Technical note

Project:	Bakerloo Line Extension	**To:**	Chris Porter, for TfL comment
Subject:	New Cross Gate Station Option 3B Review	**From:**	Neil Baker
Date:	31 Aug 2018	**cc:**	-

1. Introduction

1.1. Background

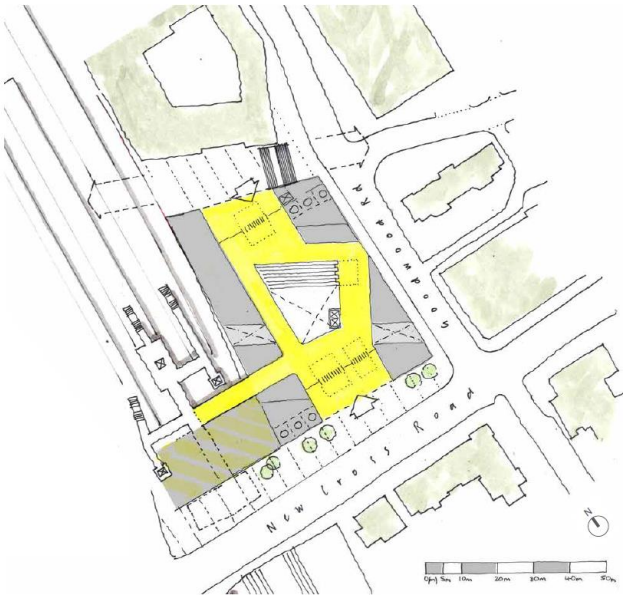
The Bakerloo Line Extension Scheme Development includes a new sub-surface station, adjacent to the existing New Cross Gate station, enabling interchange with National Rail and London Overground services. Options for locating the new station have included potential sites to the west and east of the existing station and railway tracks.

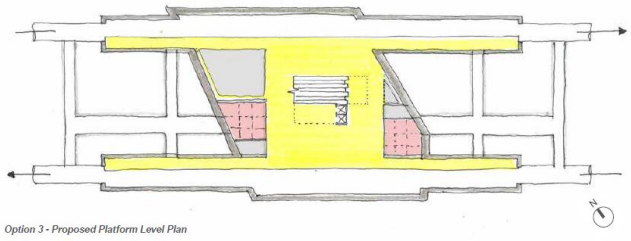
The 2017 Bakerloo Line Extension public consultation sought comments on a proposed station constructed on the site owned by Sainsbury's to the west of the existing New Cross Gate station. In response to the public consultation, Sainsbury's, together with their development partner, Mount Anvil, has prepared an alternative concept design for the new station, fully located on the site to the east of the existing station, subsequently referred to as Option 3B.

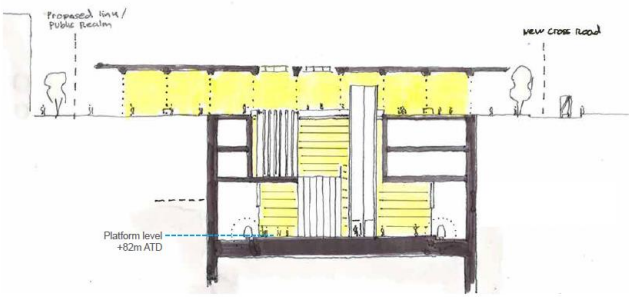
This Technical Note provides an appraisal by Atkins of the Option 3B concept design, on behalf of Transport for London (TfL), as part of an ongoing engagement process with Sainsbury's Mount Anvil (S/MA).

1.2. Option 3B Description

Option 3B has been prepared by S/MA and their design team, led by Weston Williamson and Partners, as featured in document: *'New Cross Gate - Bakerloo Line Extension Options Analysis',* prepared in May 2018. The relevant drawings for the proposal feature on pages 12 and 13 of the document and are replicated below:







The station arrangement is comprised of an asymmetric deep station box, assumed to be approximately 50m wide by 60m long, incorporating enlarged stub platform tunnels at its lowest level and a series of connecting passageways that form circulation routes outside of the station box. Further accommodation and circulation space is included at ground level, above and beyond the extent of the station box.

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The station arrangement is geometrically complex and is likely to require meticulous construction planning to mitigate the risk (and NR-percieved risks) of adverse construction impacts on adjacent operational interests.

1.3. Terms of Reference

A design review has been carried out by Atkins' multi-disciplinary team to assess station planning, civil & structural engineering, tunnel engineering, the tunnel ventilation system and fire & life safety, together with a constructability review by Atkins' construction advisor, Costain.

The review has focused on an assessment of the proposed functional and operational station characteristics against London Underground Limited's (LUL) design standards and requirements.

2. Summary of Findings

Using the limited information contained within the S/MA presentation of Option 3B, the following summary points have arisen from the multi-disciplinary design review:

- Option 3B features a railway alignment that is rotated from the current BLE Scheme Development alignment. The resulting impact of this alternative alignment on the operation of the Bakerloo line would impair LUL's objective of delivering the 'best railway' (for a publicly funded, public transport scheme);
- There is considerable uncertainty regarding the ground conditions at New Cross Gate. Risks associated with the construction of a complex station arrangement, featuring a combination of box construction and open-face mining methodologies, are greatly amplified by limited knowledge of the ground conditions at this site;
- The proposed construction worksite is highly constrained, making implementation more likely to be costly, slower and with greater associated impacts than the consulted option;
- In comparison with a standard rectilinear station box, the Option 3B arrangement is less-well performing, in terms of passenger circulation, interchange and operational efficiency;
- The asymmetric, complex station arrangement results in increased challenges related to design uncertainty and the associated need for a greater level of effort to resolve non-standard elements. As an example, it is assumed from the sketches that the tunnel ventilation system incorporates numerous changes in direction of ductwork, potentially leading to increased design input, equipment sizing and power consumption.

3. Comments and Observations

3.1. Premises & Station Planning

The following section provides a review of the station planning components of the Option 3B concept design, as illustrated in the introduction. While the plans and section have been prepared to scale, it has not been possible to obtain precise measurements from the drawings, given their 'sketch' nature and low level of design definition. All dimensions referenced below have been estimated.

The concept design has been reviewed, at high-level, against LUL Station Planning Standards and Guidelines, as well as accepted best practices in metro station design. It has also been carried out with reference to static analysis of 2031 forecast passenger demand numbers (*Rail Plan: OK243A323, 2031* with-*BLE DS High Development Scenario + NXG fix* (revised OK224)).

3.1.1. Entrance and Gateline

New Cross Gate station requires one entrance to operate in a satisfactory manner under the requirements of the Bakerloo Line extension. While the two separate entrances shown in Option 3B may introduce a degree

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of convenience for passengers arriving at, and leaving the station, the resulting duplication of entrance equipment and staff assistance is considered excessive and would result in higher levels of capital and operational expenditure. The entrance onto New Cross Road is considered sufficient for accommodating the required number of ticket fare gates, serving the NR and LUL stations, combined.

3.1.2. Horizontal Circulation and Concourses

At street level, the widths of circulation passageways appear sufficient for the movement of passengers during peak operational hours. However, the passenger movement towards the head of the escalators includes a 90º turn from the south entrance and a 180º turn from the north. These movements, in the narrow space provided, may generate unsatisfactory levels of congestion, particularly given the cross-flows of passengers from two directions (two station entrances). LUL's design standards, as well as best practice in station design, advise that 180º changes in direction should be avoided, due to the likelihood of resulting congestion and the negative impact on intuitive wayfinding.

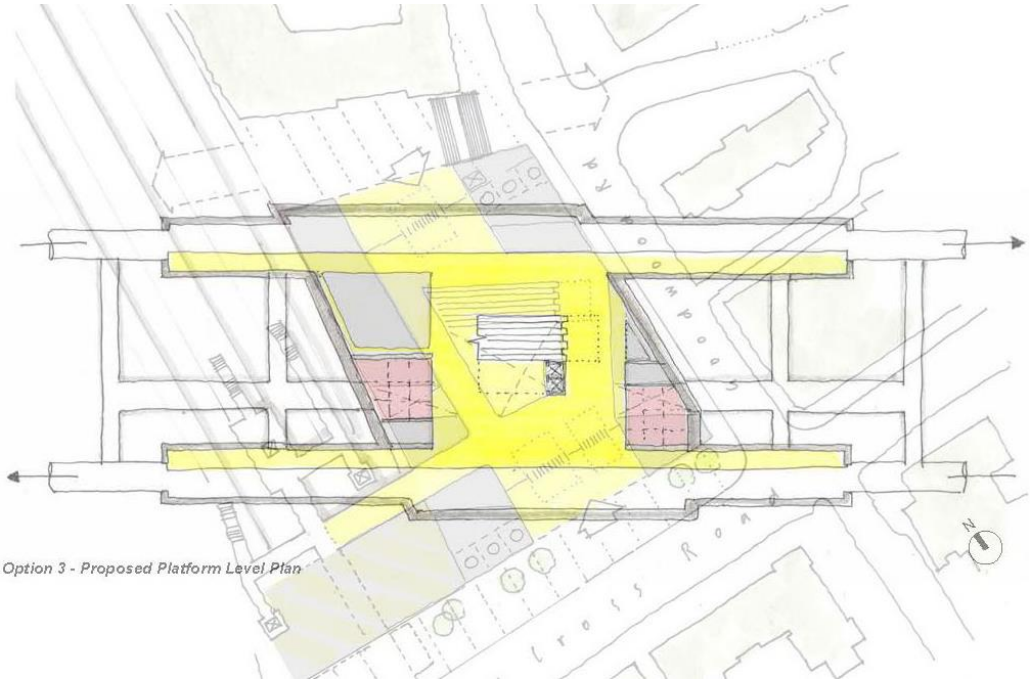
The two banks of escalators also include a 180º switchback (intermediate level), which would generate the same passenger movement issues as above.

A minimum of 3m width is required for the platforms and it is considered that sufficient space has been, or can be, provided in Option 3B.

LUL's design standards state a maximum dead-end distance of 20m to a point of platform escape. It is assumed that the adits shown approximately 20m from the ends of the platforms fulfil this requirement.

An unpaid concourse of 36.4m^2 is required at the proposed station. The requirement appears to be accommodated at both station entrances.

The illustration below provides an overlay of the two Option 3B scaled plans, provided by S/MA. The station box appears to extend beyond the site boundary, encroaching on Network Rail property and the paved areas of Goodwood Road and New Cross Road. It is considered that the box would need to decrease in length and width to allow it to be constructed in a feasible manner. The reduction in box size would likely mean that there would be insufficient residual space for passenger circulation.



3.1.3. Vertical Circulation

The static analysis calculations for the BLE indicate that 3 no. escalators are required for operation of New Cross Gate station. This requirement has been accommodated in Option 3B. The concept also allows for 2 no. passenger lifts, which again, satisfies the BLE functional requirements.

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3.1.4. Accommodation

It is considered that sufficient back-of-house space is provided under Option 3B to meet the operational and functional requirements of the station. It is assumed that the tunnel ventilation fans are orientated vertically, with the lowest part of their assemblies at street level, basement 1, or basement 2, given the need for air mixing plenums and ducting to the tunnel portals at platform level.

It is assumed that accommodation may be included on a number of levels above street level, as the TVS intake and discharge louvres will be incorporated at a higher level within the station building.

3.1.5. Large Equipment Access

While it is considered that sufficient back-of-house space is provided for major equipment, such as power transformers and the tunnel ventilation system, the routes for the delivery and removal of large equipment are not identified. Vertical lifting routes and adequately sized corridors should be shown, so that the operational viability of the station arrangement can be properly assessed.

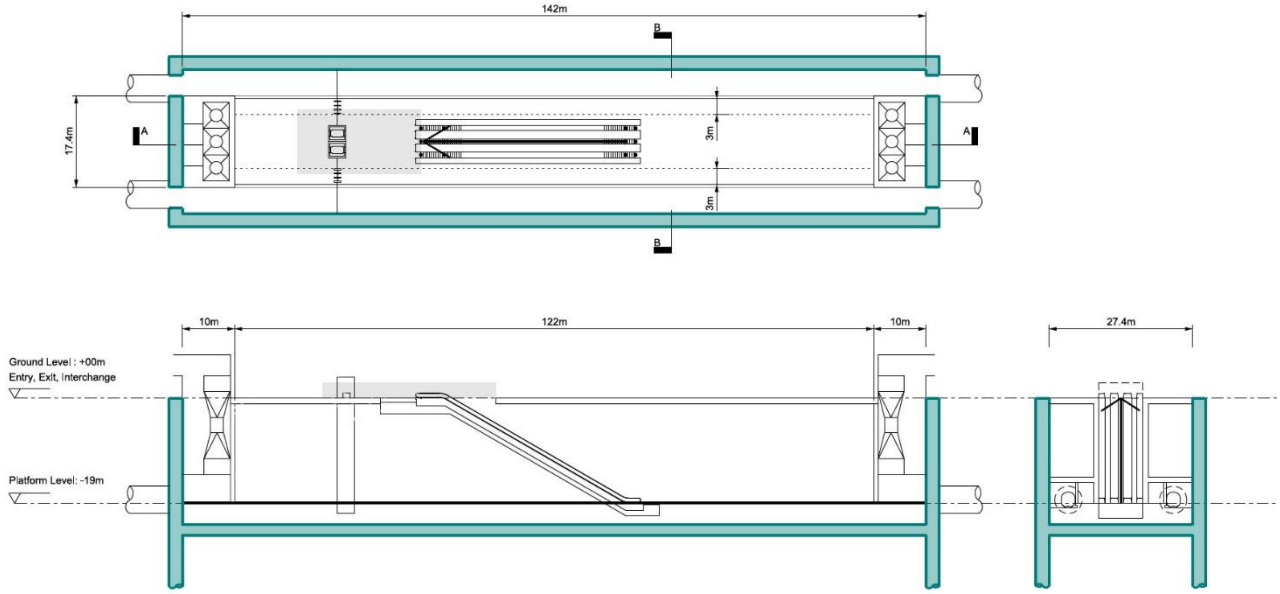
3.1.6. Interchange

A large number of Bakerloo Line passengers will interchange with National Rail and London Overground at New Cross Gate, therefore there is a requirement to focus on minimising interchange distances. While interchange provision in Option 3B is sufficient, the overall interchange distance and time is considered to be greater than alternative options sited to the west of the existing Network Rail station.

3.2. Structural & Civil Engineering

The construction of a standard, rectilinear ‘station box’ is the preferred structural option for forming the Bakerloo Line Extension stations, as this is the optimal typology for accommodating all the station functions within the ground in a compact and efficient manner. The optimal length and width of a station box are dictated by a series of technical requirements, including:

- Minimum train length and gauge requirements (the physical space required around the train);
- Minimum end-of-platform space for tunnel ventilation systems and emergency access/egress;
- Minimum platform widths and passenger vertical circulation requirements.



This station arrangement has been used wherever there is sufficient space available at ground level to build an optimised box. Where sufficient space is not available at ground level, the alternative has been to propose mined platform tunnels with shafts/boxes used for ventilation and emergency access at the ends of the platforms. This combined arrangement is not preferred, as it increases the horizontal separation between

platforms and requires mined platform cross-passages and inclined escalator barrels. These extensive sprayed concrete lining (SCL) tunnels and adits are less preferable than a single station box, due to a significant increase in cost, construction risk and arrangement complexity.

It is understood that Option 3B is a combination of a single station box with mined platforms extending both to the east and west. This is less favourable than a standard station box, from a structural perspective, as it comprises a large box to accommodate both platforms (which are spaced further apart) as well as a network of mined tunnels.

The Option 3B station box occupies a large portion of the associated proposed construction site and it is not clear where SCL equipment, required for construction, would be accommodated within the limited site area. An alternative logistics site would be required.

It is assumed that Option 3B features SCL tunnels mined under the NR station and tracks. The impact of settlement on the NR infrastructure will be more onerous than construction of a standard station box on a site adjacent to NR's property. The risks, and reasonable perception of risk, are likely to condition NR's safeguarding requirements, which may include prolonged speed restrictions during construction.

Option 3B has rotated the alignment of the platforms significantly, anti-clockwise. This orientation will need to be tested against the calculated 'ideal' alignment, to ensure that it addresses significant physical constraints, such the foundations of tall buildings to the east of the proposed Old Kent Road 2 station, and the connection to the ventilation shaft on Lewisham Way. The rotation of the alignment will result in impairment of LUL's 'best operational railway' public transport objective.

3.3. Tunnel Engineering

From a tunnel engineering perspective, the concept of a 'station box', together with a network of mined tunnels, is feasible, though significantly more complex than a standard, station box configuration. Skewed junctions between the station box and tunnel adits, due to the Option 3B station geometry, are necessary and likely to require costly construction sequences and carry construction risk.

The required box excavation largely fills the entire south east site identified in the sketches, which will result in challenging construction processes. It is considered that an additional site will be required for offices, welfare, layout, storage and parking, etc. The large volumes of spoil from the excavation will need to be immediately removed from site by the highway, as there does not appear to be an available area for spoil storage.

The layout of the tunnel network shown would likely need to be amended for efficiency of construction and to ensure that the correct size of tunnel cross-sections are provided for passenger movement, tunnel ventilation and services routing. It is assumed that the central adits connecting with the box at the lowest level, between the platform tunnels, are used to accommodate both emergency access and egress, as well as tunnel ventilation.

The geology of the site and its vicinity has been estimated from publicly-accessible borehole data from the British Geological Survey (BGS) and other data held by Atkins. There is considerable uncertainty regarding ground characterisation and the standing assumption is that conditions will be unfavourable, with ground treatment required for open-face 'mined' tunnelling (i.e. not using a Tunnel Boring Machine). This ground treatment may include dewatering, jet grouting and fissure grouting, and is likely to be required across all areas of ground were there are platform tunnels and connecting adits, as well as their respective junctions.

It is expected that the proposed tunnels are in potentially unstable, water-bearing ground (including Chalk, Thanet Sands and some parts of the Lambeth Group), hence the likely requirement for ground treatment to allow tunnel construction. The requirement and optimum solution will only be determined once detailed site investigation is carried out, though it should be assumed that a minimum 2m annulus should be required around any such tunnel to be treated by grouting. This means a grouted zone including the tunnel and extending a minimum of 2m beyond the tunnel in all directions.

The form of grouting will depend on ground conditions and is likely to consist of one or more of:

- Permeation grouting;

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- Jet grouting.

Alternative means of ground treatment exist but are less likely to be preferred. It will be possible to carry out grouting purely at tunnel level (i.e. drilling near-horizontally from a deep box excavation, or already-constructed tunnels) though it is most efficient to grout, where possible, from ground level.

There is a substantial length of mined tunnel under the existing railway. The ground here will be more difficult to treat and is a requirement that poses considerable project risks, such as third-party approvals and the interruption of Network Rail services, or prolonged speed restrictions. To grout under the railway, inclined bores could be made from ground level, either side of the railway, with 'blind spots' filled in by drilling and grouting from tunnel level. The programme time and cost are likely to be significantly high.

Option 3B also includes a substantial length of mined tunnel under adjacent private property. Again, these areas of ground would be difficult to treat and would likely require temporary road closures for grouting from ground level.

In terms of potential effects from grouting:

- Introduction of pollutants into aquifers (particularly cement grout, although chemical grouts may also be required);
- Ground settlement or heave;
- Short term pressures on buried assets (e.g. sewer pipes);
- Grout travel beyond the planned grouting zone;
- Obstruction of groundwater flow.

When well designed and executed, it should be possible to achieve a high level of ground improvement, such as would permit open-face tunnelling, without major deleterious effects on surrounding assets.

The running tunnel alignment (and associated platform tunnel alignment) appears from the sketches to be sub-optimal, in comparison with the 'ideal' BLE alignment through New Cross Gate, and is likely to result in an 'S-curve' between Old Kent Road 2 station and Lewisham. The proposed alignment also points towards a number of modern medium-rise buildings to the east that are likely to be piled. It would likely be necessary to amend the Option 3B alignment so that these piled foundations are avoided.

The proposed station configuration results, necessarily, in very widely-spaced platforms, which would be disadvantageous to the introduction, at a later date, of a crossover adjacent to New Cross Gate station.

3.4. Tunnel Ventilation System

From the limited information on TVS arrangements shown as sketch information presented in pages 12 and 13 of the presentation, we understand the station concept layout with respect to the TVS provisions would be to relocate the ventilation equipment cores towards the centre of the station, near the vertical circulation core, gate lines and TfL premises, as shown below, with TVS cores highlighted.

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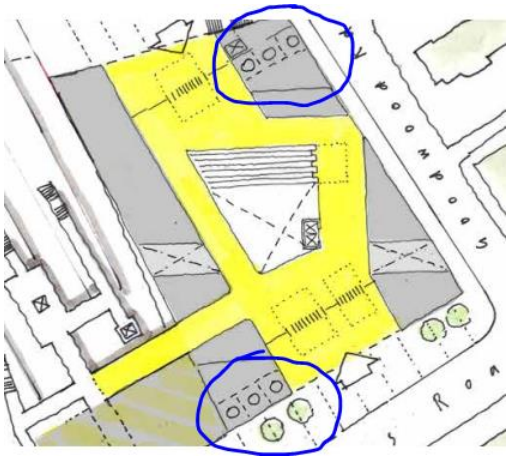
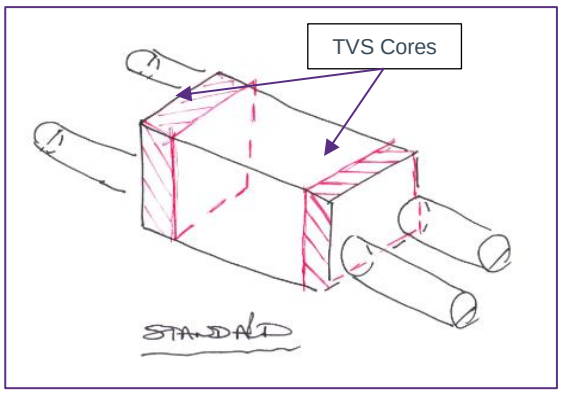


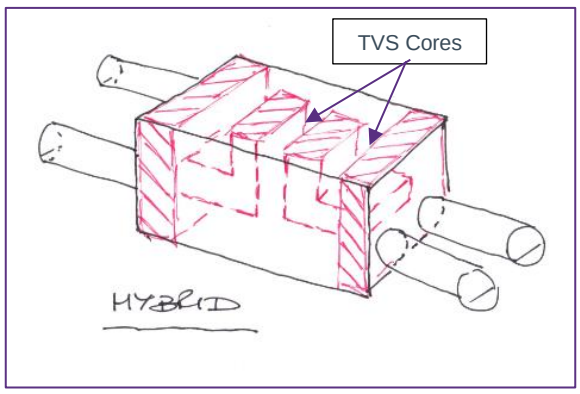
This arrangement does provide independent TVS cores serving both ends of the station box, respects the 3-fan arrangement layout per core and offers good surface separation between the combined draught relief and forced ventilation connections of the TVS, as seen conceptually at other BLE stations.

This arrangement is considered to be non-standard, in TVS terms for a metro station, and for simplicity we have referred to it as being a 'hybrid' arrangement.

We consider a standard arrangement to be:



The Hybrid arrangement that appears to be planned:



We have the following observations on this hybrid arrangement:

- The need for TVS connections within the station box at track level beyond the platform zone: the hybrid option does not appear to offer any savings in overall station length at that level;
- Relocating the TVS equipment rooms and the significant size ducts and adits that serve them from track level to surface at the ends of the station box to a centralized location, as well as the impact on space planning, is not demonstrated within the sketch proposals made;
- Relocating the TVS vertical equipment cores higher within the station box, itself, in a more central location and the impact on the overall station height and the accommodation of the vertical equipment, coupled with the respective discharge/louvre arrangements at surface level, or higher, is not demonstrated;
- The air paths, as can be seen due to additional bends, will add airway losses to a comparably sized standard arrangement. This may impact draught relief performance and require fans for forced ventilation scenarios to have increased motor sizes, resulting in greater energy consumption;

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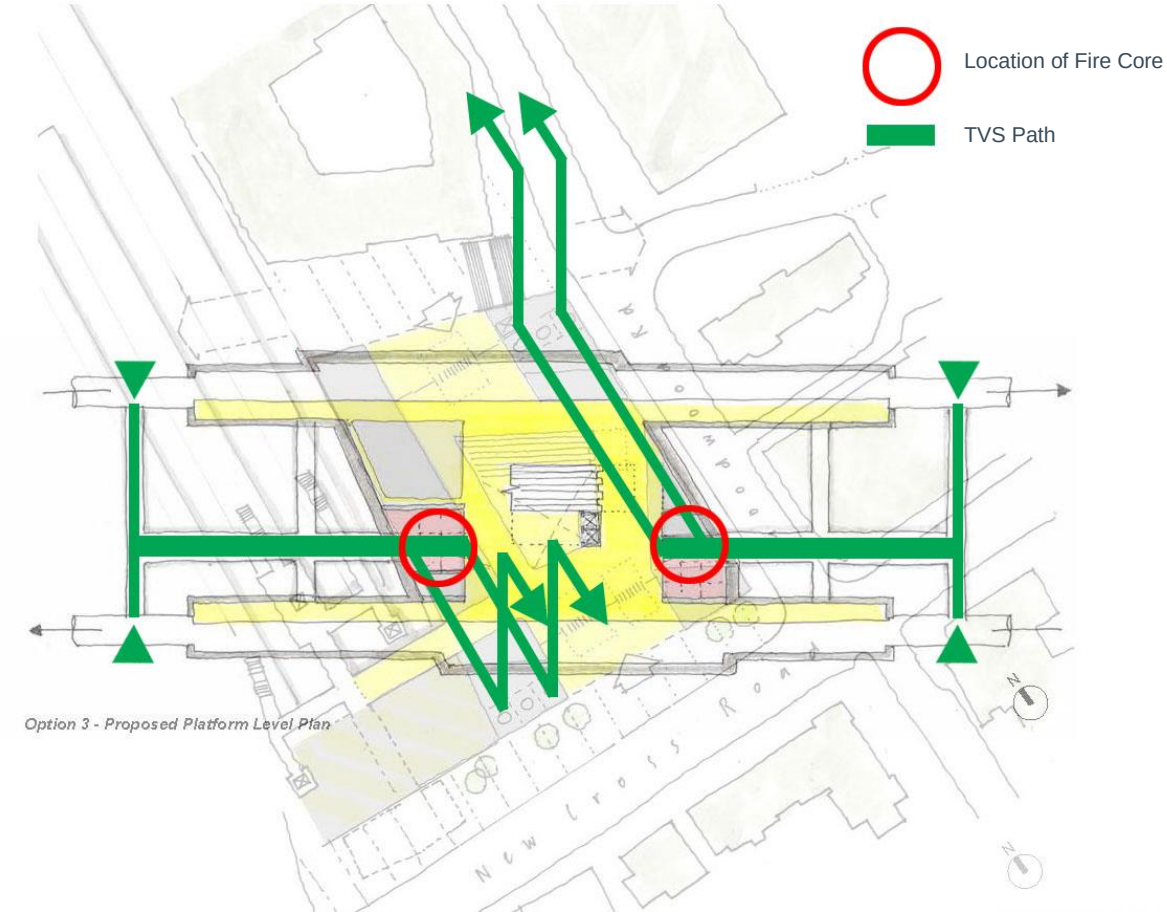

- It is not clear from the sketches presented in the S/MA document how the requirements to meet good practice guidelines in the design of a metro system, in terms of equipment maintenance, installation and replacement will be met;
- Option 3B moves the railway noise sources from the draught relief shafts, as well as the forced ventilation noise sources from the fans of the TVS, closer to Goodwood Rd and New Cross Rd;
- The ventilation openings facing New Cross Rd will be subject to an increased level of vehicle emitted pollutants particularly if the louvres were to be located at street level.

3.5. Impacts on Fire and Life Safety

The issues most likely to affect the feasibility of a concept at this stage are:

- Means of escape in case of fire;
- Access and facilities for fire-fighters.

The sketches offered in the presentation do not provide any detail of how these are to be accommodated, but the following sketch informs the general layout of the platforms:

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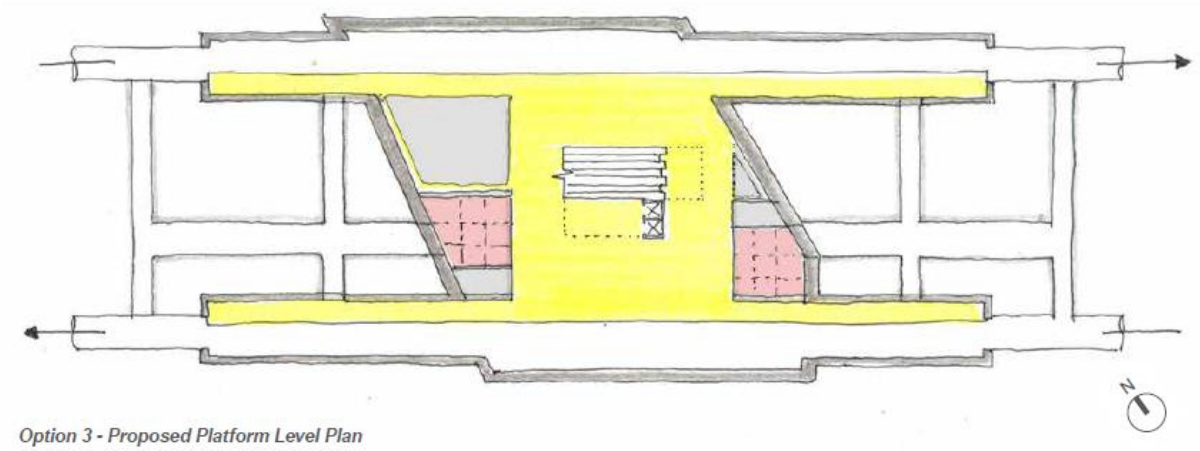

Option 3 - Proposed Platform Level Plan

This type of arrangement would appear to have the potential to be compliant with LUL standard S1371, on the basis that the multiple adits should (if wide enough) be able to accommodate a platform clearance time of <4 minutes and, provided that there are no 'dead ends' > 20 m the platform escape configuration, may be compliant. It is less certain that the < 6 minutes to reach a place of relative safety requirement would be achieved, though, if strategically-placed fire and smoke resisting doorsets can be accommodated, this may deliver a compliant solution.

The alternative would be to provide dedicated escape shafts from the platform ends, but from the sketches showing the configuration at the surface, it is not possible to see how these could be straightforwardly accommodated.

Having said the above, if compliant fire-fighting shafts can be provided, this may augment the protected means of escape capacity from the platforms and concourses.

Fire-fighting access is likely to comprise the following:

- One or two fire-fighting shafts that serve all levels in the station (including any intermediate concourses and/or staff accommodation levels);
- Fire main inlets located < 18 m from a location where fire engines can be parked;
- Fire-fighting and escape access to the station control room directly from street level (this may be combined with fire-fighting shaft access).

No indication of the above arrangements is shown in the sketches in the presentation; it cannot, therefore, be verified that these issues have been considered. Having said this, many station works have provided these facilities in sites at least as constrained as that shown; fire-fighting shafts do not necessarily have to transit directly from platform to street – it is possible to use intermediate (fire protected) corridors to link multiple shafts, meaning that they do not always have to be vertically aligned from platform to street. This may enable compliant fire-fighting access to be provided, even though the platforms do not appear to be aligned beneath locations that are part of the worksite.

By inspection, there should be no issue providing fire main inlets within 18 m of a position accessible to firefighting vehicles. Though these are usually positioned next to the entrances to fire-fighting shafts, they do not have to be, so they could be positioned next to any of the roadways that bound the site.

It should be possible to provide direct, fire protected access to the station control room from any of the public highways surrounding the station by means of careful internal planning of the staff accommodation.

In summary, it is not evident from the document reviewed that fire and life safety has been considered in this concept – none of the usual facilities such as fire-fighting shafts are indicated. These will not be straightforward to incorporate in this station arrangement, due to the platforms being located under land that

is outside the worksite at street level. If this option were to be pursued, it may be possible to address this issue, albeit at the cost of some reasonably complex internal fire-fighting arrangements, using 'transfer corridors'. There are precedents for this elsewhere on LUL.

By inspection, the configuration shown has the potential for being compliant with LUL standard S1371 regarding means of escape from the public areas of the station, but it is likely that this would require either fire and smoke resisting doorsets at platform level, or the incorporation of a platform smoke control system (as used on some of the Crossrail stations).

3.6. Constructability

3.6.1. Site availability

Based on construction experience from recent similar metro schemes, a site area of 15,000m^2 is considered the minimum size for convenient execution of all construction activities, including welfare, material storage, and vehicle movement. While it is technically feasible to construct metro stations using smaller sites, the impact of cost and programme is significant, due to the complexity of site set-up and the need for careful planning of all operations.

The Goodwood Road site identified in the Option 3B sketches is measured to be approximately 7,800m^2. At this size it is considered that activities would be significantly constrained, with an associated impact on programme and cost, due to inherent inefficiencies from working in such conditions. To operate effectively as a construction site, it would likely be necessary to acquire the existing residential housing at the northern end of the site (Auburn Close).

The reference made to Paddington Crossrail in the S/MA document is considered to be incorrect. The Paddington team acquired Eastbourne Terrace for a period, meaning that the site area was substantially increased (approximately 20,000m^2). There was also a significant storage area in an undercroft next to the Westway.

The site would require demolition of 7 no. commercial/residential units along New Cross Road, along with Goodwood House, and 7 no. residential houses on Goodwood Road. This represents a significant amount of enabling work, as well as social impact.

On the south side of New Cross Road, there is a large student residence, along with a number of private residential buildings nearby. There will likely be need for substantial noise mitigation measures, etc., to be put in place during the works.

3.6.2. Logistics

Access onto the Goodwood Road site is less favourable than the west side of the existing railway, with a main access point needing to be formed at the northern end of Goodwood Road (to maintain access during box construction phase). This will result in moving large vehicles along narrow residential streets. Current parking arrangements on Goodwood Road would need to be suspended around the proposed access point for the duration of construction.

The provision of a logistics rail siding for handling site materials is not feasible, due to the constrained worksite and proximity of the box to the boundary; therefore, all deliveries and muck away would have to be by road (see below for assessment of magnitude).

3.6.3. Site Usage

Option 3B would negate the possibility of using New Cross Gate as a principal worksite. New Cross Gate has also been identified as a potential location for the principal worksite for the systemwide fit-out works, which would, similarly, not be feasible, if Option 3B were to be taken forward.

3.6.4. Bridge

It is unlikely that there will be sufficient space to site a crane for the installation of the connecting bridge into the existing New Cross Gate station. Therefore, a temporary road closure to site the crane on New Cross Road will be necessary, which has an added cost and disruption factor to consider. (This will be dependent

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on the design of the station, as to whether the crane will be able to be positioned on Goodwood Road, or not. Goodwood Road is preferable to New Cross Road, given the reduced level of disruption it would cause).

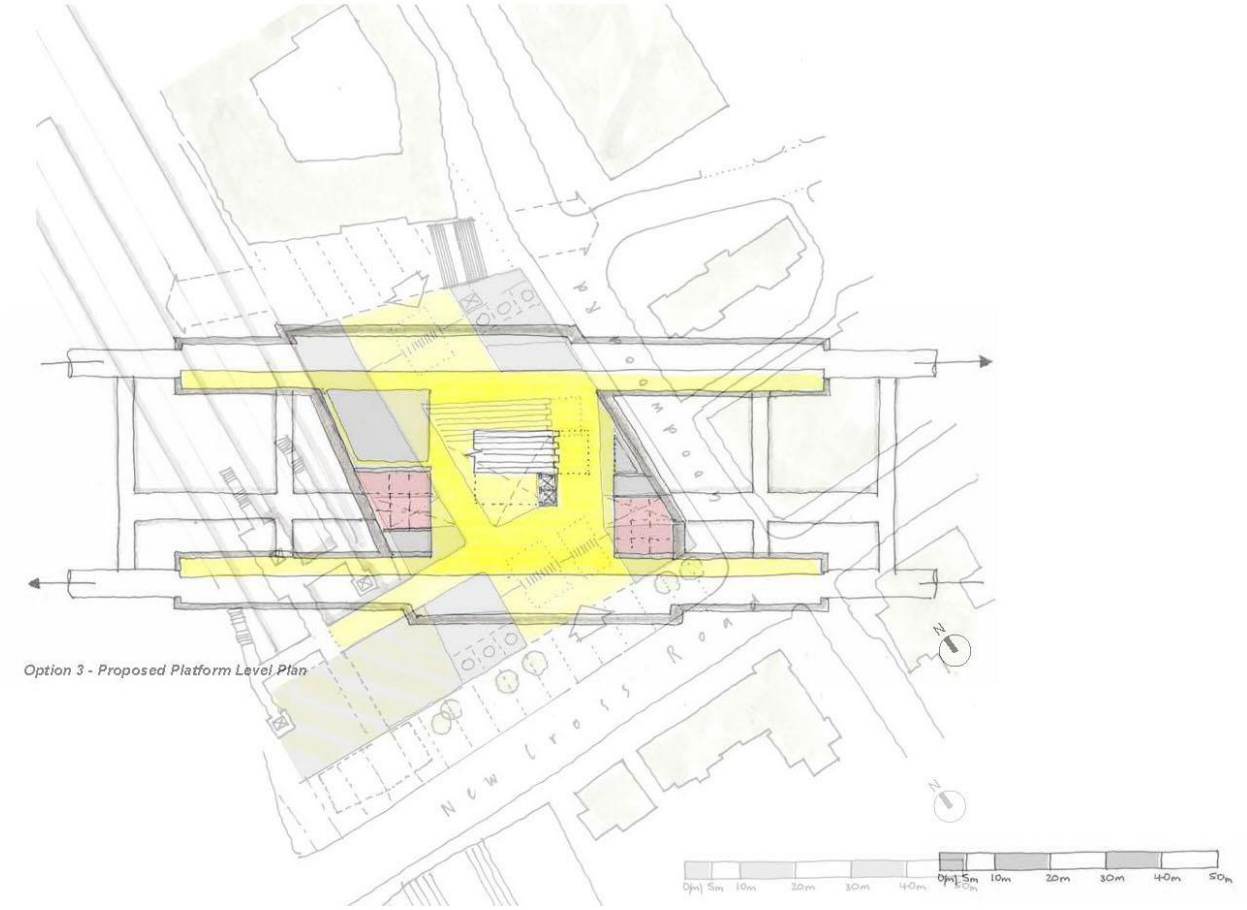
3.6.5. Programme

The additional requirement for SCL and mined tunnels under the existing New Cross Gate station will cause an increase to the programme duration, as well as the congested nature of such a small site, leading to inefficiencies in material storage, smaller plant being used and general congestion, double-handling and delays. Further, any opportunities that would use New Cross Gate as a staging post for fit-out, or other logistical activities, would be removed, due to the loss of direct access into the tunnels.

3.6.6. Box Construction

The station box is of similar dimensions to the footprint of the site, possibly extending beyond the footprint in the corners. Pending further design development, it is highly likely that services relocation within the pavement will be required, to ensure there are no clashes during piling, which will result in additional cost and additional delay to starting the box construction.

The illustration, below, provides an overlay of the two sketch plans associated with Option 3B.



The construction of the station box will likely need to employ a top-down methodology, given the physical site constraints. This is not a challenge, in itself, but will mean that any level of maintenance on the TBM, above the most minor of activities, will not be possible at New Cross Gate, resulting in 2.2km of running tunnel without surface-to-tunnel access for the TBMs.

From the sketches provided, it is understood that Option 3B has a significant length of piling / diaphragm walling (approx. 60m) along the west length of the station box, on the boundary with NR. Construction in this location represents an increased level of risk to the NR asset.

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3.6.7. Neighbouring Properties

It is understood that the proposed platform tunnels extend to the south east of the station box, below 3-storey, privately owned residential and commercial buildings, as well as a heavily used section of the highway. There is a considerable risk of settlement from construction activity, which will likely require substantial ground improvement as a mitigation measures.

Furthermore, for ground improvement to be carried out in these areas, there will be a requirement for access to the privately-owned land. It will also be necessary for a similar level of access in Goodwood Road – resulting in temporary highway closures to enable stabilising works to take place. Generally, it is considered that there will be a significant level of disruption to third parties and the general public associated with open-face mining of tunnels to the east of the station box.

3.6.8. Worksite Comparison

- Approximately 400m^2 of welfare is provided in the sketch above, if the following reasonable assumptions are made:
  - 10m^2 per office worker;
  - 5m^2 per operative (site canteen and drying room);
  - An allowance for showers and toilet facilities;
  - A 4:1 ratio of operative: office worker.

  At the peak of construction there will be an allowance for around 60 people (in total) working on the site. If the welfare is double stacked, this is around 120 people in total (96 operatives and 24 engineers, commercial, support staff). This is considered to be an extremely low assessment of staff required, given the amount of works necessary to construct a station.

- There is also no apparent allowance made for parking of site vehicles, or plant, when not in use.

- Approx. 800m^2 of storage is allowed for in the Option 3B sketch, above.
  - If it is assumed that the space will be taken up with steel cages, materials and concrete equipment, a box of approx. 2000m^2 and 20m deep = 40,000m^3 of muck, of which, inevitably, there will be some need for a stock pile on site. There appears to be no space allocated for such storage.

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  - There is no allowance shown for a holding bay for large concrete pours to be sited, to ensure continuity of supply.

- There is no obvious allowance for a safe vehicle access route from the site entrance to the workface.

- There does not appear to be sufficient space to allow for safe pedestrian walkways on the site.

- There is no allowance for a rail logistics siding shown on the site, therefore, it is assumed that all muck will be removed from site by road. If the following assumptions are made:
  - 40,000m^3 muck;
  - Bulking factor of 1.3;
  - 8m^3 per highway wagon;
  - 6500 wagons on the road at peak excavation;
  - If muck-away is permitted for a total of 14 hours per day (10-3pm and 8pm-5am), there will be continuous muck-away for 2 months, working 7 days a week, 24 hours a day. This is the equivalent of 1 wagon every 8 minutes (i.e. access/egress through the site gates every 4 minutes).