Transport for London
London Underground

Northern Line Extension

Kennington Station - Report on dynamic modelling outputs – PM peak

MAYOR OF LONDON

Table of contents

1 Executive Summary 2
2 Background and objectives 3
2.1 Northern Line Extension 3
2.1.1 Kennington station operation 3
2.2 Dynamic Modelling Objectives 4
3 Description of model scenarios 5
3.1 Model times 5
3.2 Current year model (2011) 5
3.3 Future year models 5
4 Modelling inputs and assumptions 6
4.1 Passenger demand 6
4.1.1 Current year (2011) origin-destination matrix 6
4.1.2 Future year (2031) origin-destination matrix 6
4.1.3 Access, egress, interchange demand comparison 7
4.2 Key modelling assumptions 8
4.2.1 Train service patterns 8
4.2.2 Routings 8
5 Dynamic modelling outputs 9
5.1 Station Planning Standards and Guidelines 9
5.2 Modelling output results 10
5.2.1 Cumulative mean density (CMD) maps 10
5.2.2 Cumulative high density (CHD) maps 13
6 Summary and conclusion 15
Appendix A: Modelling methodology 16
A.1 Source of drawings 16
A.2 Entity colours, speed and size 17

1 Executive Summary

This report builds on modelling work conducted in March 2013 in support of the TWAO application for the Northern Line Extension. The AM peak models focused on congestion levels on the northbound platforms pre and post completion of the extension.

This report provides an analysis and evaluation of the current and future year operation of Kennington station during the PM peak period (16:00-19:00). The Northern Line Extension (NLE) and the expected impact it will have on interchange demand at the station is the main driver for the cross passage crowding assessments that this report comments on. The proposals for the NLE include the additional cross passages at Kennington station.

The method of analysis was dynamic modelling using specialised pedestrian simulation software. Main inputs analysed were demand forecasts for future year (2031) without and with Northern Line extension; train service patterns pre and post Northern Line Upgrade 2 and boarding and alighting profiles.

The models developed for the PM peak (16:00-19:00) are:

- Current year (2011);
- 2031 without NLE;
- 2031 with NLE and current infrastructure;
- 2031 with NLE and two additional cross passages connecting the southbound platforms.

Analyses undertaken are with regards to the level of crowding on the southbound interchange cross passages in the PM Peak. Dynamic modelling outputs examined are Cumulative mean and high density maps showing Fruin's Levels of Service (LoS) (with ranges from A to F) registered in a certain area for the peak 15 minutes (18:15-18:30) of the PM Peak. Within those ranges the Station Planning and Standards Guidelines (SPSG) recognise that normal operation is not to exceed a certain value within the range covered by LoS C.

The conclusions drawn from the analysis of these crowding maps are:

- **Current year (2011) – Current station layout**:
  Crowding levels on the interchange cross passages reach LoS C

- **2031 without NLE – Current station layout**:
  Crowding on interchange cross passages reaches LoS D as a result of the increase in background demand that counterbalances the more frequent (compared to current year) train service.

- **2031 with NLE – Current station layout**:
  The additional interchange demand arising from the introduction of the extension creates additional crowding (compared to the 2031 without NLE case) and results in the forming of LoS D or E for the interchange cross passages that link to the entry and exit cross passages.

- **2031 with NLE – Added cross passages connecting southbound platforms**:
  The proposed layout is projected to provide sufficient capacity and not lead to sustained high density levels in the interchange cross passages. This conclusion is reached from the examination of the cumulative high density (CHD) maps where LoS are not sustainably greater than LoS C for the duration of the peak 15 minutes in the PM peak (with the exception of the interchange cross passages linking to the exit staircase, which still operate more efficiently than would be the case in the 2031 without NLE scenario).

It is recommended that two additional cross passages between the two southbound platforms of sufficient width should be implemented if the Northern Line Extension is to be built. This is in addition to the two additional cross passages between the two northbound platforms recommended in the earlier report.

2 Background and objectives

2.1 Northern Line Extension

The extension of the Northern Line to Nine Elms and Battersea is part of wider plans to regenerate the Vauxhall, Nine Elms and Battersea area. The regeneration is expected to improve transport links and public spaces in the area and is supported by the Mayor of London, Wandsworth, Lambeth and Southwark councils.

Up to 25,000 jobs and 16,000 new homes could be created and journey times from Nine Elms or Battersea to the West End or the City will, in some cases, be less than 15 minutes[1].

2.1.1 Kennington station operation

The Northern Line Extension (NLE) will result in the number of stations served by the Northern Line increasing by two. One will be at Nine Elms on Wandsworth Road, a second at Battersea Power Station which will provide the new terminus to the southwest of Kennington. These two stations will be served by Charing Cross branch trains travelling via Kennington station.

In addition to the NLE, the Northern Line Upgrade 2 (NLU2) will see train services permanently split at Kennington. In the PM Peak (16:00-19:00), all SB trains coming from Charing Cross will travel via Kennington to Battersea. In the same period, trains on the Bank branch will travel via Kennington to Morden.

These changes are expected to produce additional interchange movements at Kennington compared to those observed today. Passengers travelling southbound on the Charing Cross branch who wish to continue their journey to Morden, will interchange between the southbound platforms at Kennington.

Figure 1 that follows, shows the service patterns for the Northern Line post NLU2.

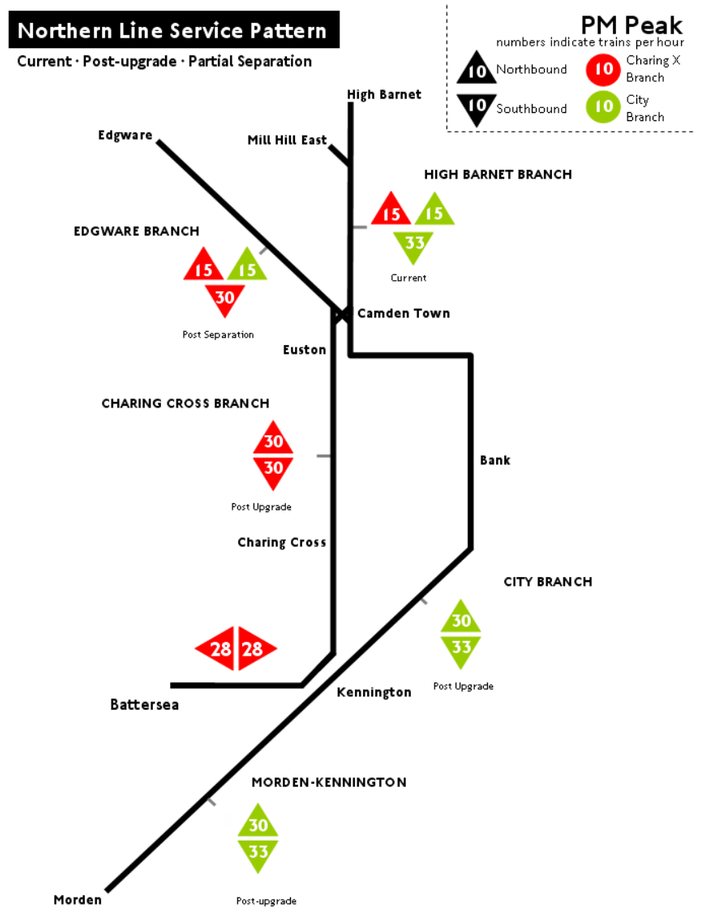

Figure 1 – Train service patterns post NLU2 and with Northern Line Extension

In the PM Peak and for the southbound (SB) direction, the train service patterns effectively result in a full separation of the Northern Line. With the Northern Line Extension the same service patterns are expected in the PM peak as the ones shown in the figure above.

Kennington station becomes a key interchange station for passengers wishing to switch to either the Charing Cross (CX) or Bank branches. A logical question therefore arises, as to whether the station will be able to cope with the additional (compared to RODS 2011[2]) interchange demand.

[1] http://www.tfl.gov.uk/corporate/projectsandschemes/21614.aspx

[2] Interchange levels as observed and by the Rolling Origin and Destination Survey for 2011

2.2 Dynamic Modelling Objectives

As a result of the observations made with regards to the operation of Kennington station post NLE and NLU2, a modelling exercise using Legion Spaceworks has been conducted to give an insight on future year station operation. The main changes that are expected to affect operation of the station are demand (specifically interchange demand for the southbound direction in the PM peak) and train service patterns brought about by the NLU2.

The modelling exercise provided the basis for a comparative analysis of output results between current (2011) and future year (2031) demand levels.

The main objective is to estimate crowding levels on platforms and interchange cross passages at Kennington station, as well as identify other areas that are expected to be affected by the number of passengers interchanging.

3 Description of model scenarios

3.1 Model times

All models described in the following section were run for the PM Peak, from 16:00 to 19:00.

The particular interest in the PM peak lies on the fact that it is the period of day when interchange movements going southbound from Kennington are expected to have in a 2031 post-NLE scenario the greatest impact on interchange cross passage utilisation.

3.2 Current year model (2011)

The base year model against which future year models are compared to is for 2011.

The current year model was run with RODS 2011 demand levels. Train service patterns input were as of Working Timetable 53.

A full description of train service patterns and demand tables is given in Chapter 4.

3.3 Future year models

Future year models were run using 2031 demand levels.

Based on various assumptions with regards to completion of NLE and infrastructure changes, the following 2031 model scenarios were simulated:

3.3.1.1 2031 without NLE

A model of Kennington station with 2031 demand levels and NLU2 train service patterns.

For this scenario it is assumed that the Northern Line Extension has not occurred.

3.3.1.2 2031 with NLE and current infrastructure

A model of Kennington station with 2031 levels and an NLU2 train service pattern with the NLE in operation but without the addition of the cross passages.

3.3.1.3 2031 with NLE and added passageways

The same scenario as the 2031 with NLE with the addition of two extra cross passages connecting the southbound platforms.

This scenario has been developed with two extra cross passages between platforms 2 and 4.

In Appendix A, the exact layout of southbound platforms is given with the added cross passages.

4 Modelling inputs and assumptions

4.1 Passenger demand

4.1.1 Current year (2011) origin-destination matrix

RODS 2011 demand data was used for the current year (2011) models.

Table 1 shows the origin destination matrix for Kennington station under 2011 demand levels.

Kennington 2011 PM Peak Demand Matrix	KENNINGTON BANK NB	KENNINGTON BANK SB	KENNINGTON CX NB	KENNINGTON CX SB	KENNINGTON EXITS	TOTAL
KENNINGTON BANK NB	30		2,211		152	2,393
KENNINGTON BANK SB			53		531	584
KENNINGTON CX NB	59				33	92
KENNINGTON CX SB	77	3,834		832	1,127	5,870
KENNINGTON T H	649	220	573	52		1,494
TOTAL	815	4,054	2,837	884	1,843	10,433

Table 1 – RODS 2011 origin-destination matrix

Table 2 gives the total number of passengers accessing, egressing and interchanging in 2011 at Kennington station.

RODS 2011 Demand	Number of passengers
Access	1,494
Egress	1,843
Interchange	7,096
Total	**10,433**

Table 2 – RODS 2011 Access, Egress, Interchange demand

4.1.2 Future year (2031) origin-destination matrix

Railplan demand forecasting outputs were used for the future year (2031) models after application of the demand forecasting formula for station modelling[3].

4.1.2.1 Railplan scenarios

The following 2031Railplan Scenarios were analysed:

NX300: 2031 demand without NLE – PM peak

NX328: 2031 demand with NLE – PM peak

4.1.2.2 Forecasted 2031 demand levels

Tables 3 and 4 show the forecasted[4] demand levels for 2031 without and with NLE respectively.

2031 without NLE Forecasted PM Peak Demand	KENNINGTON BANK NB	KENNINGTON BANK SB	KENNINGTON CX NB	KENNINGTON CX SB	KENNINGTON EXITS	TOTAL
KENNINGTON BANK NB			4,102		547	4,649
KENNINGTON BANK SB			338		1,022	1,360
KENNINGTON CX NB						
KENNINGTON CX SB	443	7,015			2,083	9,541
KENNINGTON T H	1,523	506	2,061			4,090
TOTAL	1,966	7,521	6,501		3,652	19,640

Table 3 – 2031 without NLE origin-destination matrix

The demand shown in Table 3 is after the application of the demand forecasting formula on the Railplan output from scenario NX300 for 2031 without NLE.

[3] For further information regarding application of the demand forecasting formula please refer to the following document: *Station Demand Modelling v1.1, June 2005, page 16*

[4] Forecasted demand is the output of the application of the demand forecasting formula on Railplan Scenarios NX254 and NX255.

2031 with NLE Forecasted PM Peak Demand	KENNINGTON BANK NB	KENNINGTON BANK SB	KENNINGTON CX NB	KENNINGTON CX SB	KENNINGTON EXITS	TOTAL
KENNINGTON BANK NB			3,856	197	518	4,571
KENNINGTON BANK SB			291	1,642	1,013	2,946
KENNINGTON CX NB	1,578	305			235	2,118
KENNINGTON CX SB	386	6,476			1,995	8,857
KENNINGTON T H	1,517	488	1,969	196		4,170
TOTAL	3,481	7,269	6,116	2,035	3,761	22,662

Table 4 – 2031 with NLE origin-destination matrix

Similarly, demand for the 2031 with NLE scenario in Table 4 is the output of the application of the demand forecasting formula on Railplan scenario NX328 for 2031 with NLE.

The section that follows provides an insight on the differences between the two 2031 demand scenarios per movement (access, egress and interchange).

4.1.3 Access, egress, interchange demand comparison

Analysing the demand forecasts for 2031 with and without NLE, it becomes clear that there is an increase to the interchange movement City SB to Charing Cross SB as a result of the split service south of Kennington.

With Nine Elms and Battersea stations added, passengers will interchange at Kennington from the Charing Cross SB platform (platform 2) to platform 4 with train continuing to Morden (from the City branch).

Figure 2 shows the level of demand for access, egress and interchange for the 2031 scenarios without and with NLE.

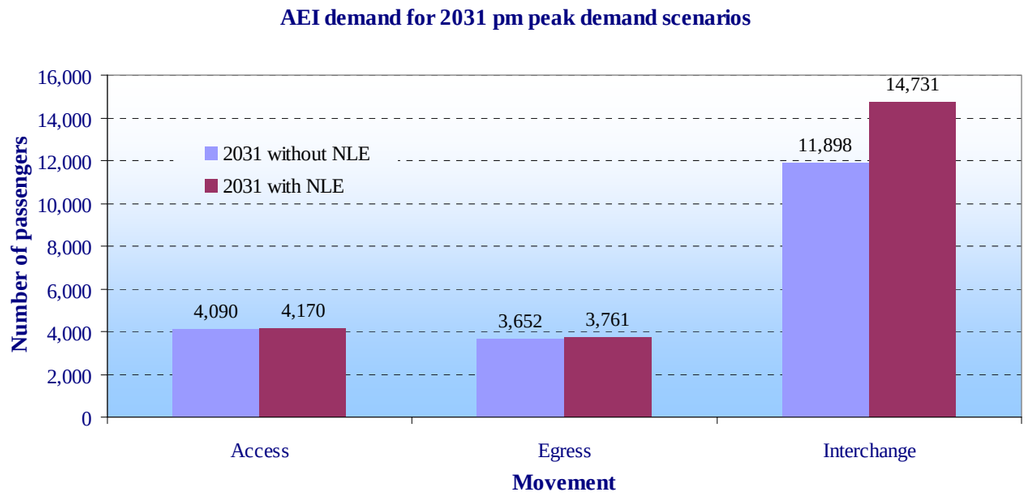

Figure 2 – 2031 access, egress and interchange demand without and with NLE

The introduction of two new stations post-NLE results in a 24% increase on total interchange demand compared to the 2031 demand scenario without NLE.

The additional interchange demand from platform 4 (Bank SB) to platform 2 (Charing Cross SB) movement is for the 2031 with NLE scenario 1,642 passengers during the three hours in the PM peak.

For the busiest 15 minutes[5], this is a total of 175 passengers[6] going through the 3 passageways from platform 4 to platform 2 alone.

No significant differences are observed between the two 2031 scenarios for access and egress demand.

[5] Based on RODS 2011, the busiest 15 minutes have been identified to be between 08:30-08:45

[6] Station Planning Standards and Guidelines, Section 2.2 for the calculation of peak15 minute demand based on a three hour total

4.2 Key modelling assumptions

4.2.1 Train service patterns

For the Current Year (2011) model, train service patterns were drawn from Working Timetable 53.

For the 2031 future year scenarios, Figure 1 shows the train service patterns that are expected to operate post-NLE. These have been summarised in Table 6 below.

The trains per hour going through platforms 1 and 3 for the northbound direction and platforms 2 and 4 for the southbound direction for each of the model scenarios (described in section 3) are as follows:

Trains per hour for current year (2011) model		16:00-17:00	17:00-18:00	18:00-19:00
Platform 1	Charing Cross Northbound	14	16	16
Platform 3	Bank Northbound	16	16	16
Platform 2	Charing Cross Southbound	16	20	20
Platform 4	Bank Southbound	18	19	21

Table 5 – Trains per hour assumptions for current year (2011) model

Trains per hour for future year (2031) models		16:00-17:00	17:00-18:00	18:00-19:00
Platform 1	Charing Cross Northbound	30	30	30
Platform 3	Bank Northbound	30	30	30
Platform 2	Charing Cross Southbound	30	30	30
Platform 4	Bank Southbound	30	33	30

Table 6 – Trains per hour assumptions for future year (2031) models

In the PM Peak, 14 more trains in the peak hour will be scheduled to run through the Bank southbound platform compared to what was the case in 2011.

4.2.2 Routings

The models developed take into account the mid-concourse and platform levels.

Figure 3 shows the extent of the model that is covered in the simulations of Kennington station operation in the base and future year scenarios.

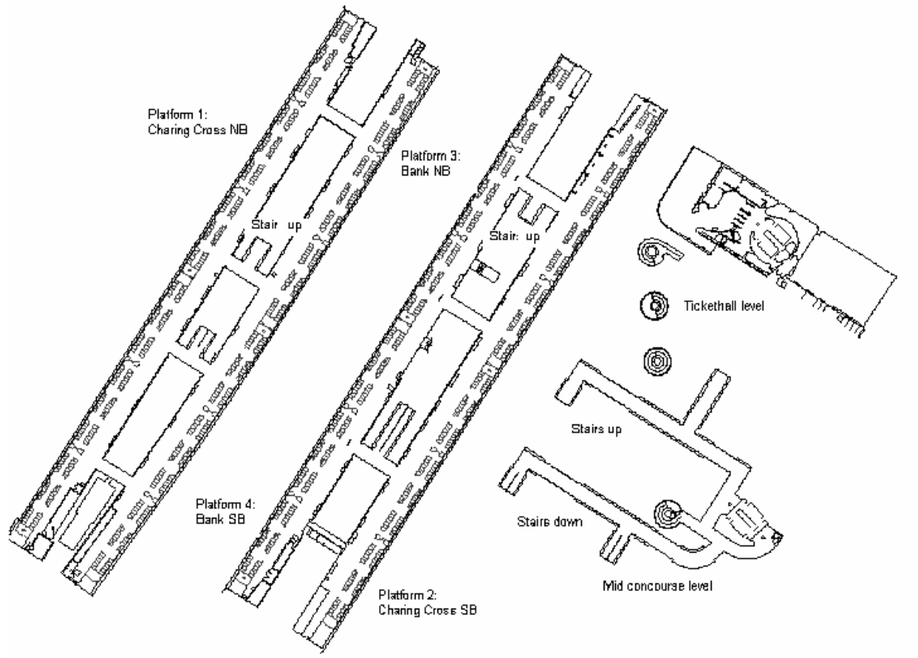

Figure 3 – Kennington station layout

Of the station areas shown in Figure 3, mid concourse and platform levels have been included in the developed models.

Lifts operate as through lifts at mid concourse level. On exiting the lifts passengers move to the right and use the stairs to go down the northbound or southbound platforms.

From platform level, exiting passengers use the stairs going up highlighted in Figure 3, as at mid concourse level this provides an easier access to the lift entrance.

5 Dynamic modelling outputs

5.1 Station Planning Standards and Guidelines

Modelling output results analysed are with regards to crowding levels on interchange cross passages and platforms.

The Station Planning Standards and Guidelines (SPSG)[7] document is used as a reference guide to identify areas in the station that do not meet space planning criteria.

Space planning, as defined in the SPSG, is based upon passenger density and the concept of “levels of service”.

Figure 4 shows the correlation between “levels of service” (LoS) and the quality of the passenger’s space.

Level of service	Description (for queuing areas, walkways and stairways)
A	Free circulation.
B	Uni-directional flows and free circulation. Reverse and cross-flows with only minor conflicts.
C	Slightly restricted circulation due to difficulty in passing others. Reverse and cross-flows with difficulty.
D	Restricted circulation for most pedestrians. Significant difficulty for reverse and cross-flows.
E	Restricted circulation for all pedestrians. Intermittent stoppages and serious difficulties for reverse and cross-flows.
F	Complete breakdown in traffic flow with many stoppages.

Figure 4 – Levels of service description

The SPSG sets requirements for space planning under a normal operation in order to minimise congestion and be resilient to train service disruption.

These requirements differ based on the station area, for example platforms, open concourses, cross passages, staircases and escalators.

[7] Station planning and standards guidelines, 2012 edition

Figure 5 highlights the LoS concept for the normal operations category of station operations per station area:

	Normal operation	
Station Area	LoS	Quantitative measure
Open concourses	B	1.0m² per person
Queuing for ticket hall facilities	C	0.8m² per person
Passageways- one-way	D	50 passengers /minute/m width
Passageways- two-way	C	40 passengers /minute/m width
Stairs- one-way	D	35 passengers /minute/m width
Stairs- two-way	C	28 passengers /minute/m width
Escalators		100 passengers /minute
Platforms	B/C	0.93 m² per person

Figure 5 – Levels of service under normal operation per station area

The main assessment conducted on the modelling output results are with regards to crowding levels on cross passages and platforms.

As the models have been run for the AM Peak, the analyses are focused on the northbound platforms and the four cross passages that connect them.

The section that follows, comments on modelling output results for each of the four models described in section 3. In relation to the SPSG requirements for normal operation LoS, the outputs commented on are for Cumulative Mean Density (CMD) and Cumulative High Density (CHD) maps.

5.2 Modelling output results

5.2.1 Cumulative mean density (CMD) maps

5.2.1.1 CMD maps description

A Cumulative mean density map (CMD) shows the mean level of density registered in a station area within a defined period of time.

Fruin's levels of service for walkways were used to produce the maps shown in this section.

LoS (Figure 4) is a measure by which transport planners determine the quality of the service on transportation infrastructure. LoS takes into account several factors and it is a measure of traffic density, rather than overall speed of the journey.

To visualize this information Legion uses a thermic map to report the density values associated with Fruin's levels.

For LoS Walkways, the thermic map assigns a range of values of the measure "persons per square metre" on each of the six LoS (A to F).

Figure 6 shows this LoS map legend, as will appear next to the CMD maps that follow.

Figure 6 – Levels of service for walkways map legend

5.2.1.2 CMD maps time period

The CMD maps in this section are for the period 18:15 – 18:30.

The reason this fifteen minute period was selected is because it has been identified from RODS 2011 that 18:15-18:30 is the busiest period in the PM peak.

In the case of the future year (2031) model scenarios, arrival profiles per 15 minutes have been used as per RODS 2011. Therefore, for the future year (2031) models CMD maps are also extracted for the 18:15-18:30 period.

5.2.1.3 CMD maps current year (2011) model

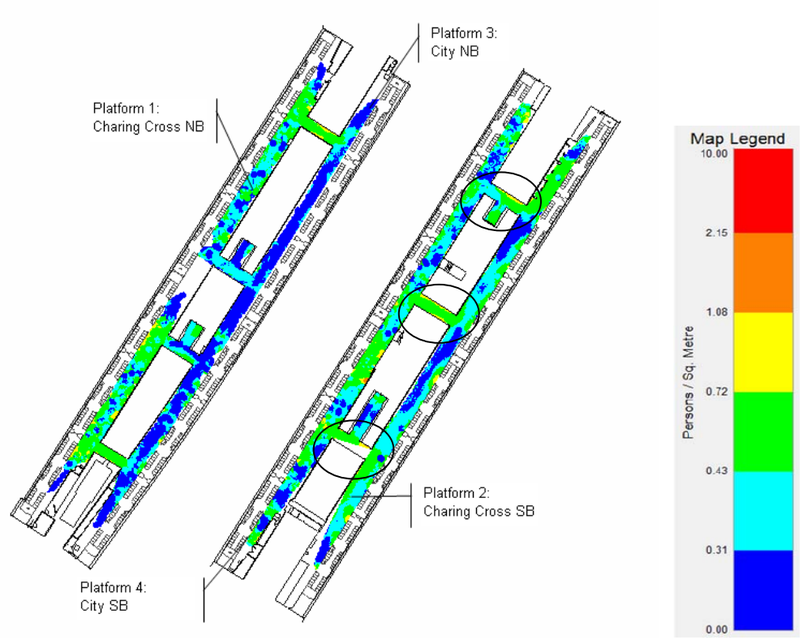

Figure 7 – CMD map 18:15-18:30, Current year (2011) model

The modelled current year (2011) train service pre the Northern Line Upgrade 1 (NLU1) delivers 5 trains going through platform 2 and 5 trains going through platform 4 (as per Working Timetable 53). This is for the peak 15 minutes of the PM peak (18:15-18:30).

The amount of people alighting from and interchanging through the southbound platforms (2 and 4) creates the crowding effect on the interchange cross passages as is shown in Figure 7.

From the analysis of the mean crowding map of the southbound platforms it can be concluded that with 2011 PM peak interchange demand, crowding levels in the interchange cross passages (circled in Figure 7 above) do not exceed LoS C (the level of crowding under normal operation as set in the SPSG).

5.2.1.4 CMD map 2031 without NLE

The origin-destination matrix for 2031 without NLE (Table 3) shows an increased demand on the Underground as travel grows in line with factors such as population and employment.

The effects of a more frequent train service (compared to current year-2011-model) is counterbalanced by the increased demand, producing crowding levels on the southbound platforms and the interchange cross passages as is shown in Figure 8.

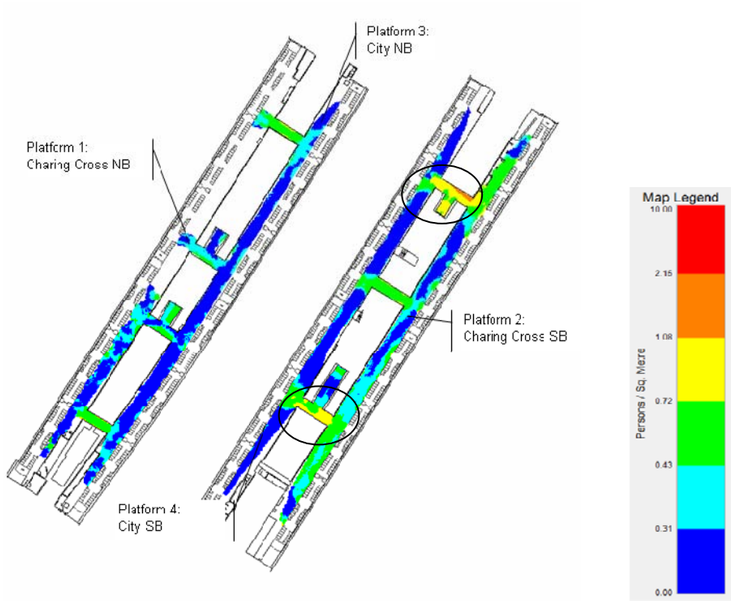

Figure 8 – CMD map18:15-18:30, 2031 without NLE

The CMD map is for the peak 15 minutes (18:15-18:30) and highlights the effect that interchange demand (along with the number of passengers alighting and exiting) has on crowding in the passageways connecting the southbound platforms.

Without the NLE in place, the main interchange movement is from platform 2 (Charing Cross branch-southbound) to platform 4 (Bank branch-southbound). This creates the observed LoS on the through cross passages as highlighted in Figure 8.

Circled in this figure is the cross passage that links to the exit staircase. As a result of the interchange and exit demand going through that cross passage (2031 without NLE) in the peak 15 minutes the registered level of congestion during the peak 15 minutes is D. There is also noticeable congestion forming on the south end cross passage which links to the entry staircase (circled in green).

5.2.1.5 CMD map 2031 with NLE

The introduction of two new stations on the Charing Cross branch post NLE, creates an additional movement from platform 4 (Bank branch SB direction) to platform 2 (Charing Cross SB).

This movement is created from passengers travelling southbound via Bank and arriving at Kennington on platform 4. To switch on to the Charing Cross branch (and alight from either Nine Elms or Battersea stations) they will be interchanging through the passageways onto platform 2 (Charing Cross branch SB direction).

During the peak 15 minutes (18:15-18:30) this means an additional (compared to the rest of the interchange demand) 174[8] passengers using the existing three passageways to interchange.

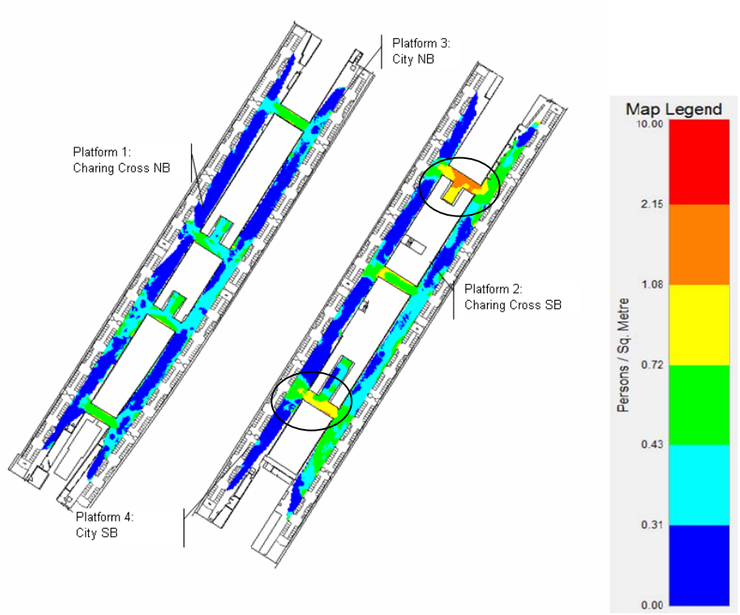

Figure 9 – CMD map 18:15-18:30, 2031 with NLE

Circled areas on Figure 9 highlight that crowding on the interchange cross passages reaches LoS levels D or E. Also, compared to Figure 8 where it can be seen that crowding reaches LoS D, during the peak 15 minutes of forecasted 2031 NLE demand levels crowding reaches LoS E in the worst case.

[8] Please refer to section 4.1.3 for an explanation of how this figure is obtained based on demand levels

5.2.1.6 CMD map 2031 with NLE and added passageway

The CMD map in Figure 10 is from the 2031 with NLE model scenario with addition of two passageways.

The addition of these two passageways results to an improvement of crowding levels on interchange cross passages compared to the 2031 with NLE and current infrastructure scenario (Figure 9).

The CMD map that follows shows crowding levels for the peak 15 minutes in the PM peak, with two additional passageways connecting the southbound platforms 2 and 4.

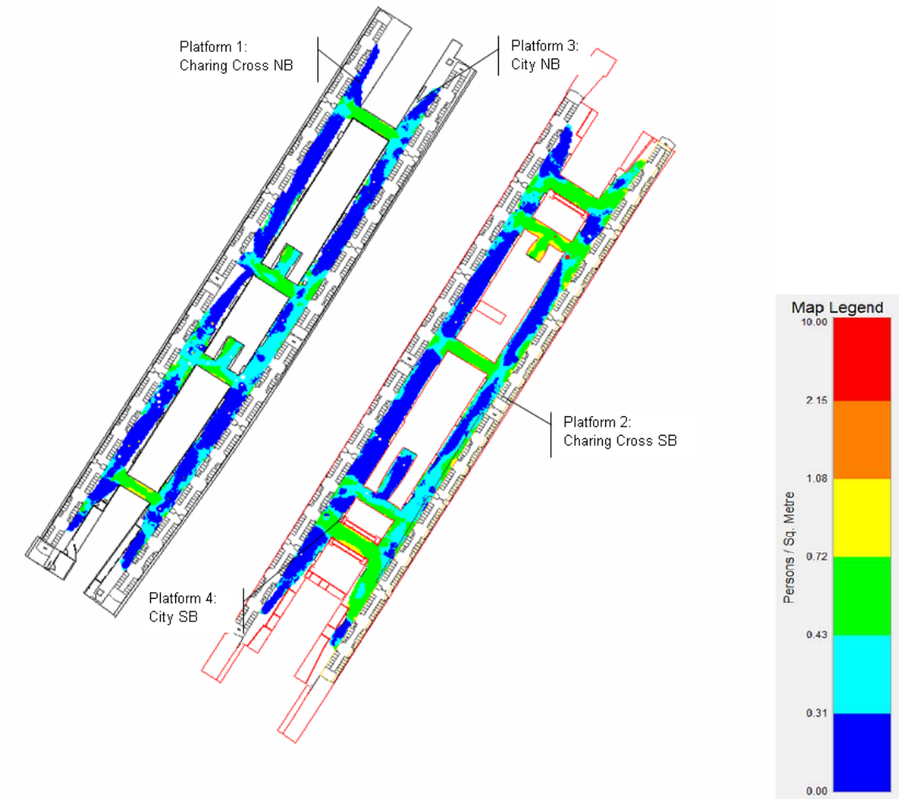

Figure 10 – CMD map 18:15-18:30, 2031 with NLE and added passageways

It is clear from the CMD map of the peak 15 minutes that LoS C is maintained across the peak 15 minutes period for all five passageways.

An improvement is also observed on platform crowding (compared to Figure 9 of the 2031 with NLE and current infrastructure scenario).

Therefore, a scenario of five passageways connecting the southbound platforms (as is currently the recommended design) improves distribution of passengers along the platforms.

5.2.2 Cumulative high density (CHD) maps

5.2.2.1 CHD maps description

CHD maps are used for identifying “hot-spots” within that station. This means areas where high levels of density are sustained. It asks the question “is this design creating persistently uncomfortable crowd densities”?

The map legend for the CHD maps that follow show the duration of time within the peak 15 minutes (18:15-18:30) for which LoS in the simulated station operation remains above LoS for normal operation as set by the SPSG (as described in section 5.1 and Figure 5).

Figure 11 – CHD map legend

5.2.2.2 CHD map 2031 without NLE

From the CHD map of the peak 15 minutes for the 2031 without NLE model, it can be concluded that LoS is exceeded for less than 2 minutes on the interchange passageways linking to the entry and exit staircase (circled in Figure 12).

The middle passageway linking platforms 2 and 4 has crowding levels within acceptable levels for the duration of the peak 15 minutes examined (18:15-18:30).

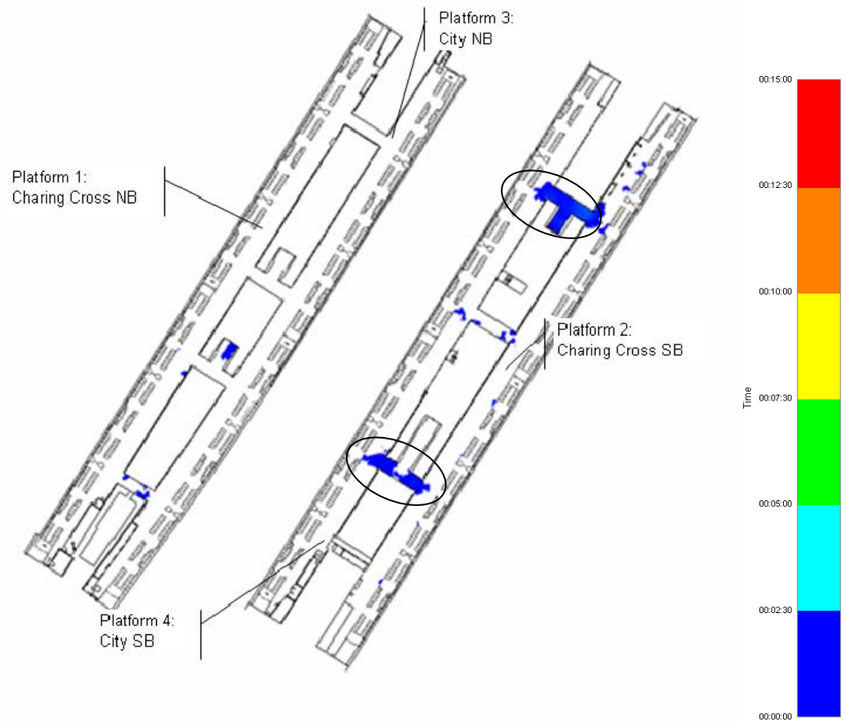

Figure 12 – CHD map 18:15-18:30, 2031 without NLE

5.2.2.3 CHD map 2031 with NLE

It is clear from the CHD map for the 2031 with NLE scenario (Figure 13) that the additional interchange demand creates additional crowding (compared to the 2031 without NLE case-Figure 12) in the interchange cross passages that link to the entry and exit staircases (those cross passages are circled on Figure 13).

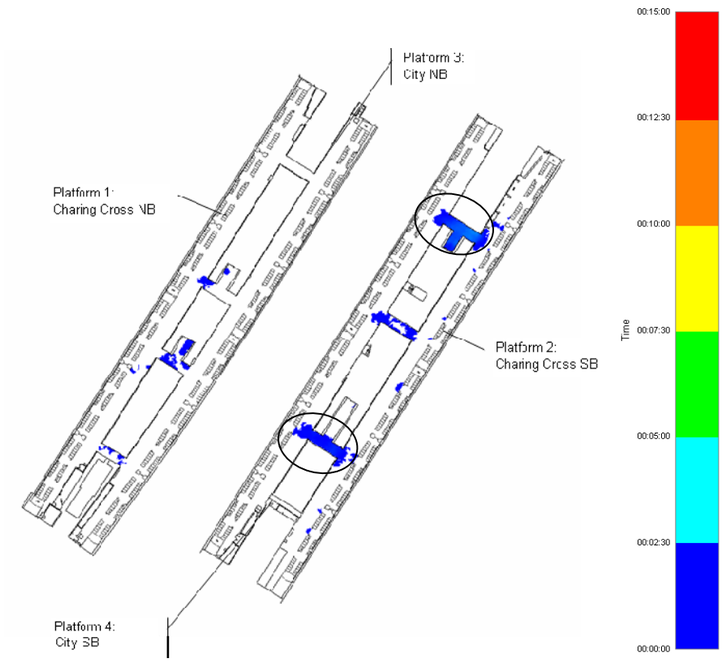

Figure 13 – CHD map 18:15-18:30, 2031 with NLE

More specifically, for the 2031 with NLE model scenario crowding on the interchange cross passages is sustained above the SPSG normal operation criteria for an average of 2 minutes for the two passageways mentioned above.

Compared to the 2031 without NLE scenario it is evident that interchange passageways and platforms will experience more crowding as passengers interchange from both platforms (platform 2: CX SB to platform 4: City SB and vice versa). This is due to both the increased number of passengers interchanging plus that the flows are now two way and hence are meeting at times in these passageways designed for a one way flow.

5.2.2.4 CHD map 2031 with NLE and added passageways

Compared to the CHD map of the 2031 scenario with NLE and current layout (Figure 13), the addition of two passageways creates crowding levels during the peak 15 minutes which are not sustainably greater than LoS C as can be seen from the CHD map (Figure 14).

In other words, a design with 5 passageways is projected to have sufficient capacity for interchange and so not lead to sustained high density levels in the interchange cross passages. This conclusion is the result of examination of the CMD and the CHD map simulation outputs for the 2031 with NLE scenario with current layout (Figure 13) and with the addition of two passageways (Figure 14).

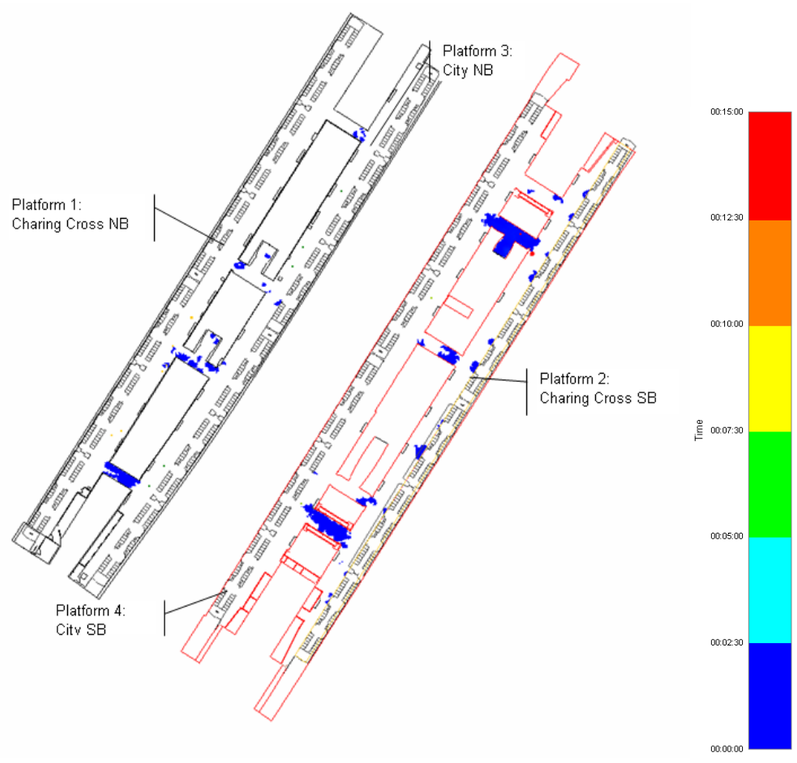

Figure 14 – CHD map 18:15-18:30, 2031 with NLE and added passageways

6 Summary and conclusion

The dynamic models developed in Legion Spaceworks provided the basis of the analyses documented in this report. The purpose was to ascertain the impact of future year demand forecasts, changes to train service and the introduction of the Northern Line Extension on interchange cross passages crowding levels during the PM peak. The report is a continuation of the AM peak modelling outputs report submitted as part of the NLE Transport Works and Acts Order (TWAO).

The main focus of the current report was on interchange cross passages of the southbound platforms in the PM peak.

Interchange demand is high today (as shown from the current year model demand-Table 1) and is projected to be high in the future (Figure 2) even without the introduction of the NLE.

Analysis of the cumulative mean density and cumulative high density maps for the current year model (Figure 7) and the future year (2031) model without NLE (Figures 8 and 12) showed that crowding levels on the interchange cross passages connecting the southbound platforms are sustainably high during the peak 15 minutes (18:15-18:30).

The assessments were made in reference to SPSG's LoS for normal operation (Figure 5) per station area.

Similar assessments of the 2031 model with NLE clearly indicated the effect of the interchange demand increase (Figure 2) on interchange cross passage crowding levels. Figures 9 and 13 (showing the CMD and CHD maps for the 2031 scenario with NLE) demonstrate that compared to the 2031 without NLE scenario LoS for interchange cross passages is sustained above LoS C for an average of two minutes in the peak 15 minutes. Also, comparing the CHD maps of the 2031 without and with NLE scenarios (Figures 12 and 13 respectively) it is observed that crowding above LoS C for an average of 2 minutes is projected to form on platform 2 (Charing Cross SB) after the introduction of the NLE. This is most noticeable in the platform area closer to the cross passages.

The main reason for this effect in the with-NLE is the fact that the introduction of the extension produces an additional interchange movement from the Bank SB branch (platform 4) to the Charing Cross SB branch (platform 2).

This is because post-NLE, a partial separation of the Northern Line means that passengers travelling southbound on the Northern Line on the Bank branch will need to interchange to the Charing Cross SB branch if they wish to continue their journey to either Nine Elms or Battersea. Also, passengers travelling southbound on the Charing Cross branch will only be able to continue their journey to Morden if they interchange at Kennington. The effect of the interchange movements between the two southbound platforms inevitably affects the crowding forming on the interchange cross passages.

Under the proposed layout where two cross passages are added linking the southbound platforms, the CMD and CHD maps clearly showed that with the addition of two cross passages on the southbound platforms, LoS only reaches level B and C during the peak 15 minutes of the PM peak. Figure 5 shows LoS under normal operation per station area as suggested by the SPSG. This demonstrates that interchange efficiency at Kennington station is improved by the introduction of the NLE with two additional cross passages, even when compared to a scenario with the NLE.

It is recommended that cross passages are implemented if the NLE is to be built.

Appendix A: Modelling methodology

A.1 Source of drawings

Current layout

The station layout drawings that were used are for the current year (2011)

Layout with two added cross passages on northbound platforms

For the future year 2031 scenario with added cross passages, the current year station layout for the northbound platforms was used to add in the CAD two cross passages in between the existing ones.

The CAD that resulted from this edit is not the final design for the station under a scenario of additional cross passages on the northbound platforms.

A.2 Entity colours, speed and size

In the dynamic models developed in Legion Spaceworks, the entities have been coloured by destination. The following colours have been assigned to each entity. No entity level outputs have been included in this report.

Entity colour	Entity destination
	to street
	to platform 1
	to platform 2
	to platform 3
	to platform 4

Table 7 – Model entity colour legend

The entity speed and size used in all models was as defined by the “Station modelling with Legion: Best Practice Guide”, issued by LUL on 3 July 2009, based on separate research by both Legion and LUL.

Entity Grouping	Luggage settings	Average speed	Speed distribution
N	No luggage	1.53m/s	normal distribution
A	Large luggage	0.58m/s	fixed
B	Small luggage	0.80m/s	fixed
C	Medium luggage	1.53m/s	normal distribution
D	Large luggage	1.32m/s	normal distribution
E	Large luggage	1.37m/s	normal distribution

Table 8 – PRM entity types and speed