratio	Financially Positive (no net cost)

Delivery

- 2.9 Both projects will be managed by the Rolling Stock Renewals team. LU's Trains Modifications Unit will carry out the modifications to the D-Stock trains.
- 2.10 The design and development of the pallet-mounted Sandite dispensing module for the Piccadilly line RAT will be delivered by a specialist contractor. This will not be competitively tendered because a single contractor possesses the experience and expertise needed to complete the work before September 2017. The installation will be carried out by the Fleet maintenance team.

Appendix 5 – Remote Track Monitoring

1 Background

- 1.1 Dynamic track monitoring (to replicate track movement under loaded conditions) is required to enable LU to meet its obligations to provide a safe railway by determining the condition of the track asset. It is a key component of the track maintenance regime and enables reactive and planned maintenance to be targeted to manage asset risks. Today, monitoring is achieved through:
 - a. data collection by a combination of Automatic Track Monitoring System (ATMS) and the Track Recording Vehicle (TRV); and
 - b. data processing by a series of internal systems and teams to provide track asset condition information to maintenance teams.
- 1.2 ATMS is being installed and used on a number of passenger trains on the Bakerloo, Victoria, District, Circle, Hammersmith & City and Metropolitan lines. The system provides statutory four-weekly monitoring through daily data capture and supports the optimisation of maintenance activities.
- 1.3 The TRV is LU's primary track monitoring asset. It operates on an eight-weekly cycle on the Central, Jubilee, Northern and Piccadilly lines and on a six-monthly cycle on the lines that are routinely monitored by ATMS.
- 1.4 The TRV is life expired and there is a high risk of it being unserviceable for extended periods. Unavailability of the TRV would compromise LU's ability to demonstrate a safe railway. This would result in increased track inspections and speed restrictions. Ultimately, a 25mph speed limit would need to be imposed on the lines that are not monitored by ATMS.
- 1.5 The Remote Track Monitoring (RTM) projects seek to deliver key principles aligned with a vision to "provide a safe, highly reliable and customer focused train service that supports London's future capacity demands at low whole life cost". These principles are:
 - a. protection of current capability;
 - b. reduction in operational costs of the current capability; and
 - c. enhancement of the capability to reduce long term operational costs and improve reliability.

2 Proposal

- 2.1 The scope of RTM is to:
 - a. complete delivery of the ATMS project;
 - b. extend the life of the TRV and develop a contingency plan for TRV unavailability; and
 - c. develop medium- and long-term solutions for dynamic track recording.

- 2.2 The ATMS project is fully authorised and, by 31 March 2017, will have incurred cost of £13.55m (87 per cent of the current EFC of £15.56m).
- 2.3 Additional authority of £1.41m is requested in this submission to protect the current TRV capability.

Benefits

- 2.4 From 2017/18, ATMS will deliver annual operational savings of £2.273m across the six lines that it supports.
- 2.5 The work to extend the life of the TRV and develop a contingency plan will enable LU to continue to meet its obligations to operate a safe railway.
- 2.6 The medium term objective of the project is to reduce RTM operational costs by enabling unattended operation and combining the data processing and maintenance function. The long term objective is to increase the monitoring capability to further reduce track maintenance costs. These benefits are yet to be quantified.

Delivery

- 2.7 The RTM scope will be managed by an internal team within the Rolling Stock Renewals team. Specialist contractors and other internal teams will be employed to deliver specific packages of work.

Appendix 6 – Mechanisation of Track Maintenance and Renewal

1 Background

- 1.1 The following track maintenance and renewal activities are currently delivered using manual practices:
- a. Points & Crossing (P&C) Renewal. Access constraints mean that pre-fabrication of replacement track junctions (points and crossings) is not currently viable. This contributes to high costs for the work which typically requires one weekend closure plus nine follow-up shifts in engineering hours per junction.
 - b. Ballasted Track Maintenance and Renewal. Ballasted track replacement is currently completed manually under weekend closures. The unit rate is £2,500/m for full track renewal and £1,800/m for ballast replacement. Between 500m and 900m of track can be renewed on a weekend closure, or 8m per shift in engineering hours.
 - c. Concreted Track Renewal. Concreted track renewal in deep tube tunnels is typically completed in engineering hours and requires materials and tools to be transported by hand through stations. The unit rate is £5,500/m and 3m of track can be replaced per shift.
 - d. Rail Head Maintenance. The manual grinding or milling of the rail head is completed in engineering hours utilising hand tools or leased equipment when available and appropriate. This activity maintains the optimum contact area between the rail and the train wheels, ensuring the safe and reliable performance of the track asset.
- 1.2 Increased mechanisation of these tasks would reduce costs and access requirements and improve the reliability and life of the track asset.

2 Proposal

P&C Package

- 2.1 In 2014, £4.64m of capital funding and £21.5m of lease funding was authorised to enable the development and purchase of:
- a. tilt wagons and cranes to enable prefabricated P&C modules to be transported to site to reduce the installation time and cost; and
 - b. two “tamping units” to consolidate ballast material and set and maintain the track alignment.
- 2.2 Progress to date has seen the delivery of the two tamping units, which are in beneficial use, and completion of the concept design for the tilt wagons and cranes. By 31 March 2017, the project will have incurred costs totalling £4.0m.

- 2.3 In order to maximise the benefit from the tilt wagons and cranes, £4.46m has been budgeted to deliver a materials handling facility within the track loading bay area at Ruislip Depot and coordinate the streamlining of the P&C renewals process. This submission requests Programme and Project Authority of £0.5m for the concept design of the facility.
- 2.4 The table below shows the incremental financial effect of the P&C Package compared with the base case of not proceeding with the project. Based on the track programme work-bank, the project is estimated to save a total of £7m over the 10 year lease period:

Economic Appraisal	
Estimated Final Cost, £m (at outturn prices, including risk)	(9.097)
Incremental Net Present Values, £m (preferred option minus base case)	
Discounted NPV EFC (including risk)	(4.797)
P&C Replacement Savings (net of lease)	11.860
Net Financial Effect	7.063
Payback Period	1 year
Customer Benefits	26.815
Total Benefit	
Benefit : Cost Ratio	Financially Positive (no net cost)

- 2.5 The scope will be managed by the Rolling Stock Renewals team with the core works being completed by specialist contractors; the tamping machines have been supplied by Matisa and Kirow is developing the tilt wagons and cranes. Additional specialist engineering assurance support has been commissioned from Ricardo Rail.

Overnight Ballasted Track Renewal (OBTR)

- 2.6 This scheme seeks to mechanise the ballasted track renewal activity. Work completed to date, from an initial authority of £0.33m, has identified that with new equipment, 57m of ballasted track could be renewed during engineering hours, at a unit rate of £1,178/m, across 74 per cent of the ballasted rail network.
- 2.7 The scope of work to achieve mechanised OBTR is threefold:
- a. procurement of new, bespoke, plant that can replace track ballast during overnight engineering hours;
 - b. provision of a purpose built material handling facility and associated infrastructure at Ruislip Depot to load/unload the new plant; and
 - c. changes to organisational and commercial arrangements to fully realise the benefits of mechanisation.
- 2.8 Additional authority to progress this project, which has an EFC of £51.41m, will be sought in 2018.

2.9 Based on the track programme work-bank, the OBTR project is estimated to save a total of £163m and deliver customer benefits of £353m over a 25 year period. The savings will be achieved through reductions in the unit rate of renewals and customers will benefit from fewer weekend line closures.

2.10 The table below shows the incremental financial effect of OBTR compared with the traditional methods:

Economic Appraisal	
Estimated Final Cost, £m (at outturn prices, including risk)	(51.413)
Incremental Net Present Values, £m (preferred option minus base case)	
Discounted NPV EFC (including risk)	(45.200)
Track Programme Savings	64.600
OPEX (+ or -)	23.320
Revenue	120.180
Net Financial Effect	162.900
Payback Period	4 years
Customer Benefits	353.480
Total Benefit	
Benefit : Cost Ratio	Financially Positive (no net cost)

2.11 Plant procurement will follow a three-phase approach:

- a. pre-qualification questionnaire assessment to shortlist four suppliers;
- b. the four suppliers independently and concurrently develop their solution to a technical requirement specification; and
- c. the preferred supplier is selected to deliver their solution under a manufacture and supply agreement.

2.12 The materials handling facility will be developed by a specialist consultant through to single option concept design stage, whereupon the design and build will be competitively tendered.

2.13 The internal management team will deliver the necessary business change, utilising specialist contractors where required.

Mechanised Renewals Vehicles (MRVs)

2.14 In order to mechanise the renewal of concreted track, feasibility work has identified two concepts:

- a. Partial mechanisation which would focus on track alignment adjustment, spoil removal and concrete pouring. The proposal would utilise commercially available components, with minimal customisation, to achieve productivity of 9m per engineering shift within two years and deliver a unit rate reduction of c£800/m.

- b. Full mechanisation of the majority of the renewal activity. The proposal would utilise custom designed equipment to achieve productivity of 15-17.5m per shift within six years and deliver a unit rate reduction of c£1,500/m.

2.15 Analysis of the options has identified that the preferred approach is to provide one vehicle to deliver partial mechanisation as the initial investment and then to develop two MRVs to fully mechanise the renewal activity. Additional authority of £0.47m, giving a total of £0.74m, was approved in October 2016 to complete proof of concept work by mid 2017.

2.16 This submission requests Programme and Project Authority of £1.5m for the design of the partial mechanisation vehicle and development of the associated infrastructure at Ruislip Depot.

2.17 Based on the track programme work-bank, concreted track renewal mechanisation is estimated to save £138m over a 25 year period.

Economic Appraisal	
Estimated Final Cost, £m (at outturn prices, including risk)	(21.459)
Incremental Net Present Values, £m (preferred option minus base case)	
Discounted NPV EFC (including risk)	(16.842)
Operational costs	(4.091)
Track Programme Savings	158.612
Net Financial Effect	137.679
Payback Period	6 years
Total Benefit	
Benefit : Cost Ratio	Financially Positive (no net cost)

2.18 The project is being managed by the Rolling Stock Renewals team, utilising specialist contractors where necessary.

Rail Head Re-profiling

2.19 The outline proposal is to develop a mechanised rail head re-profiling machine that can operate across the LU network. This capability would increase productivity and reduce the cost of the activity. The benefits have yet to be quantified.

2.20 Initial Programme and Project Authority for the project, which has an EFC of £4.22m, will be requested in 2018.

2.21 The project will be managed by the Rolling Stock Renewals team and the development and manufacture of the rail head re-profiling machine will be competitively tendered.

Appendix 7 - Engineering Vehicle Life Extension and Replacement

1 Background

1.1 The scope of this work package comprises four individual projects.

Engineering vehicle overhaul

1.2 To ensure that LU's fleet of engineering vehicles continues to operate reliably, a programme of overhaul is required. Funding of £0.999m was approved in February 2017 to commence the overhaul of the engineering vehicle fleet.

Wagon replacement

1.3 The engineering vehicle fleet includes eleven types of wagon that are used to transport materials across the LU network. These wagons have suffered from minimal investment and are of a design that restricts the volume of work that can be delivered.

1.4 Funding of £11.498m was approved in June 2016 for the direct purchase of 86 new wagons to replace 99 existing wagons. Due to currency rate changes since the EU Referendum, the preferred supplier revised their quotation. Despite this increase in cost, the bid was still the most economically advantageous but the scope of the contract has needed to be reduced to 71 new wagons to remain affordable. A subsequent review of the requirements has resulted in a revised future fleet size of 185 wagons.

Battery locomotive life extension

1.5 LU operates 29 battery locomotives (of 1964, 1969, and 1973 builds) and 14 'Schoma' diesel locomotives (of 1995 and 2015 builds). These locomotives haul the other types of engineering vehicle to work sites to deliver the track renewal programme and track maintenance works.

1.6 The battery locomotives have a design life of 40 years and were not designed to run on the 750V power supply which the Four Lines Modernisation Programme will implement on the Metropolitan, District, Circle and Hammersmith & City lines.

1.7 In 2011, £27.9m was approved to extend the life of the battery locomotive fleet until 2026 and to modify the vehicles to make them compatible with a 750V line voltage.

Heavy haulage

1.8 Due to limited space in the cab and beneath the train, battery locomotives can only accommodate two different types of modern signalling systems. Similarly, the Schoma locomotives can only accommodate one modern signalling system.

1.9 There are currently three modern and two legacy types of signalling systems in use on the LU network. Following the Piccadilly line upgrade in 2026, this will increase to four modern and two legacy types of signalling system. As a result of this added complexity, and given the available numbers of locomotives, elements of the track renewal programme and maintenance would not be deliverable beyond 2026 without significant closures and/or increase in costs.

2 Proposal

Engineering vehicle overhaul

- 2.1 This authority submission seeks an additional £1.34m to overhaul 17 engineering vehicles in 2017/18. The overhaul of these vehicles is essential to support the track programme.

Wagon replacement

- 2.2 Based on the whole-life (40 years) cost, the net savings from the procurement of 71 new wagons are estimated to be £2.535m. The business case for the project is financially positive with a 20 year payback period.

Battery locomotive life extension

- 2.3 By 31 March 2017, the life extension works will have been completed on 22 battery locomotives and the project will have incurred costs totalling £18.9m (80 per cent of the current EFC of £23.5m). Work on the 29th locomotive is due to be completed in August 2019.
- 2.4 Extending the life of the battery locomotives has delayed the cost of procuring a replacement fleet and will reduce the maintenance cost of the vehicles to 2026 by £1.8m. The life extension project will be delivered without affecting the track programme and track maintenance works.

Heavy haulage

- 2.5 This scheme proposes to replace the existing battery locomotive fleet with a modern equivalent by 2026. The project, which has an EFC of £20.95m, is expected to design and manufacture the first two replacement locomotives, with the intention that the remainder of the fleet will be obtained through a lease arrangement. It is proposed to initiate the project in 2018 with a feasibility study.
- 2.6 The modern battery locomotives will provide the following benefits:
- a. a 20 per cent increase in capacity, enabling the total number of locomotives to be reduced;
 - b. a signalling back-bone to enable four different signalling systems to be installed and allow the locomotives to operate across the LU network; and
 - c. reduced maintenance costs (to be quantified).

Delivery

- 2.7 The engineering vehicle life extension and replacement projects will be managed by the Rolling Stock Renewals team.
- 2.8 The overhaul of the engineering vehicles will be managed by an internal team within the TransPlant organisation, utilising specialist contractors (normally the original equipment manufacturer) to complete the works.
- 2.9 The life extension of the battery locomotives will be completed by the Trains Modification Unit and the contract to replace the heavy haulage capability will be competitively tendered. Specialist engineering contractors will be used where necessary.

Appendix 8 – Trains Modification Unit Workshop

1 Background

- 1.1 LU's overall strategy for engineering, manufacturing and specialist services is to develop, consolidate and retain key internal capabilities and competencies that will enable the organisation to provide a timely, economic and efficient service. Given that LU owns the freehold, and in consideration of its geographic location, existing functions and good transportation links, Acton Works has been selected as the preferred location to consolidate activities.
- 1.2 Trains Modification Unit's (TMU) workshop capacity at Acton Works is constrained. It is accommodated in buildings that date back to the 1920s and which are approaching the end of their structural life. These facilities provide insufficient capacity for the efficient delivery of the Central line Improvement Programme (CLIP), are not connected to the railway and cannot accommodate full length trains.
- 1.3 CLIP provides the incentive for LU to make a long-term investment in new facilities for TMU now, but it is not the sole reason for the proposed investment. The facility will support the delivery of rolling stock heavy maintenance, any modifications needed on the new Deep Tube Upgrade Programme fleets (eg signalling equipment fitment) and the modification and refurbishment of passenger trains and engineering vehicles for the next 40 years and beyond.

2 Proposal

- 2.1 The proposal is to erect a new TMU workshop on the Acton Works site comprising:
 - a. four rail-linked train maintenance roads;
 - b. one flat maintenance road for component work;
 - c. welfare facilities; and
 - d. office accommodation.
- 2.2 The project has existing authority of £0.55m which has funded the feasibility and concept design stages. This submission requests additional Programme and Project Authority of £22.07m for the design and build of the workshop. The completed workshop will be handed over to TMU by December 2018, ready for the start of the CLIP works.

Benefits (and Value)

- 2.3 Constructing a new workshop will produce a net saving of £3.5m (present value) over the next 10 years compared with refurbishing TMU's existing facilities. This results from:
 - a. the savings that will be achieved from the efficient delivery of CLIP;
 - b. avoidance of the cost of providing maintenance facilities at Neasden Depot;

- c. operating cost savings from TMU carrying out S-Stock heavy maintenance; and
- d. avoidance of storage leasing costs from 2022.

2.4 A summary of the economic appraisal, over 25 years, of the proposed option and the base case option of refurbishing TMU’s existing facilities and delivering CLIP externally is tabulated below:

Economic Appraisal	New workshop	Refurbishment
Estimated Final Cost, £m (at outturn prices, including risk)	(22.618)	(13.636)
Net Present Values (NPV) ,£m		
Discounted NPV EFC (including risk)	(20.904)	(12.767)
OPEX (+ or -)	7.240	(13.020)
Other Income (recoverable costs)	0.422	0.030
Net Financial Effect	(13.241)	(25.756)

2.5 This analysis shows that the cost of the new workshop would need to be as high as £33.4m (present value) before the option of refurbishing the existing facilities had a lower net financial effect.

Delivery

2.6 This project is being managed and delivered by the Construction team within LU Renewals and Enhancements Directorate, using sub-contractor framework contracts. Tender returns for a fixed price design and build contract are due to be received in April 2017. The enabling works for the construction will be a separate work package to reduce the risk priced by the main contractor.

Concept Design Image

