Station modelling with Legion Spaceworks: Best Practice Guide

UNDERGROUND OVERGROUND CROSSRAIL DLR TRAMS AIR•LINE

EVERY JOURNEY MATTERS

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1. Introduction

This third edition of Station modelling with Legion: Best Practice Guide summarises the key steps for modelling TfL Rail & Underground (R&U) stations with Legion. These allow the model to produce consistent and accurate outputs from which stakeholders can make informed decisions.

The objective of this Best Practice Guide is to provide a foundation for all TfL R&U station models, creating consistency across projects.

This best practice guide applies to the use of the Legion SpaceWorks for modelling passenger flows in TfL R&U stations. Legion SpaceWorks can be used to support a variety of projects including, but not limited to:

- Congestion relief schemes, including design improvements and calculation of social benefits for use in business cases
- Step-free access projects
- Operational tests, Commercial Uses etc.

This updated edition is issued for comment to various Legion SpaceWorks users within and outside of TfL.

1.1. Purpose of the document

The guide aims to promote a framework for using Legion SpaceWorks to develop robust and accurate models with consistency and extensibility for TfL R&U. Recommendations of modelling approaches are provided which modellers can follow to obtain optimal results.

1.2. Scope

This guide provides guidelines in developing Legion SpaceWorks models for TfL R&U stations. It outlines basic requirements and includes technical suggestions for modelling station facilities; however it does not provide step-by-step procedures for using Legion SpaceWorks.

The guide is tailored for TfL R&U stations, for the Overground only stations which are fully TfL owned / operated are subject to this Best Practice Guide. While some principles and guidelines may also apply to other railway stations, the relevant best practice should be agreed with the project stakeholders.

This best practice guide has been developed based on Legion SpaceWorks R5 (5.2.0) and its accompanying user manual.

Hereafter, any reference to “Legion” denotes “Legion SpaceWorks R5” pedestrian modelling package.

1.3. Structure of the Best Practice Guide

The Best Practice Guide is divided into three parts. Each part can act as a standalone document in addition to complementing the other volumes.

Part 1: Best Practice Principles presents the fundamentals of station modelling. The generic modelling processes and an outline of expected inputs and outputs from Legion are provided.

Part 2: Modelling Notes contains technical details on station model development. It provides recommendations on the model development process, suggested coding of station facilities and methodology to validate and analyse a model.

Part 3: Generic Station Modelling Parameters includes tables of standard modelling parameters to be used for station modelling and analysis.

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Station modelling with Legion Spaceworks: Best Practice Guide

Part 1: Best Practice Principles

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2. Principles of station modelling

Station modelling can be a long and complex process. Throughout its development, modellers should ensure that models retain their quality and integrity, while remaining simple. Planning and creative thinking are required to ensure the model can cope with all the proposed scheme changes.

Sometimes project objectives demand extra detail in particular areas of a model, modellers and stakeholders should recognise the requirements and adjust the models to fit the purpose.

Each station model should have the following recommended qualities.

2.1. Accuracy

2.1.1. Each model of a station should be built as close to reality as practicable.

2.1.2. A base model of the current layout of the station with the 'current' (latest available) data should be validated against real life data from a proper pedestrian survey in order to establish creditability. The model name should specify the demand year within the model.

2.1.3. All further models would then use this validated model as a base.

2.2. Authenticity

2.2.1. All inputs into a station model should come from trusted and accurate sources. R&U can provide references to appropriate data sources.

2.2.2. All data sources should be fully referenced and documented. Assumptions made during model development should be agreed with project stakeholders and documented as described in section 5.2.

2.3. Consistency

2.3.1. Option / future models for the same project should be based on the validated Current Year model.

2.3.2. Modellers should make minimal changes to the Current Year model for use in other models; all changes should be documented and auditable.

2.3.3. A single ANA file (analysis file) should be used for analysing all models within the same project as far as possible. Where the 'future' model differs considerably a second ANA file may be required, but should use the same base as far as possible, and again all changes documented. This ensures consistency across models in measuring journey times, undertaking social cost analysis and recording maps and videos.

2.4. Reliability

2.4.1. Given the same inputs, the model should produce replicable results in each simulation run.

2.4.2. The ORA file (simulation file) exported from a LGM (model file) should produce a replicable result on any computer.

2.5. Compliance

2.5.1. Standard Legion settings and TfL-defined parameters should be used as far as possible.

2.5.2. Any settings that do not use default values should be documented and explained.

2.5.3. Part 3 of this guide provides most of the default values required.

2.6. Extensibility

2.6.1. The objective of extensibility is to minimise the changes needed to turn the Current Year model into other demand/scheme models.

2.6.2. This may involve planning everything from placement and settings of objects, supply types and routings, to the positioning of different levels of station CAD at the beginning.

2.6.3. Modellers should collect as much of the input data required for all modelling at the earliest opportunity. Keeping extensibility in mind when building the initial model helps to maintain the consistency and integrity of future models.

3. Modelling process

All station modelling processes are similar, regardless of modelling packages used.

Despite the iterative nature of the model development process, there are some key modelling tasks within the workflow that can assist the smooth running of the development and quality control.

3.1. Generic process for modelling tasks

3.1.1. Modelling takes a variable amount of time depending on the scope and status of the project. Reporting should be a continual task, while analysing and development can be iterative until completion.

3.1.2. Stakeholders and modellers should have a mutual understanding of the tasks involved and understand the risk of modelling issues arising that may delay the process. Sufficient contingency should be agreed.

3.1.3. A generic flow chart of model development is provided in Figure 1 below.

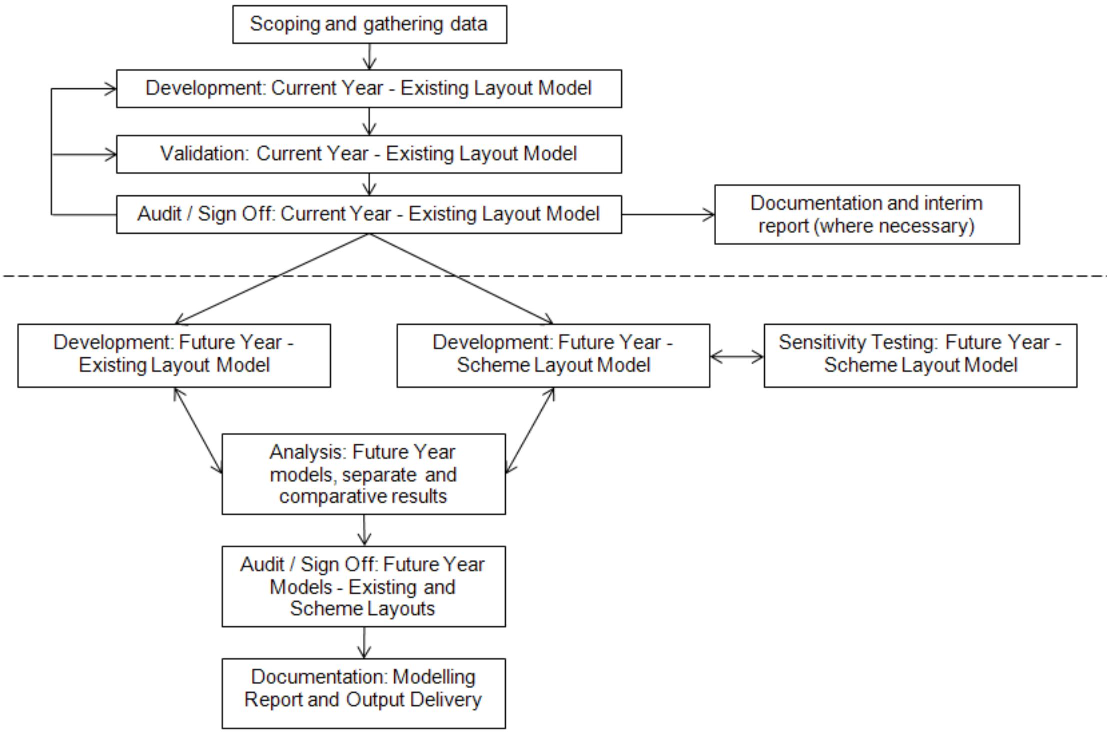


Figure 1: Typical station modelling flow; this applies to most pedestrian modelling applications including Legion

3.2. Scoping

3.2.1. Prior to the model development, it is required that all parties involved agree the scope of the modelling project. The agreed scope should be documented in a project brief or scoping report, and signed off by all parties.

3.2.2. The project brief/scoping report helps to minimise disputes later in the development process and avoid "scope creep" that may disrupt the model development programme.

3.2.3. For Overground stations the scoping exercise should identify the appropriate Best Practice Guidance to follow. As a general rule stations owned and operated by TfL (eg Rotherhithe) would used TfL guidance, and those owned and operated by Network Rail (eg Forest Hill) would use Network Rail best practice. Where this is unknown or elements of both are present it should be agreed with stakeholders from both authorities.

3.3. Assumption Cover Sheet

3.3.1. An Assumption Cover Sheet (ACS) should be submitted alongside all models (a single ACS may be used to cover off a number of small model variations). This document should include the background of the model development, description and structure of the models and all the assumptions made during the development and their sources.

3.4. Validation

3.4.1. The Current Year model should be validated using real-life data collected through a station survey. Journey times and passenger flow rates are good measures of the validity of a model. The method and result of validation should be documented.

3.4.2. In some circumstances, TfL R&U may allow station staff with extensive station knowledge to help validate the model by visual observation. This must be explicitly agreed with the project sponsor and stated in the Modelling Methodology Document.

3.4.3. For more information on model validation, please refer to Part 2**: Modelling Notes.**

3.5. Model auditing

3.5.1. All models must be audited by the TfL Strategy & Service Development (S&SD) Transport Modelling team for acceptance for use in TfL R&U projects. Where appropriate independent third parties may be used to assist with model auditing at TfL's discretion.

3.5.2. The model audit is a key part of the model development process and is a milestone for project management to introduce accountability. The model audit checklist forms the basis of the audit process as well as acting as a development reference checklist.

3.5.3. It is recommended that key assumptions which differ from TfL standards, or are not covered in this Best Practice Guide be referred to the S&SD Transport Modelling team for agreement early in the process to avoid abortive work.

3.5.4. A copy of the audit checklist is attached at the end of this guide.

3.6. Reporting

3.6.1. Documentation of assumptions used should be included in the ACS and report towards the end of the process.

3.6.2. The modelling report should document full findings from the modelling and describe the implications and conclusion. In addition a presentation pack of results may be requested, stakeholders and modellers should agree and document which outputs are required to represent the findings of the model in the presentation and the report. Section 4 describes Legion outputs that may be useful for R&U commissions.

3.7. Sensitivity tests

3.7.1. Demand sensitivity tests are often required for any modelling of new or modified infrastructure. The tests required should be agreed with stakeholders (including S&SD Transport Modelling) early in the modelling process, and documented.

3.7.2. Historically sensitivities of 30-35% on top of the forecast year have been required for testing the space-proofing of the design. The compliance requirements for this test should be agreed by the project sponsors.

3.7.3. A number of sensitivities may be required for business case analysis and to consider space proofing of infrastructure. Sensitivities will generally be an uplift percentage applied to all movements and therefore should use the 'Scenario Manager'.

3.7.4. In some projects, including those with new or significantly modified platforms, train service perturbation tests are likely to be required. The details of these tests should be agreed with the sponsor and stakeholders including S&SD Transport Modelling early in the modelling process and documented.

4. Analysis principles

The analyses performed on the model should reflect the objectives of the project. Analyses may look at passenger density, flow rates, journey times, social costs etc.

Depending on the project, TfL R&U may request different outputs from a Legion model; the key outputs should be agreed and documented in the scoping document. This section describes some of these outputs and suggests when they should be used.

- Cumulative Mean Density Plots
- Cumulative High Density Plots
- Desire Line Diagrams
- Space Utilisation Plots
- Model Screenshots
- Clearance Times
- Journey Times
- Videos
- Social costs

For all maps discussed in this section it is recommended the image format used is .PNG and the minimum image dimensions used are 1024 x 480.

4.1. Cumulative Mean Density plots

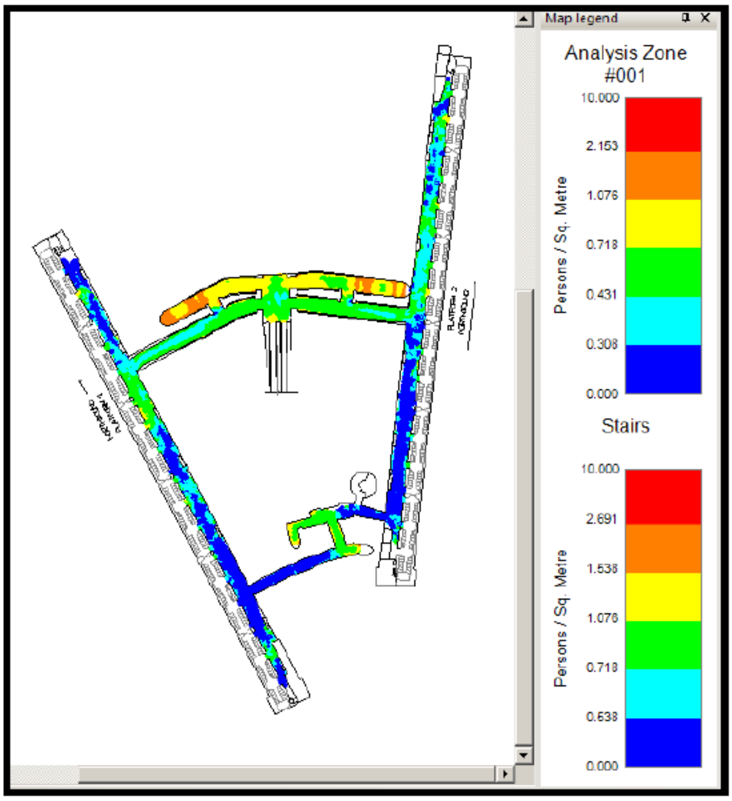


Figure 2: Example of Cumulative Mean Density plot

Description

4.1.1. "Cumulative Mean Density (CMD) plots display the mean levels of density registered in an area from the beginning of playback to the current moment. They are ... used in combination with value ranges corresponding to widely used Fruin's Levels of Service." [From Legion manual].

4.1.2. The CMD plot provides a "mean" density which is calculated only whilst the area is occupied; areas of complete inactivity are not part of the calculation. Where there is a period of extremely high level of activity mixed with a long period of inactivity; the CMD plot would reflect the average level of service during the high level of activity in the period only.

4.1.3. The appropriate Fruin's Levels of Services (LoS) should be used for different areas in a model. The analyser can be configured to show the LoS for walkways and stairs on a single plot. This approach is preferred where possible. The plot should be labelled as to whether it is a single or mixed LoS.

4.1.4. Queuing LoS plots are rarely required and should only be included if expressly requested by stakeholders. This minimises the number of maps to ensure messages are communicated clearly. Commentary of the difference between Walkway and Queuing LOS for compliancy may be provided in the text accompanying Walkway CMDs. Where Queuing LoS Maps are used, only areas which fall under the 'Queuing LOS' should be shown, analysis zones should be used to achieve this. The plot must be clearly labelled with the LoS used.

4.1.5. Plots should always be 15 minutes in duration and cover the four 15 minute periods in the peak hour, the main report should include the busiest 15 minute period, with others provided in the appendices unless otherwise specified. The 15 minute periods should start at 0, 15, 30 or 45 minutes past the hour. Shorter durations or alternative time periods may be agreed with stakeholders (especially where there is overlap with NR services) this should be agreed in advance of the analysis and documented.

4.1.6. The CMD plot should only cover appropriate areas of the station, and therefore should not show density on trains, escalators or inside lifts.

4.1.7. A legend should be included with any CMD, to explain what each colour demonstrates and the time intervals for which the plot is produced.

4.1.8. Smoothing should not be applied to CMD maps.

Example of use

4.1.9. Showing the mean Level of Service experienced by entities on a Walkway / Staircase / Queuing area over the peak 15 minutes.

4.2. Cumulative High Density plots

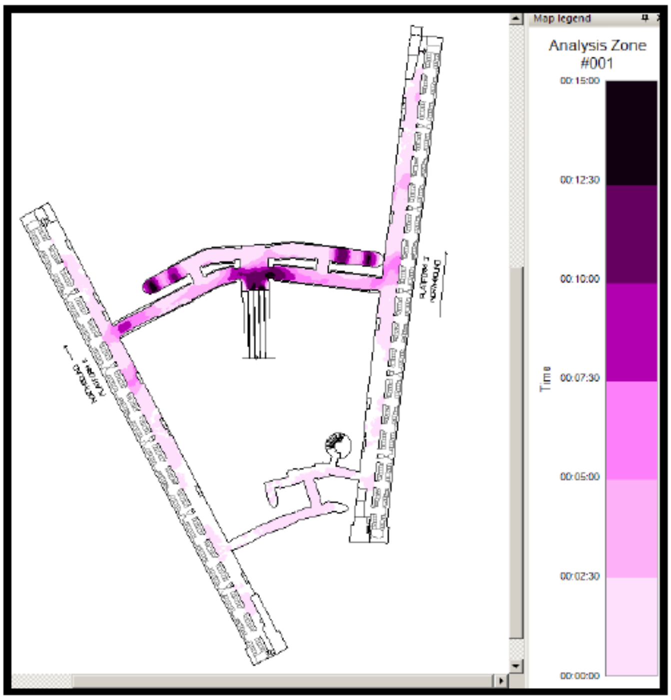


Figure 3: Example of Cumulative High Density plot

Description

4.2.1. The CHD shows how long areas of a station have registered densities greater than a specified limit. The range of colours represents time above a specified density level. Areas that have experienced high levels of density for a long time appear black/dark purple; those that have experienced shorter periods of density appear lighter purple/pink.

4.2.2. The colour scheme recommended for this map is <u>not</u> the default Legion setting. The colour scheme as shown above is recommended for TfL projects, and can be added to the available map settings by adding a new Value Range in the analyser. The colours to use are set out below:

Level 1 (Very Small)	253,224,250	Level 4 (Average Large)	178, 0,177
Level 2 (Small)	253,175,250	Level 5 (Large)	100,0,96
Level 3 (Average)	253,127,250	Level 6 (Very Large)	17,0,16

4.2.3. The CHD plot required for the majority of projects will be time spent above 1.08 persons / Sq. Metre (the threshold for exceeding LOS D on walkways, LOS C on stairs and LOS B on queuing areas). The duration of the plot should be 15 minutes, matching a corresponding CMD plot, and the 15 minute periods should be always start at 0, 15, 30 or 45 minutes past the hour. The colour to value assignment should be set to a maximum of 15 minutes.

4.2.4. Other CHD maps can be provided in addition to the map specified above, against specific limits set against the guidelines in SPSG and agreed with the project sponsor as appropriate. When the design includes a new or significantly changed platform, a separate platform performance map may be requested, the Transport Modelling team can advise of the parameters to be used in this instance. This must be clearly documented.

4.2.5. The CHD map should only cover appropriate areas of the station, and therefore should not show high density on trains or escalators.

4.2.6. A legend should be included with any CHD, smoothing should not be used.

Example of use

4.2.7. Showing the time spent in a passageway above Level of Service D during the peak 15 minutes (as specified in 1.2.2)

4.3. Desire Line Diagrams

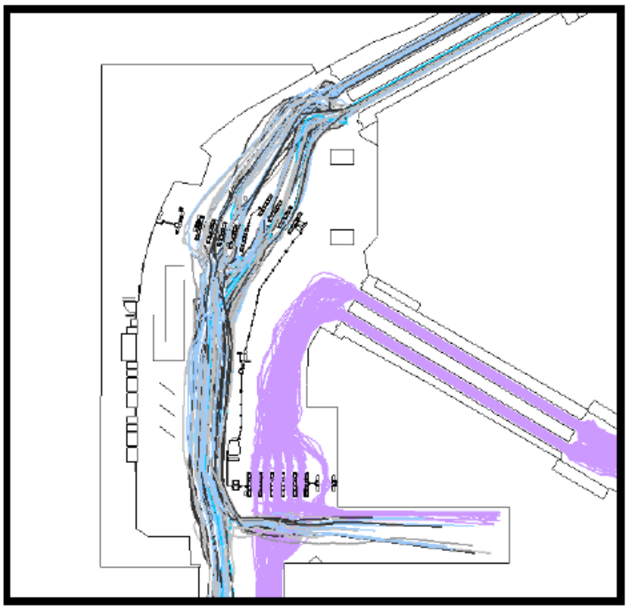


Figure 4: Example of Desire Line Diagram

Description

4.3.1. Intelligent Tracking of entities needed; selecting a fair proportion of each entity type to ensure all desire lines are taken into account.

4.3.2. Entity Colours need to be unique to identify their different characteristics (eg routing, destination, Person with Restricted Mobility etc.). An entity colour scheme generally needs be added separately in the model build to code entities by characteristics other than final destination.

4.3.3. Entities can be selected to highlight their routes.

Example of use

4.3.4. Testing and comparing Ticket Hall designs for possible cross flow issues

4.3.5. Testing and comparing Gateline Configurations for possible cross flow issues

4.3.6. Sense checking for Non-Person with Restricted Mobility (PRM) / PRM routing

4.4. Space Utilisation plot

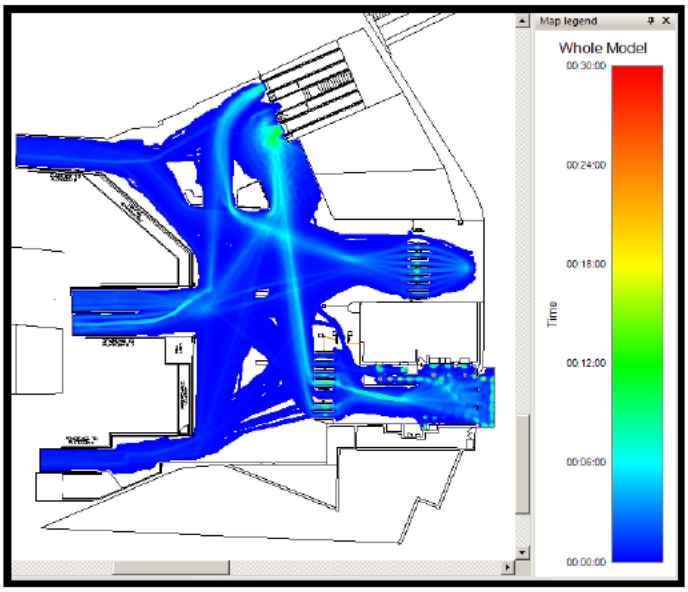


Figure 5: Example of Space Utilisation plots

Description

4.4.1. Space Utilisation plots are useful to understand how space is used. Colours represent how often the space is used: dark blue being lightly used, red being heavily used, background colour not used at all.

4.4.2. Space Utilistaion plots can highlight popular movements, and demonstrate any unconventional movements.

4.4.3. A legend should be attached to each plot to illustrate the range of time each colour represents.

Example of use

4.4.4. Demonstrate existing space usage in a ticket hall area, to decide where a ticket machine could be placed.

4.4.5. Identifies areas which may be appropriate for advertising, busking or commercial use without negative impact on the desire lines of passengers.

4.5. Model Screenshots

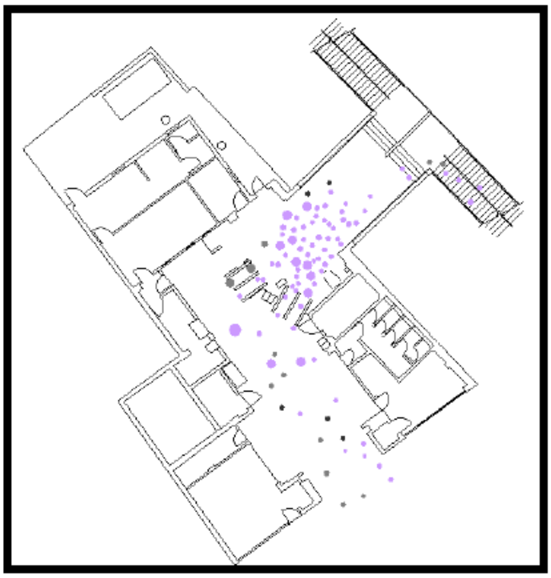


Figure 6: Example of Model Screenshot

Description

4.5.1. Pausing the model during a RES (result) file run and taking a screenshot of the point of interest in the model at that moment in time.

4.5.2. Can be used to compare the same location at the same time in two different scenarios.

4.5.3. If a screenshot is to show the changes in CAD, it is recommended a white background is used. If a screenshot is to show entity positions, the background which provides the best contrast to highlight the entity colours is recommended.

4.5.4. It is best practice to add labels to key features to assist those less familiar with the station layout. Markings to show how different levels of the station link together can be useful.

Example of use

4.5.5. Showing the maximum congestion build up in the model.

4.5.6. Showing the extent of a model and/or changes to a model layout.

4.6. Clearance Times

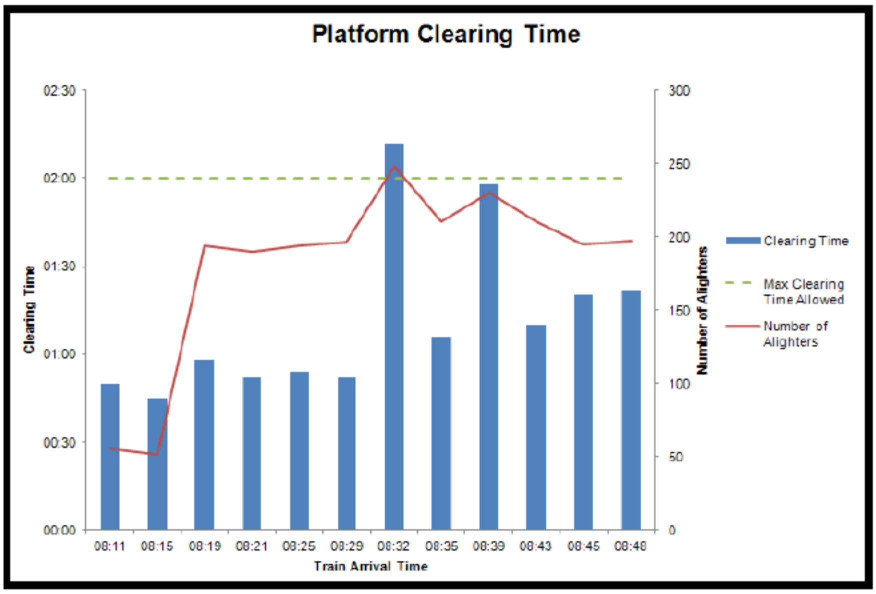


Figure 7: Example of Clearance Time graph

Description

4.6.1. Setting up analysis line(s) and using graph function to determine the duration of activity on the analysis line.

4.6.2. Preferred metric is averaged over a minimum of 12 seconds.

4.6.3. Numeric outputs can be used to analyse a number of things including: clearance time, journey times, space density, and entity counts.

Example of use

4.6.4. Time for a gateline to clear after a train arrival (e.g. where the gateline is relatively close to the platforms)

4.6.5. Time for a platform to clear after a train arrival. Both the minimum time before next train (based on signalling and other constraints) and the average time should be graphed.

4.6.6. Checking throughput (escalators, gatelines etc) is appropriate as part of the model audit process. It should be noted that short periods of higher throughput may occur in Legion, therefore checks should be made over an appropriate length of time.

4.7. Journey Times

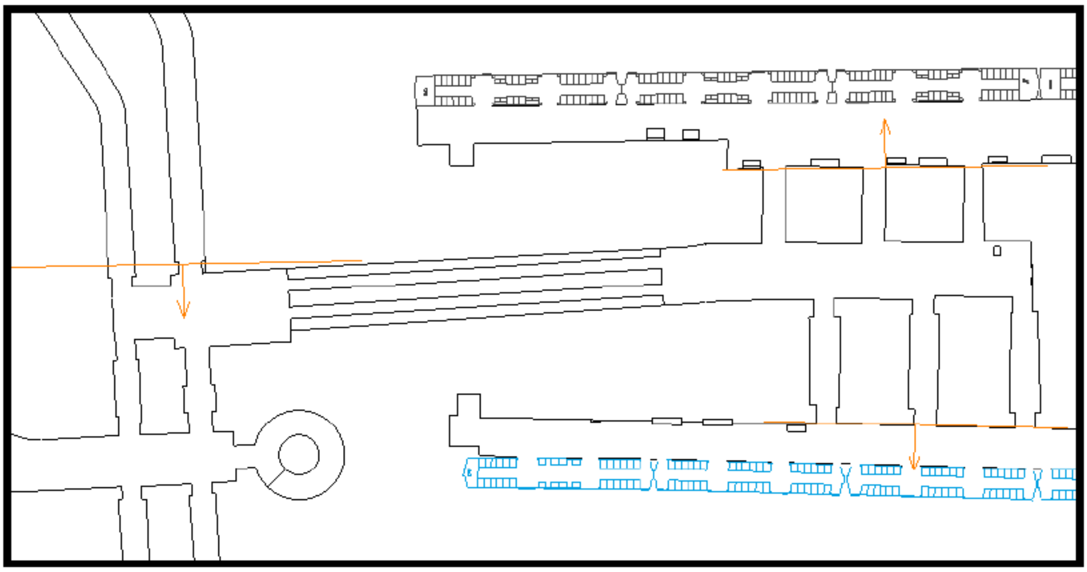


Figure 8: Using Multiple Analysis Lines to measure journey time between two points

Description

4.7.1. Using a series of analysis lines to analyse journey times around the station.

4.7.2. Long durations may induce bias so appropriate time slicing is required to ensure congestion/delays in the peak are taken in to account. Appropriate results may include: Journey Time in free flow conditions, mean of peak hour Journey Time, 85th percentiles etc.

Example of use

4.7.3. Journey times from platform to gateline, gateline to platform, platform to platform for validation purposes.

4.7.4. If possible, a journey should be split into multiple legs so sections of the journey can be analysed more closely.

4.8. Video

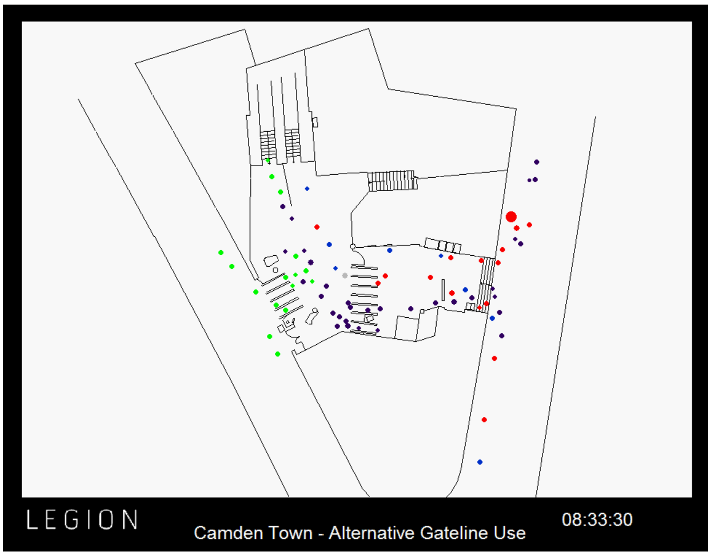


Figure 9: Example of some screenshot from a Legion video

Description

4.8.1. Video shows dynamically how passengers negotiate around the station.

4.8.2. It can show a single area or move around to highlight different features around the model.

4.8.3. Microsoft Video 1 format is recommended, with the speed set to 10x.

4.8.4. A video is convenient to distribute to stakeholders without Legion access.

4.8.5. The use of 3D videos should be considered, especially where the video is to be used for stakeholder consultation including TWA / public consultations.

4.8.6. Entities should normally be coloured by destination as set out in Part 3 of the guide, however additional videos which assign colours to show the level of service they are experiencing may also be used to demonstrate density more clearly.

Example of use

4.8.7. Showing the busiest 5 minutes of the model to stakeholders to highlight issues.

4.8.8. Showing how a passenger can navigate through a station.

4.9. Generalised Journey Time and Costs

BY ACTIVITY

	Weighting	JT	GJT	CF	Cost Journey	Cost Congestion	Total Cost	Annualised
Global: Walking	2.000 + CF	1431304.2	2862608.4	105488.3	£6,377.27	£235.01	£6,612.28	£1,653,069.09
Global: Waiting	2.500 + CF	1022662.8	2556657.0	27988.6	£5,695.68	£62.35	£5,758.03	£1,439,507.61
Global: Queuing	3.400	1226.4	4169.8	0.0	£9.29	£0.00	£9.29	£2,322.33
Global: Delayed	2.500	66296.4	165741.0	0.0	£369.24	£0.00	£369.24	£92,308.76
Global: On Stairs Up	4.000	71130.6	284522.4	0.0	£633.85	£0.00	£633.85	£158,463.57
Global: On Escalator Up	1.500	226356.6	339534.9	0.0	£756.41	£0.00	£756.41	£189,102.55
Global: On Stairs Down	2.500	46141.2	115353.0	0.0	£256.98	£0.00	£256.98	£64,245.37
Global: On Escalator Down	1.500	147349.8	221024.7	0.0	£492.40	£0.00	£492.40	£123,098.79
TOTAL		3012468.0	6549611.2	133476.9	£14,591.11	£297.36	£14,888.47	£3,722,118.05

Figure 10: Example of Legion Spaceworks social cost results

Description

4.9.1. As a minimum the Legion Spaceworks 'Summary GJT, JT and Social Cost report' should be provided for each scenario requested, alongside the RES file. Detailed reports of journey time and generalised journey time can be provided as appropriate.

4.9.2. Results should focus on Journey Time (JT), Generalised Journey Time (GJT) and Congestion Factor (CF) outputs and these values should be presented separately.

4.9.3. The value of time in TfL business cases is now to be reviewed on an individual station basis and project sponsors will use a separate spreadsheet tool to calculate and test a variety of values.

4.9.4. The generic latest passenger values of time can be found in the TfL Business Case Development Manual (BCDM). This may be used as an input in Legion (as a value must be entered), however if no appropriate VoT is available at time of modelling a value of £1 may be used. The value used should be made clear in the summary report.

4.9.5. For results which are intended for use in Business Cases a minimum of three runs of each scenario should be produced, with the average results of the three presented in addition to providing the summary of each run. Where the results of three runs do not converge well, at least two additional runs are recommended to ensure the average is as representative as possible. The poor convergence of runs and likely reasons should be documented.

4.9.6. Different weightings apply to different activities, representing their undesirability. The Global GJT Weightings in Legion Spaceworks reflects the BCDM weightings at the time of writing for the activities available.

4.9.7. Activities related to lifts are not captured within the global analysis. Specific analysis zones are required to capture passengers waiting for lifts and riding in lifts separately from the global analysis, weighted based on BCDM. The weightings for lifts in BCDM (May 2014) are available in Part 3 of this guide.

4.9.8. All social costs delivered from Legion modelling which have used BCDM values of time as an input must document the year/version of BCDM used.

Example of use

4.9.9. Comparing the generalised journey time between the existing layout and scheme designs.

4.9.10. Understanding the amount of time spent in congested conditions in the existing layout and scheme designs.

4.9.11. Highlighting the passenger disbenefit in a certain train service perturbation scenario within a station.

5. Reporting principles

Document as much as possible: original project objectives, requirements, approach, assumptions, inputs, results, result interpretations etc.

Documentation is useful when assumptions are challenged, as well as to aid project handover between modellers.

Given the importance of documentation, the modeller should set aside a reasonable amount of time during the project for reporting.

5.1. Documentation

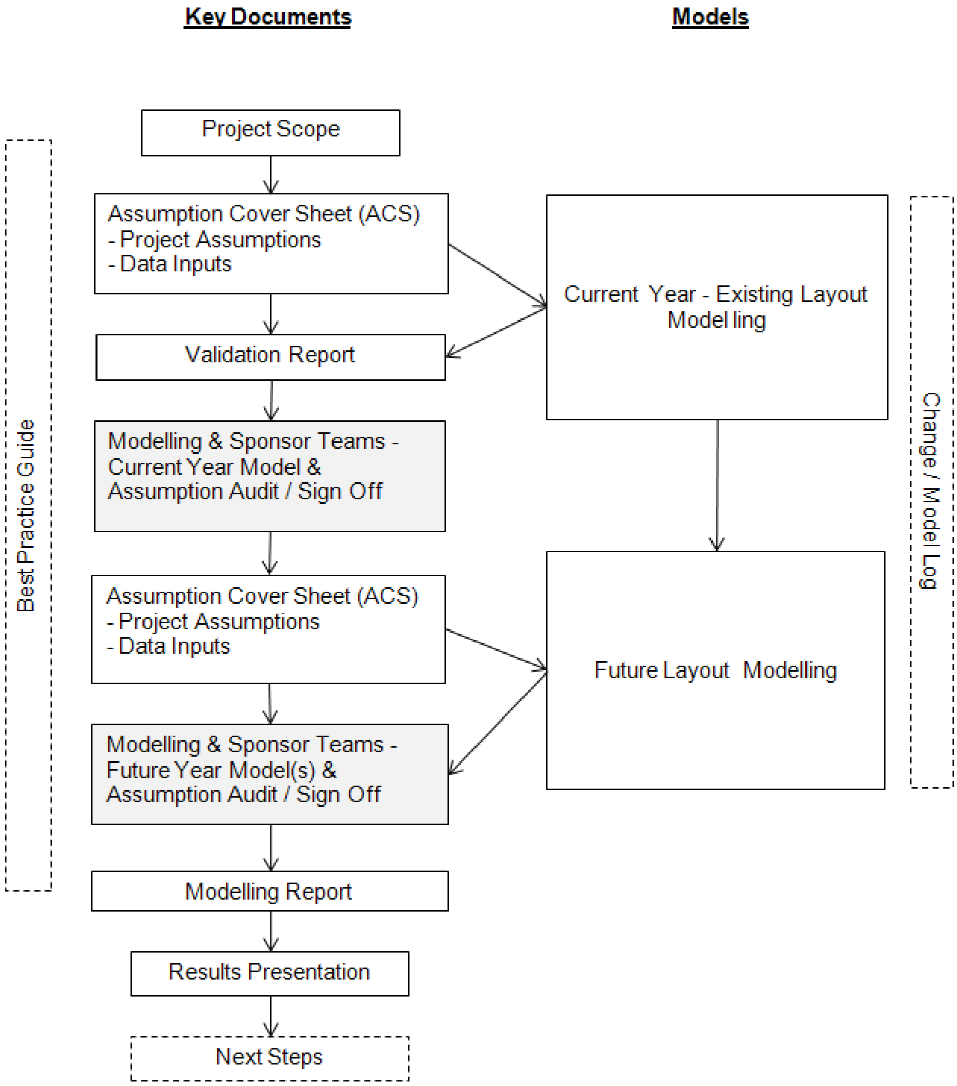


Figure 11: Typical information flow in documentation

5.1.1. For each modelling project, there should be an Assumptions Cover Sheet that keeps all the model inputs together, and a Modelling report that shows the outputs of the model and what they represent. A Validation report should also be included when the model has been validated in the modelling project.

5.2. Validation Report

5.2.1. The Validation Report should detail how the model has been validated and the observed data it is validated against.

5.2.2. Generally a survey of the station would be conducted to collect the necessary model inputs, which is likely to include counts, journey time measurements of certain routes, and flow rates at specific locations.

5.2.3. The Validation Report should include survey methodology, collected data, the equivalent modelled data and conclude how well validated the model is.

5.2.4. The Validation Report needs not be another document, it can be included as part of either Assumptions Cover Sheet or Modelling Report.

5.3. Assumptions Cover Sheet

5.3.1. All models should be submitted to TfL R&U with an accompanying Assumptions Cover Sheet (ACS). This document should include the background of the model development, description and structure of the models and all the assumptions made during the development.

5.3.2. The ACS does not have to be in report format, but should be easy-to-read and well laid out. A template ACS can be provided by TfL R&U on request, however other formats are also acceptable provided all factors are covered.

5.3.3. The Legion Data Template should also be provided as part of the modelling submission and may be referenced in the ACS.

5.3.4. The Assumptions Cover Sheet should contain the following information:

- Last update of model and documentation
- Model times (eg AM period 07:00-10:00)
- Layout of extent of model (Existing infrastructure and scheme)
- References to drawings used, eg sources, drawing numbers
- Explanation of key locations within the model and their respective physical location in the station
- Indication of physical constraints in station infrastructure
- Explanation of entity colours, speed and size
- Demand description and Origin - Destination matrices
- Train services, and service patterns
- Arrival profile per 15 minutes (if applicable)
- Platform alighting profile per car (if applicable)
- Platform boarding profile per carriage (if applicable)
- Parameters if different from default (gatelines, ticket facilities)

- Station operation configuration (escalators, one-way stairs, one-way passageways, ticket gates, ticket machines/windows, lifts), and associated assumptions
- Routing assumptions, PRM routing assumptions (if different)
- Any modelling techniques that deviate from this Best Practice Guide
- Electronic copy of all input data and processing spreadsheet files

5.4. Modelling Report

5.4.1. The purpose of a Modelling Report is to document all the findings of a station modelling project. It should present the objectives of the project, how they have been achieved and its conclusion.

5.4.2. The modelling report should be written in simple English, and be able to be understood by readers who have no technical knowledge of station modelling. It should contain selected Legion outputs which suit the project objectives (see section 4) and offer comparison between relevant scenarios.

5.4.3. The modelling report should contain the following information:

- Executive summary of modelling findings
- Social benefit summary
- Background and objectives of modelling project
- The version of Legion used
- Reference to validation report (if applicable)
- Reference to other standards and guidelines on which the modelling work was based
- Reference of sources of all data used for modelling
- Reference to Assumptions Cover Sheet
- Summary of key modelling assumptions
- Description of scenarios modelled (year, time, infrastructure, train services), and relationship between scenarios
- Summarise findings of each scenario: description, defined Legion outputs and conclusion
- Comparison between scenarios and findings
- Details of social benefit findings
- Summary and conclusion

Station modelling with Legion Spaceworks: Best Practice Guide

Part 2: Modelling Notes

Issue v3.2 February 2016

6. Modelling Overview

Spatial objects in Legion model file (LGM) define how entities move within the model. The positioning and linking of these objects has a direct influence in the accuracy and reliability of the model, and subsequently the outputs generated from it.

This volume describes TfL R&U Legion modelling best practices in greater depth. It includes all the technical aspects of inputting data into a model, laying Legion objects to direct entity flows to gathering social cost output from a model.

While the practices included in this volume apply to most models, localised settings may apply to some models. It is at the modeller's discretion to choose the best method for the model. However any model undertaken by or for TfL R&U should have deviations from best practices clearly documented.

6.1. Conventions used in this guide

In this Guide, “entity” means the Legion representation of a pedestrian within a model; “passengers” or “pedestrians” refers to the physical human beings in real life.

There are three different levels of comments in this Guide:

6.1.1. Key note—procedures that should be implemented

6.1.2. Best practices—modelling techniques that help to implement the best practices and other considerations for the modeller

6.1.3. Other suggestions—comments on other techniques and examples of modelling scenarios

7. Initialising and gathering input information

It is important to specify the modelling objectives prior to commencing modelling, consulting with the stakeholders to ensure their expectations will be met.

It is important that input information should be gathered from authentic sources and documented properly. All parameters should be defined within the Legion Data Template where possible, and all other working spreadsheets that produce Legion input files should also be documented.

7.1. Establishing project scope

7.1.1. All the models within the modelling project should have the objectives, time periods and key assumptions established beforehand, and these should be documented in the Scoping Document.

7.1.2. The key assumptions established in the Scoping Document should form the initial basis for the Assumption Cover Sheet (ACS), elements of which may be agreed as part of the scoping stage.

7.1.3. The following information should be established, agreed with stakeholders and documented, preferably before modelling commences:

- The objectives of the modelling
- The station or part of a station to be modelled
- The project(s) to which the modelling relates
- The modelled years (Current (Latest available data) and Future Year)
- Station layouts and scheme layouts
- Scenarios (e.g. construction phases, operational scenarios)
- Outputs required

7.1.4. The outputs required from the model, the degree of realism required for specific areas, and the level of detail of the model would all affect the time required for modelling and analysing.

7.1.5. For a list of useful Legion outputs, please refer to part1 of this.

7.2. CAD

7.2.1. CAD used in the model should be the most accurate available. Where station fire plans are used, or the CAD is potentially out of date, on site measurements of critical widths should be taken to verify the CAD.

7.2.2. Scheme CAD should be positioned and aligned well with existing CAD.

7.2.3. Rolling stock CAD should be positioned and aligned well with existing CAD, so that potential gaps between CAD lines are sealed and all accessible space contained properly.

7.2.4. It should be documented whether the CAD represents the floor plate or the maximum width of curved passages. Additional simulation CAD may be required to imitate 'edge effects' on new infrastructure.

7.2.5. The vertex count of the model CAD should be reduced as much as possible. Use of arcs of CAD with small features irrelevant to the operation of the station should be avoided, if arcs are used it is recommended that the arc-tolerance settings be amended to lower the vertex count of arcs.

7.2.6. The following CAD layering conventions are recommended:

- Sim-only - non-physical boundaries created to guide or impede pedestrian flows
- Sim & Pres — obstacles exist physically and obstruct pedestrian flows
- Pres-only — non-obstacle CAD lines
- Pres-text — descriptive texts
- Trains — train CAD that limits pedestrian flows
- Small objects — items that are not to be used for auto-navigation in Legion, e.g. central hand-rails, small pillars

7.2.7. For larger stations it may be appropriate to split the CAD into additional stages to assist with presentational input and expedite the process of updating designs should they change in the future. This should be done by the conventions in 7.2.6 combined with the station level, e.g. Sim-Only Ticket Hall 01, Sim-Only Platform 01/02.

7.2.8. Modellers should verify the lengths of stairs and escalators (especially if they have been split between drawings) as well as dimensions of other key locations.

7.3. Demand origin-destination matrix

7.3.1. An Origin-Destination (OD) matrix should be obtained for the agreed model duration (generally 3 hours for AM peak and PM peak). This matrix should form the base for all station model demand inputs. The Legion Data Template should be used to input all OD information into the model.

7.4. Model Naming Conventions

7.4.1. All models in a single project should have a clear and consistent naming convention. Model names must include:

- the TfL Standard Station 3 letter code (eg TCR)
- the demand year of the model (eg 2031)
- the time period of the model (eg AM)
- the infrastructure layout (eg Existing, Option 1 etc)

7.5. Persons with Restricted Mobility (PRM)

7.5.1. PRM should be included in all station models and have appropriate speed, size and routing profiles assigned.

7.5.2. Each station has a varying degree of PRM usage. Some PRM would require different routing and have to be accommodated separately. See **Part 3** for recommended PRM usage by station.

7.5.3. Where PRM size causes unrealistic blockages within the model, due to the inability to adjust the body ellipse, it may be acceptable to temporarily 'shrink' PRM using Direction Modifiers. The use of 'shrinking' should only be used to remove unrealistic behaviour in small areas (eg train doors) and must be agreed with the R&U Transport Modelling team and documented. The entity / supply types for PRMs should be captured in the Legion Data Template and any models being compared for social cost must use the same assumptions and settings.

7.6. Entity types and supply types

7.6.1. Entity Types (ET) should be set up appropriately with the profiles of the passengers they represent using the Legion Data Template (LDT).

7.6.2. Supply Types (ST) should be set up in such a way that the correct number of each entity enters the model from the entrances.

7.6.3. There should be a basic ET set up for each unique PRM type.

7.6.4. Generally there should be an individual ST set up for each unique origin in the model.

7.6.5. Additional STs may be used; often egress and interchange passengers will need to be captured separately to achieve the correct PRM mix, or stations with multiple exits may require multiple egress STs to allow for the necessary train alighting profiles for each exit.

7.6.6. For each of ST, there should be 6 ETs representing each of the PRM classes. See **Part 3** for PRM settings and classification.

7.6.7. Examples of Legion Data Template (LDT) inputs for Supply Types are provided in Figure 12and Figure 13

Entity Types	Entity type	Name	ET	ETA	ETB	ETC	ETD	ETE
		Colour	(colour)	(colour)	(colour)	(colour)	(colour)	(colour)
		Category	UK	UK	UK	UK	UK	UK
		Gender (% male)	50.00	50.00	50.00	50.00	50.00	50.00
	Size profiles	Entity size	Default	Default	Default	Default	Default	Default
		Male						
		Female						
		Luggage	None	Large	Small	Medium	Large	Large
	Speed profiles	Flat ground	UK Comm	ETA	ETB	UK Comm	ETD	ETE
		Stair - up	Inferred	Inferred	Inferred	Inferred	Inferred	Inferred
		Stair - down	Inferred	Inferred	Inferred	Inferred	Inferred	Inferred
Supply Types	Composition	Supply Type Name						
	100.00%	EST_TH	96.95%	0.00%	0.21%	2.03%	0.77%	0.04%
	100.00%	EST_NL NB egress	97.75%	0.00%	0.21%	1.46%	0.54%	0.04%
	100.00%	EST_NL NB int	97.09%	0.00%	0.16%	1.94%	0.73%	0.08%
	100.00%	EST_NL SB egress	97.75%	0.00%	0.21%	1.46%	0.54%	0.04%
	100.00%	EST_NL SB int	97.09%	0.00%	0.16%	1.94%	0.73%	0.08%
	100.00%	EST_NR egress	97.75%	0.00%	0.21%	1.46%	0.54%	0.04%
	100.00%	EST_NR int	97.09%	0.00%	0.16%	1.94%	0.73%	0.08%

Figure 12: Example LDT input - Entities tab

Is the OD matrix specified in percentages?		No					
		Destination:	EX_TH	EX_NL NB	EX_NL SB	EX_NR passageway 4	EX_NR pa
Origin	Supply/Entity Type	Composition	(colour)	(colour)	(colour)	(colour)	(colour)
EN_TH	EST_TH	4451		2442	1929	40	40
EN_NL NB	EST_NL NB egress	7898	7898				
EN_NL NB	EST_NL NB int	28				14	14
EN_NL SB	EST_NL SB egress	4676	4676				
EN_NL SB	EST_NL SB int	6				3	3
EN_NR	EST_NR egress	1619	1619				
EN_NR	EST_NR int	1461		428	1033		

Figure 13: Example LDT Input - OD matrix tab

7.7. Train frequency/arrival times

7.7.1. For high frequency train services, i.e. more than one service per 12 minutes, the frequency based train arrivals from the LDT should be used, formed of 15-minute intervals.

7.7.2. For current year models, or those showing an unchanged TPH then the 'actual' train service from Trackernet can be used to specify the service.

7.7.3. The settings for minimum service interval (headway) should be based on the TPH of the service, as per the table below.

TPH on line	Minimum Service Interval
<20	90s
20-23	70s
24-29	60s
30+	50s

7.7.4. It is recommended that in the LDT arrivals should be made 'random' and noise of 2, 8 should be applied.

7.7.5. Frequencies for existing R&U services are listed in **Part 3**. For future years the expected TPH should be sought and agreed, potential sources include the Railplan assumptions used in the forecasting of the future year, or recommendations from the R&U Train Service Planning or Transport Strategy teams.

7.7.6. On platforms where entry/exit routes are shared, it may be requested that there be at least one occasion when trains arrive on both platforms simultaneously

7.7.7. When modelling National Rail (NR) platforms in models for TfL R&U, high frequency services should be modelled as above; for low frequency, a different profile should be assumed for passengers wishing to board a train as it is expected that most of the boarders would arrive onto the platform close to the departure time of their target train.

7.7.8. Pulses of National Rail terminus station arrivals to R&U gatelines should be fairly represented; hence these entrances should never have an even arrival profile spread.

National Rail train arrival times can be obtained from timetables or live departure board on National Rail website. For future years the expected TPH should be sought and documented, potential sources include the Railplan assumptions used in the forecasting of the future year or the R&U Rail Development Team.

7.8. Train dwell times

7.8.1. **The dwell time is an input to the Legion model, and thus dwell times and/or boarding alighting times should not be reported as an output of the model.**

7.8.2. **The use of a simulated 'driver' can be used to enforce the preset dwell time, but cannot be used in conjunction with a delay point to randomly alter the dwell.**

7.8.3. The LDT should be used to create an availability profile, with an offset of 5 seconds before boarding. The duration of boarding should be based on the TPH / typical dwell at the station with local information, where station specific information is not available defaults as per the table below can be used:

Station Type	Total Dwell Time	Available Time
City	35s	30s
Inner Suburb	30s	25s
Outer Suburb	30s	25s
Shopping	35s	30s
Tourist	35s	30s
Terminus	40s	35s

7.9. Ticket hall facilities usage and delay assumptions

7.9.1. Ticket hall facility assumptions vary between stations and time of day. It is important that assumptions are agreed with stakeholders and documented.

7.9.2. TfL R&U may be able to provide ticket purchasing information if required. However in order to obtain accurate data, an on-site survey may be necessary.

7.9.3. For new stations the appropriate station 'type' should be agreed with the S&SD Customer Strategy team and the number of ticket machines should reflect the values set out in SPSG or the station plans once available.

7.9.4. As part of the Fit for the Future Stations Programme most ticket offices are being closed, often these will be replaced with additional ticket machines. Information should be sought on the immediate and long term plans for ticket offices, and included in the modelling where possible.

7.10. Routing assumptions

7.10.1. It should be agreed with the stakeholders early in the modelling process how the routing is to be assigned; this should be documented in the ACS.

7.10.2. For new stations, routing by Legion Final Destination should be used as the starting point to identify the quickest routes through the station and the entity desire lines. Further iterations of the modelling may require intervention to reflect proposed station signage and preferred routings.

7.10.3. For existing stations signage and one way control systems should generally be adhered to in the modelling. Where on site observations show notable disobedience of signage or one way control, or multiple route choices are used, the routes modelled should be agreed with stakeholders and documented. Surveys may be necessary to inform the percentages of passengers using different routings.

7.11. Lift assumptions

7.11.1. Where lifts are modelled, assumptions of usage, cycle times and configuration should be gathered and documented.

7.11.2. Fixed cycle lifts should normally be used to represent lifts.

7.11.3. Call-button lifts should only be used when waiting time is being specifically investigated and when the lifts serve three levels or more.

7.11.4. Please refer to section 8.11 for further details on lifts.

7.12. Scenarios

7.12.1. Scenarios should be set up in Scenario Manager for all sensitivity tests and "what-if" demand scenarios within a model.

7.12.2. By using Scenario Manager, the modeller can ensure that the model structure remains the same, as required for consistency (see **Part 1**)

7.13. Object naming

7.13.1. Model objects should be named consistently and standard notations and abbreviations (see section Error! Reference source not found.) **should be used where ossible.**

7.13.2. In large models it is recommended that a number of Activity Object Layers be used to assign objects to specific areas.

7.13.3. It is recommended that each distinct level of a station be represented with a different activity object layer, e.g. Ticket Hall Level, Platform Level etc. where elements connect layers it is recommended they are incorporated in the area which they serve in the access direction, or in a separate vertical circulation layer.

7.13.4. Numbering should use a minimum of two digits, e.g. FN_01 rather than FN1. Where elements are to be copied/pasted the first of these should be included in the numbering, e.g. FN #001

7.14. Documenting assumptions

7.14.1. All assumptions made as well as any deviation from suggested best practices in this guide should be documented in the Assumptions Cover Sheet.

7.14.2. All input information should be included in the Legion Data Template, rather than directly input through the model interface to assist with model auditing.

8. Model coding

Spatial objects in Legion define how entities move within the model. The positioning and linking of these objects has a direct influence on the accuracy and reliability of the model, and subsequently the outputs generated from it.

Various areas of a station provide different amenities and entities behave in different ways. The modeller should make sure all entities reach their destinations using appropriate routes.

Modellers should also pay extra attention to station configuration and local arrangements.

8.1. Station entrance/exit

8.1.1. All station entrances and exits should be modelled using appropriate demand.

8.1.2. Station entrances may be modelled with pulsed flows if they are connected to busy bus stops and other rail platforms.

8.1.3. Entrances and Exits should be placed outside station boundaries to ensure that full journey times can be measured.

8.1.4. Where one of the issues being investigated includes changes to street use, e.g. from station control being enacted to hold pedestrians on street, the streetscape beyond the bostwick gates should be included, with any relevant bus stops, crossings and road junctions incorporated.

8.1.5. For stations with multiple entrances/exits, the usage split between them should be obtained from RODS or agreed with stakeholders and documented. Where new station entrances are being introduced, an understanding of passengers' desired surface level destination should be sought and reflected in the modelling.

8.1.6. The number of Entrances / Exits should be kept to a minimum. A single exit per train/service is recommended. Where there are a number of entrances / exits from the Ticket Hall to approximately the same street destination it is recommended that a single Entrance / Exit is used, with intermediate objects (Focal Nodes, Level Entrances, Stairs etc) used to proportion passengers correctly. This is intended to minimise the O-D Matrix and allow flexibility for changing assumptions of use.

8.1.7. Modellers should be aware of any one-way entry/exit systems in place that may affect passenger flows.

8.1.8. If the model uses passenger flow data from another model in the form of a seam line, the seam line data should not be manipulated any further.

8.2. Station Control / Outside station areas

8.2.1. When station control is required, station staff may hold passengers outside the station, thereby a holding area is required to accommodate all waiting passengers. Obtain advice from stakeholders (preferably Operation staff) to decide how best to reflect station control. Space density may be used as criteria to invoke crowding control.

8.2.2. Where LU/DLR stations interact directly with Network Rail station infrastructure the extents of the Network Rail infrastructure and demand to include should be agreed with stakeholders in both TfL and Network Rail.

8.2.3. The appropriate extent of modelling outside of station which exits straight to street should be considered and agreed with the TfL Surface Outcomes Delivery team where appropriate.

8.2.4. The modeller should be aware of the environs of the station and how the station entrances/exits interact with the surroundings outside the station.

8.3. Ticket hall facilities

8.3.1. Ticket hall facilities should be modelled if they have notable usage, or their presence notably affects passenger flows within the ticket hall.

Ticket hall facilities include:

- Ticketing facilities such as POMs - AFM, MFM, FFM, QBM, TVM
- Service facilities such as cash machines,
- Non permanent obstacles to movement such as photo booths, shops, seats, and Metro stands.

8.3.2. Part 3 of this guide provides the delay for ticketing facilities. Delay for other facilities should be agreed with stakeholders and documented.

8.3.3. Usage of each facility should also be agreed with stakeholders and documented.

8.3.4. Modellers should be aware of any queuing system serving station facilities. All queuing systems should be modelled if present.

8.3.5. Other ticket validating facilities in other parts of a station, such as standalone validators (e.g. continuation and route validators), should be modelled if they have notable usage.

8.4. Gatelines

8.4.1. All station gatelines should be set up with appropriate configurations and assigned with appropriate delay.

8.4.2. For the recommended settings for the Delay Profile of each type of ticket gate, please refer to part 3 of this guide.

8.4.3. Gatelines should have a single configuration throughout the modelled period.

8.4.4. The default distance between ticket gate stanchions should be 620mm, according to Station Planning Standard section 3.3.2.12.1. However for Legion modelling, it is recommended that sufficient width should be allowed for an entity with medium luggage to get through, this may be achieved by moving elements of the CAD to the presentation layer.

- Two direction modifiers on each side of the gateline, to select the entities which need to be directed to the gates. First DM for Non-PRMs and second for PRMs to direct to WAGs as appropriate (not shown on diagram)
- One delay point (DP) inside each gate (DP1, DP2, DP3, DP4)
- One focal node (FN) on the entry side of each gate (FN1, FN2, FN3, FN4). Under target parameters the option to use focal point for auto navigation should be unchecked. On the links tab the option to use target availability should be unchecked.
- The focal nodes should be linked one-by-one to the individual delay points (FN1→DP1, FN2→DP2, FN3→DP3, FN4→DP4)
- A route guide (RG) should be placed across the gateline. This is considered essential when an adjacent set of gates serving the opposite direction exists. The route guide will help prevent entities in the model from entering the gate from the wrong side.
- Direction modifiers for each gate may be required to stop unrealistic movements of entities changing gate at the last moment, this is most likely at overcapacity gatelines.

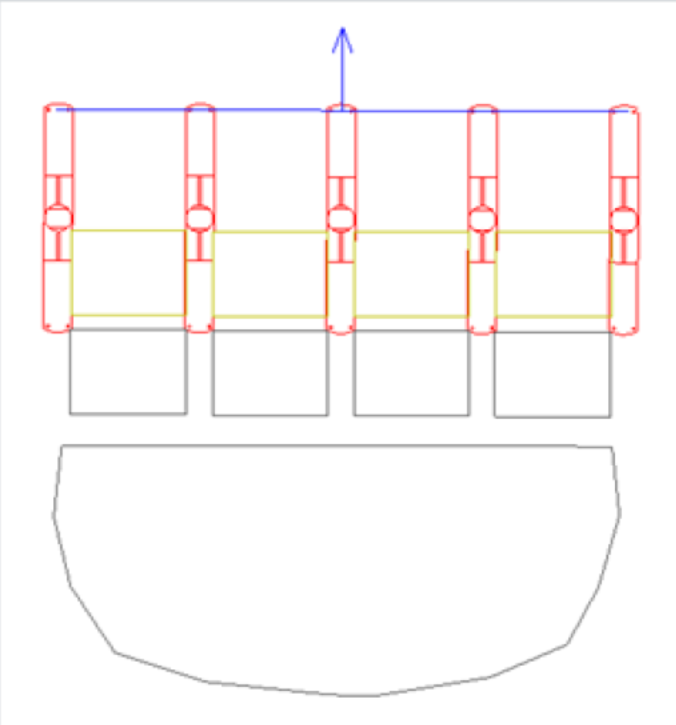
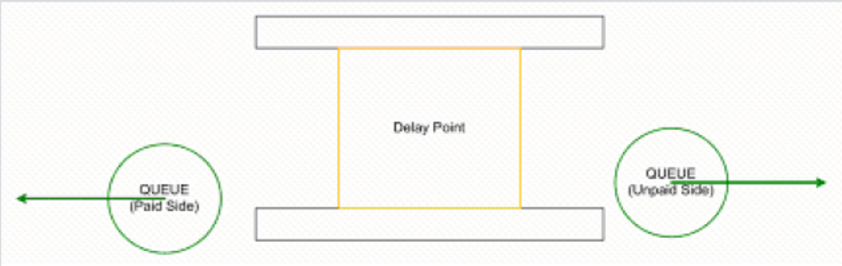


Figure 14: Modelling a simple gateline

Bi-directional gates



- In the event that both queues are occupied, the first queue built will have to clear before people from the second queue can start moving
- First queue to build will be on the paid side
- Both queues will be linked to the delay point
- Some refinement with exact position of queues and size of delay point will be needed
- A drift zone for those exiting would help movement of passengers through the gate. It is required when there is a big flow of passengers to avoid

Figure 15: Bi-directional gates

8.5. Escalators

8.5.1. The modeller should ensure each Escalator (ES) has the correct dimensions, with default width as 1m.

8.5.2. If no information is available, the distance to comb line should be assumed to be 1m long.

8.5.3. Escalators may be configured as filtering objects (to allow for Final Destination Routing) or as target objects. Where there are two escalators in the same direction the distribution of entities to the two escalators should be realistic, this is often more simply achieved through use of target escalators.

8.5.4. Default ES settings should be retained for standard escalators. Small local differences in escalator speed are not recommended to be modelled unless on site surveys have been undertaken to confirm escalator throughput rates.

8.6. Moving walkways

8.6.1. The default escalator settings should be used for the modelling of a moving walkway. These settings achieve the anticipated throughput of a moving walkway which is primary to the model.

8.6.2. The differences between escalators and walkways, in the proportions of passengers standing or walking, does not require specific modelling as this is reflected in the Generalised Journey Time weightings for each type.

8.6.3. The gradient should be accurately reflected; a survey and a validation may be required if the moving walkways form a significant part of the model

8.7. Stairs

8.7.1. The number of risers, width and size of landings of all stairs in CAD should be verified.

8.7.2. Stairs may be configured as filtering or target objects depending on the routing method used in the model. When using filtering stairs focal nodes or other objects may be required to ensure the usage of stairs is realistic.

8.7.3. Stairs can be bi-directional, uni-directional or segregated flows. The modeller should agree with the sponsor and modelling team the most appropriate representation for the given circumstance.

8.7.4. The modeller should be aware of handrails on stairs and place them within Small Object layers as appropriate.

8.7.5. On occasions where a bi-directional staircase is divided by a larger object (e.g. dividing wall) which means the stairs cannot be properly modelled as bi-directional, it may be acceptable to model the stair as two separate uni-directional stairs.

8.8. Spiral stairs

8.8.1. For spiral or scissor staircases, the modeller should verify the number of risers and number of different levels (or landings) as station layouts do not always provide sufficient information.

8.8.2. For spiral stairs the full width of the stair should not be assumed to be utilised, rather it is recommended the throughput of the spiral stair should be surveyed at busy spiral staircases to validate assumptions on utilisation. Where spiral stairs are used less heavily the width should be restricted to the area which has a full tread depth.

8.8.3. For spiral stairs, one DZ for up stairs and one DZ for down stairs can be used to represent each section.

8.8.4. When using Level Entrances and Level Exits to connect each section of a spiral or scissor stairs, make sure there are sufficient overlap between LE and the corresponding LX.

8.8.5. It is advised PRM A, B, D, E do not use spiral staircases unless strictly necessary. If PRM using spiral staircases cause unrealistic issues with entities getting 'stuck', the shrinking while on the stairs is recommended.

8.8.6. If the heights of stairs are not included in CAD, the steps should be assumed to have a tread length of 300mm and a rise of 150mm.

8.9. Passageways

8.9.1. The modeller should be aware where and when any one-way systems are in operation and they should be modelled accordingly.

8.9.2. Where multiple route choices are present for entities, DMs with conditions can be used to encourage more balanced distribution, this is especially important when using Final Destination routing.

8.10. Ramps

8.10.1. According to the LUL Station Planning Standard (1-371, issue A2), section 3.10.9.2, "the width [of a ramp] shall be calculated in the same way as that for a passageway unless the gradient is steeper than 1 in 20. In this case a 10% reduction in the flow rate shall be assumed."

8.10.2. Any ramps with gradient steeper than or equal to 1:20 should be modelled with a reduced speed.

8.10.3. For Legion modelling purpose, DZ should be laid on top of the extent of a ramp with a speed reduction of 10%, regardless of flow direction.

8.10.4. A survey can be carried out and the result used in the model if speed reduction on ramp is observed to be significantly different from 10%. Such variation should be documented and included in the Assumptions Cover Sheet.

8.11. Lifts

8.11.1. All passenger lifts within the model should be modelled with appropriate cycle time, usage and capacity.

8.11.2. BCDM has provided guidance in speed and stop time on each floor for lifts. These parameters should be used for modelling lift cycles, unless engineering parameters or survey results are available.

8.11.3. The practical capacity of the lift being modelled should be sought and agreed. The extents of the lift CAD may not appropriately accommodate or limit the number of entities entering the lift, additional CAD may be required or specific numbers used in selecting entities to enter the lift or send entities back to the waiting area if the lift is full.

8.11.4. The types, proportions and logic of passengers using the lift should be discussed and agreed with the appropriate stakeholders. For PRM lifts it is likely that a set proportion or type of PRMs will need to be directed to the lifts to test the space-proofing of the design.

8.11.5. The model should reflect which doors open at each level, whether a group of lifts share the same waiting area, and any corresponding one way systems.

8.11.6. Lift cycle time should include travelling time between levels, door opening/closing times, and boarding/alighting times (which include lags between alighting and boarding commencement).

8.11.7. Time lag and special DZ (HighPriority, VehicleAlighters) may be used to aid the boarding and alighting flows.

8.11.8. In a busy lift waiting hall the unrealistic blocking of entities when only a proportion of those waiting can board should be avoided.

- A selection segment may be used in the DM to try and select those nearest the lift to board first.
- It is recommended to use the 'Entity Special Behaviour' setting in the Waiting Zone (WZ) of Vehicle ➔ Waiting.
- Analysis should be undertaken to ensure that lift boarding is reasonable.

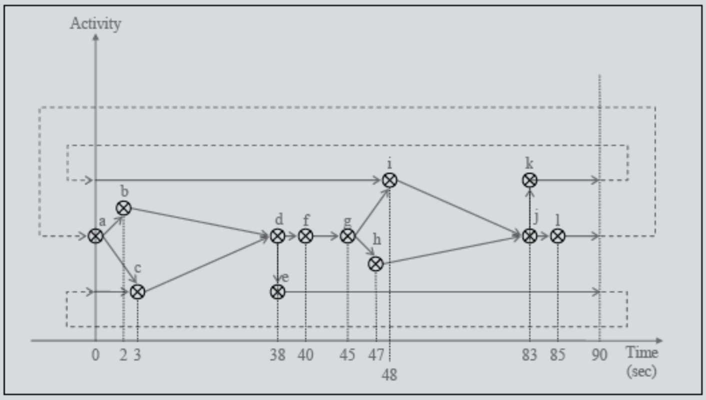
8.11.9. All elements of the lift cycle should be captured within the LDT.

8.11.10. An example is provided overleaf to explain how fixed cycle lift can be developed. Please note all times are indicative only, and exact cycle times for modelling should be sought from the Sponsor on a station by station basis.

A cyclical 2-level lift in a Legion model is one that traverses regularly between two levels, regardless of whether there are any passengers who actually need to use it. In essence, the activities that take place in a basic 2-level lift cycle are listed in the table below.

Activity	Precedent*	Activity time (sec)
a. Lift with passengers from Level 2 arrives at Level 1, and open its door	l	2
b. Passengers from Level 2 exit lift	a	36
c. Passengers from Level 1 enter lift	a (3), e	35
d. Lift closes its door and prevents passengers from entering or leaving it	b, c	2
e. Passengers arrive and wait for lift at Level 1	d (0)	49
f. Lift traverses to Level 2	d	5#
g. Lift with passengers from Level 1 arrives at Level 2, and opens its door	f	2
h. Passengers from Level 1 exit lift	g	36
i. Passengers from Level 2 enter lift	g (3), k	35
j. Lift closes its door and prevents passengers from entering or leaving it	h, i	2
k. Passengers arrive and wait for lift at Level 2	j (0)	49
l. Lift traverses to Level 1 *[The cycle repeats]*	j	5#

* Value in brackets denotes time lapse between start of preceding activity and itself.
# These values are indicative times used for this illustration only. Actual times would need to be computed separately.
The activities can be portrayed in the timeline below.



The activities can be executed by the representation using Legion objects in the figure below.

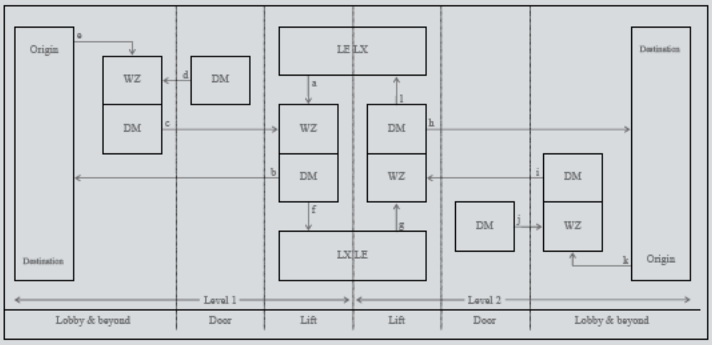


Figure 16: Modelling a fixed cycle list

8.12. Trains

8.12.1. Train CAD should, as a minimum, include the outline of the appropriate rolling stock.

8.12.2. Trains should be modelled with an individual EN per train car using the 'sub-origins' in the LDT. Where there is mixed rolling stock using the same platform this can be achieved using different distributions in the sub-origins.

8.12.3. Train CAD should be aligned at the appropriate stop mark on a platform.

8.12.4. The model should represent any selective door opening which is in place both for those exiting the train and where people choose to wait on the platform.

8.12.5. Stayers on train may be included to simulate available train capacity for the purpose of modelling left behind passengers as discussed in section 8.15.

8.13. Train boarding and alighting

8.13.1. The boarding and alighting times should be specified in the LDT and should replicate a reasonable dwell time for the TPH service assumed, see section 7.8.3.

8.13.2. To avoid entities attempting to board the train as it departs, either the boarding time should be reduced to reflect the time it takes entities to board once they have been given the instruction, or entities should be sent back to the platform WZ by DMs once the train is due to depart.

8.13.3. The method used for model boarding and alighting should be consistent within a station modelling project.

8.13.4. The distribution of passengers alighting a train should be based on observation / survey / load-weigh data where possible. Where no data is available alighting distribution should reflect platform distribution assumptions from the Station Planning Standard section 3.11.4.1.

8.13.5. It is recommended to allow some dedicated time for alighting before boarding commences, 5 seconds is a reasonable default but could be adjusted based on factors such as total dwell and alighting demand.

8.13.6. DZs with entity priority (high/low) and direction preference (left/right) may be used to help the boarding and alighting flows between train and platform. It is recommended a single drift zone is used over the whole train/platform.

8.13.7. Figure 17 shows the recommended basic method of modelling the platform-train interface is demonstrated.

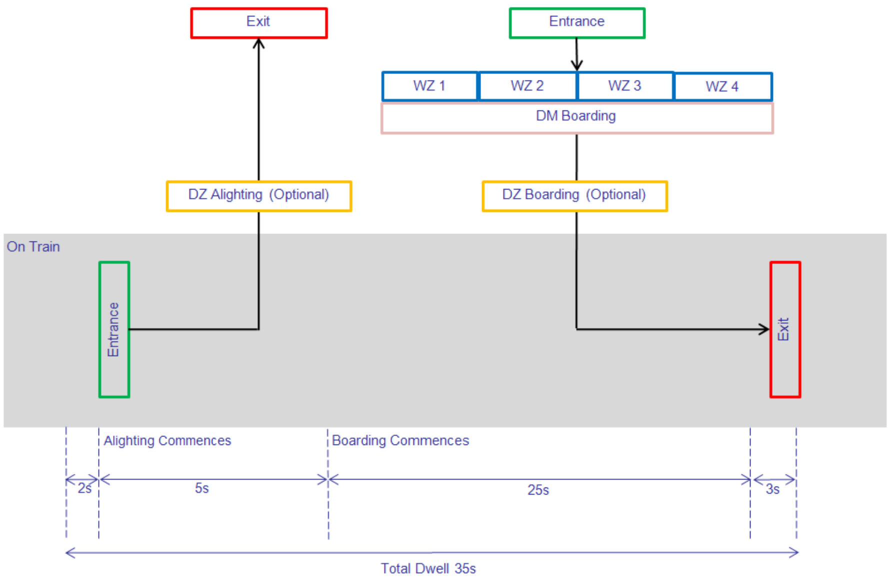


Figure 17 - Modelling train boarding and alighting

8.13.8. Often more complex behaviours will be required at busy platforms to replicate existing or expected conditions. Potential enhancements to model more complex alighting and boarding behaviours are provided below:

- DMs sending back passengers unable to board before train departure
- DMs/WZ for 'left behind' passengers
- FNs/DZs to specify door usage
- DMs to encourage passengers to move down the platform
- AZ/DMs to control boarding based on alighting passengers

8.14. Platforms

8.14.1. Platform width should be verified and any platform furniture that forms physical obstacles should be included in the CAD.

8.14.2. There should be a clear space of at least 500mm between the edge of the platform WZ and the platform edge. (This does not apply where there are Platform Edge Doors)

8.14.3. On platforms which serve different destinations and a high proportion of passengers are anticipated to wait on platform for the correct service, this should be included in the model. The recommended method to achieve this is by creating an on train exit for each service, paired with a service type sequence in the Legion Data Template 'origin settings'. In most circumstances a proportion of passengers will board any train, therefore an 'any train' option in the OD matrix is recommended.

8.14.4. It should be considered whether additional waiting zones are required on platform to reflect the behaviour of passengers waiting for a particular train.

8.14.5. Similarly where trains arriving at a platform are from different origins, and the loading of trains would be notably different, this should be included in the model.

8.14.6. The distribution of passengers waiting on the platform should be based on observation / survey data where possible. Where no data is available platform distribution should reflect the Station Planning Standard section 3.11.4.1.

8.14.7. Modelling various train origins or destinations should be achieved through using a 'service type sequence' in the LDT. For different destinations an exit object for each service will need to be modelled.

8.14.8. Where both origin AND destination are a factor this cannot be achieved easily within the LDT, and the use of a set timetable is likely to be required. This functionality should only be used when necessary.

8.15. Left behinds

8.15.1. The capacity for the train service to accommodate the demand on the platform should be considered and 'left behinds' modelled where appropriate.

8.15.2. Modelling left behinds requires additional data and introduces more complexity, so should only be modelled as necessary. Where alighting demand is higher than boarding demand, where trains are not heavily loaded, or where platforms are not being expressly considered, the modelling of left behinds is not likely to be necessary, however this should be agreed and documented in the model scoping document.

8.15.3. The modelling of 'left behind' passengers should be based on the train loading where information is available. Where possible Train Service Model (TSM) outputs may be used to estimate the available boarding capacity of each individual service.

8.15.4. The modelling of left behind passengers can be achieved by specifying the number of boarders on each service (though this requires a timetable approach) or by modelling passengers on the train. Where passengers on the train are to be modelled this may be best achieved in a specific modelling area away from the train CAD.

8.15.5. Future train loading may be estimated from Railplan to indicate whether train capacity is likely to be a constraint.

8.15.6. It is not recommended to use a percentage based approach to select those affected by DMs on the platform as there are cumulative effects.

8.16. General routing

8.16.1. Entities should generally be left alone to auto-navigate themselves using Final Destination, their main movements should not be interfered with unless necessary.

8.16.2. Minor movements, including the use of adjacent escalators / adits may require more intervention to ensure results are realistic. Where possible dynamic assumptions implemented through DMs with conditional analysis should be used to achieve this.

8.16.3. The use of DZ should be kept to a minimum, and should be used to create realistic passenger movements only. Where DZ are used in modelling, they should be used consistently across all models and documented as appropriate.

8.16.4. Routing from objects should where possible revert to final destination or link by final destination or entity type, with extensibility kept in mind. For minor route choices, such as adjacent escalators, gates, or ticket machines appropriate 'entity choice' decision methods should be used.

8.16.5. Routing by Final Destination is generally useful in reducing the number of objects required in a model. However where extensive use of direction modifiers or drift zones are then required to produce realistic entity movement then traditional routings using Focal Nodes may be considered for simplicity and traceability.

8.16.6. FN and DM should be used reasonably and should not keep changing the target of an entity. DMs should not change the Final Destination of an entity.

8.16.7. Density-based conditional DM (DC) can be used to route entities when multiple routes are available.

8.16.8. Special DZ such as high/low priority or keep left may be used to lower the possibility of model blockages at pinch points.

9. Model analysing

Being able to analyse the model outputs is just as important as building a model. Model results should be presented as clearly as possible to show how the project objectives have been achieved.

Results should be presented and interpreted without bias.

9.1. Model verification

9.1.1. The model should have no errors or significant warnings from the QA process in the Model Builder and no errors or significant warnings while simulating.

9.1.2. The model should have no unreasonable prolonged blockages, which may have been caused by modelling errors, throughout the duration of simulation.

9.1.3. The model should have no unreasonable blockages attributable to PRM behaving unrealistically, e.g. not being able to exit single doors, being stuck against each other, stuck in gatelines. Interventions such as high priority drift zones and shrinking of PRM should be considered to avoid unrealistic behaviour.

9.1.4. Entities within the model should have no unusual movement characteristics.

9.1.5. The accessible space within the model should be confined to actual publicly accessible areas in real-life.

9.1.6. A basic check should be done on the number of entities in the OD matrix from a simulation plus leftover at the end of the model. This total should equal the original demand.

9.2. Model validation

9.2.1. A model should be validated to:

- Provide evidence that it reflects the actual situation in real life
- Give confidence to stakeholders, this is especially important if the modelling results may be presented to public inquiries
- Offer a basis to build Future Year (existing layout and scheme) models
- Provide a trusted basis for third parties who may re-use the model for later development

9.2.2. Journey times on key routes and pedestrian flow counts at key locations should act as main elements for validation.

9.2.3. The simulated journey times of key routes should correspond with the surveyed journey times, and be within 10% of the latter.

9.2.4. In addition it is possible to use visual validation by comparing model movements and observations in station. However, visual validation must only be conducted by station staff with very good experience and be signed off by TfL R&U.

9.3. Model auditing

9.3.1. TfL R&U has devised an auditing process whereby the auditor reviews all of the modelling files (LGM, RES, ANA) along with the LDT, ACS and supporting documents and decides whether the model is fit for purpose.

9.3.2. In general the audit checklist (see the back of this Volume) is a list of logical checks on any station models, helping modellers to avoid basic modelling mistakes and acting as a reminder to look out for warnings and errors.

9.3.3. All TfL station models should be audited and signed off by TfL S&SD Transport Modelling Team.

9.4. Model outputs

9.4.1. All maps, videos and graphs should be produced in a consistent format (see Part 1) for more details on key model outputs.

9.4.2. All maps should assess areas by the appropriate Level of Service as far as possible. Walkway, staircase and queuing Levels of Service can be plotted on a single map in Spaceworks.

9.4.3. All LGM, RES, ANA files and working spreadsheets should be included in the deliverables.

9.5. Generalised journey time and congestion factor for social cost

9.5.1. Social cost is the monetised generalised journey time (GJT) and congestion factor (CF) of all passenger flows within a station model. It is used heavily in the TfL business case development process to justify the benefit provided by a scheme.

9.5.2. The following sections in BCDM (May 2014)

- §2.6 Carrying Out An Appraisal—explain appraisal periods, passenger benefits and benefit:cost ratio
- §3.3 Passenger Benefits—value of time, passenger journey weighting
- §A3 Project Appraisal Example-Stations—example of station work business case
- §C3 Benefit and Revenue Parameters—value of time, growth in value of time
- §D1 Average LUL Travel Speeds 2003—Escalator speed, lift speed, walk speeds
- §E1a Values of Time (2014) for main modes
- §E3a Weights for Elements of LUL Journey Time (1)
- Example after §E3c—calculating weighted journey time of a journey

9.5.3. The value of social benefit provided by a scheme is the existing layout GJT+CF minus scheme GJT+CF. Hence it is important to make sure the analysis of the two scenarios is undertaken in a consistent manner.

9.5.4. In this guide, Generalised Journey Time (GJT) represents the weighted time measured within Legion, and after multiplying by the value of time and annualisation factor, it would then become social cost (normally in unit of £m/annum).

9.6. Measuring GJT and CF

9.6.1. It is recommended that a single ANA file should be set up to extract the social costs for all scenarios.

9.6.2. The 'Summary GJT, JT and Social Cost report' should be produced for each scenario.

9.6.3. A minimum of three runs of each scenario should be produced, with the average results of the three presented. Where the results of three runs do not converge well, at least two additional runs are recommended to ensure the average is as representative as possible.

9.6.4. Different weightings apply to different activities, representing their undesirability. The Global GJT Weightings in Spaceworks reflects the weightings for the activities available, at the time of writing.

9.6.5. Activities related to lifts are not captured within the global analysis. Specific analysis zones should be set up to capture passengers waiting for lifts and riding in lifts separately from the global analysis, weighted based on BCDM.

9.6.6. Each ANA should be named appropriately describing the area and the activity it is measuring.

9.6.7. Generic passenger values of time for LU/Rail passengers can be found in BCDM. These may be used as an input in the Legion Analyser (as a value must be entered), however it is also acceptable to enter a 'test' value i.e. £1. The GJT +CF will be tested outside of the Legion modelling to test a range of values of time for input to the business case.

9.6.8. See section 4.9 for more details on how this is used in business case analysis.

Station modelling with Legion Spaceworks: Best Practice Guide

Part 3: TfL Generic station modelling parameters

Issue v3.2 February 2016

10. Delay used on ticket facilities

10.1. Delay used on ticket issuing facilities

10.1.1. A station survey should be conducted to collect the relevant information; otherwise, the values below may be used. All figures in seconds.

	Min, Mean, Max
Multi Fare Machines (MFM)	20, 45, 70
Ticket Vending Machine (TVM)	20, 45, 70
Advanced Fare Machine (AFM)	15, 20, 30
Queue Buster Machine (QBM)	15, 40, 70

Automated Teller Machine (ATM)	30, 45, 60

10.2. Delay for ticket gates

Automatic	(fixed) 1.8
Manual gates	3 .0
Uni-directional Wide Aisle Gate (WAG)	1.8
Bi-directional Wide Aisle Gate (WAG)	7.5
Standalone passenger validator (ie not attached to a manual gate)	1.0

11. TfL train service frequencies and capacities

11.1. Rolling stock capacity

Line	Stock	Capacity
District	D	971
	S7	1,037
Circle	S7	1,037
Hammersmith and City	S7	1,037
Metropolitan	S8	1,186
Jubilee	1996	972
Piccadilly	1973	801
Northern	1995	787
Bakerloo	1972	847
Central	1992	1,047
Waterloo and City	1992	506
Victoria	2009	999
DLR	2-car	469
DLR	3-car	704
Overground	4-car Class 378	666
Overground	5-car Class 378	832
Crossrail	9-car Class 345	1,763

LU figures quoted from "London Underground Train Capacities", Charles Baker, LUL, drafted June 2009. DLR and Overground figures from David Arquati Sept 2015. The figures assume 5 standing passengers per m2 i.e. represent practical crush capacity.

11.2. LU train services (peak periods)

11.2.1. The following table depicts the planned train service frequencies for London Underground in July 2015. Modellers should always verify the frequencies to be modelled with stakeholders.

Line	Section (both directions)	2015 AM services TPH			2015 PM services (TPH)		
		7-8 am	8-9 am	9-10 am	4-5 pm	5-6 pm	6-7 pm
Bakerloo	Queen's Park – Elephant & Castle	19.5	22	21.5	21.5	21	20.5
Central	White City – Stratford	24.5	29.5	26.5	27	28.5	28
Jubilee	Willesden Green – North Greenwich	27.5	29.5	28.5	26.5	30.5	28.5
Northern	Kennington – Camden Town (Charing Cross)	20	22.5	21	20	22.5	22
Northern	Kennington – Camden Town (Bank)	20.5	24	22.5	20	23.5	21
Northern	Morden – Kennington	26	28.5	26.5	23	28	26.5
Piccadilly	Arnos Grove – Acton Town	23.5	24	24	23	24	24
Victoria	Brixton – Walthamstow Central	30	34	33.5	31.5	34	33
Waterloo & City	Waterloo – Bank	22	22	20	19.5	22	22
Crossrail	Bond Street – Whitechapel (2019)	22	24	21	22	24	21

11.2.2. For stations outside of the central sections presented in the table above, the TPH should be sought on an individual station basis.

11.2.3. The service frequencies for the Circle, Metropolitan, Hammersmith & City, and District vary across different sections, and need to be considered both separately and jointly, therefore these should be sought on an individual station basis.

11.3. DLR train services (peak periods)

11.3.1. The following table depicts the planned train service frequencies for DLR from September 2015. Modellers should always verify the frequencies to be modelled with stakeholders.

Services (both directions)	2015 AM services TPH	Number of Cars on service
Bank - Lewisham	15	3 Car
Bank - Woolwich Arsenal	7.5	3 Car
Tower Gateway - Beckton	7.5	3 Car
Stratford – Canary Wharf	7.5	2 Car
Stratford – Lewisham	7.5	2 Car
Stratford International – Woolwich Arsenal	7.5	2 Car
Stratford International – Beckton	No peak service	

11.3.2. It should be noted that at a number of stations two (or more) services will serve the same platform when modelling total TPH.

12. Recommended Entity Colouring

12.1.1. It is recommended that modellers use the following colours for entities, representing their final destinations. Please note that these colours are assumed to be used on a white background. Amending the colours for improved contrast on white/grey/black backgrounds or to other entities is acceptable, though it is recommended to stay on a similar colour scale.

Direction 1		Direction 2	
Bakerloo	137, 78, 36	Bakerloo	190, 107, 50
Central	220, 36, 31	Central	230, 89, 86
Circle	255, 206, 0	Circle	255, 239, 91
District	0, 114, 41	District	0, 185, 65
Overground	236, 158, 0	Overground	255, 190, 55
Hammersmith & City	215, 153, 175	Hammersmith & City	188, 86, 122
Jubilee	134, 143, 152	Jubilee	174, 181, 186
Metropolitan	117, 16, 86	Metropolitan	178, 24, 130
Northern	64, 64, 64	Northern	96, 96, 96
Piccadilly	0, 25, 168	Piccadilly	96, 119, 254
Victoria	0, 160, 226	Victoria	144, 222, 254
Waterloo & City	118, 208, 189	Waterloo & City	115, 220, 205
DLR	0, 175, 173	DLR	91, 255, 255
Crossrail	128,87,145	Crossrail	111,67,113

Exit 1	180, 205, 155
Exit 2	127, 0, 254
Exit 3	139, 208, 139
Exit 4	0, 254, 0

13. Person with Restricted Mobility

13.1. PRM type definitions

13.1.1. TfL R&U have devised five types of PRM and one type of non-PRM entity types for Legion modelling purpose. These types are defined as below.

Entity Type	Description	Example accompanying items
N	Non-PRM	Handbags, backpacks, umbrella laptop case, pocket dogs, single shopping bags
A	Wheelchair users	Wheelchairs
B	Passengers with permanent or temporary physical mobility impairments	Walking sticks, guide dogs
C	Non-disabled passengers with heavy luggage	Rucksacks, sports bag, tennis racket bags, multiple shopping bags, toolbox, wheelie case (flight cabin luggage), fold bikes, fishing rods, golf bag, guitar case, dogs on paws
D	Non-disabled passengers with large luggage	Cello case, all suitcases and large bags (including wheelie cases that are bigger than flight cabin luggage), full-size bikes, flat pack packages
E	Adults with young children (including with pushchairs)	Young children, pushchairs

13.2. Routeing for PRM

Entity Type	Routing preference
N	No particular preference
A	Always WAG and lifts. Cannot use stairs or escalators
B	Preferably lifts, then escalators & stairs
C	Use WAG and lift if busy or if they cannot get pass normal gates
D	Prefers WAG and lifts. Can use stairs and escalators
E	Prefers WAG and lifts. Can use stairs and escalators

13.3. PRM type characteristics

Entity Type	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

13.3.1. Entity Group A -100% of entities travel at 0.6 m/s, using the "UK" entity profile

13.3.2. Entity Group B - 100% of entities travel at 0.8 m/s, using the "UK" entity profile

13.3.3. Entity Group C - As UK commuters, no further specifications.

13.3.4. Entity Group D -"UK" entity profile with speed distribution as below.

m/s	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
%	5%	8%	12%	16%	18%	16%	12%	8%	5%	0%

13.3.5. Entity Group E -"UK" entity profile with speed distribution as below.

m/s	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
%	0%	5%	8%	12%	16%	18%	16%	12%	8%	5%

13.4. PRM percentages for different station types

CITY	AM peak			Inter peak			PM peak			Weekend			Average		
% Passengers by PRM Category	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)
A - Wheelchair	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
B - Physical mobility Impairment	0.21	0.21	0.16	0.58	0.57	0.43	0.29	0.29	0.22	0.37	0.37	0.28	0.37	0.36	0.27
C - Medium encumbrance	2.03	1.46	1.94	5.38	3.87	5.16	8.23	5.92	7.89	9.24	6.64	8.86	6.11	4.39	5.86
D - Large encumbrance	0.77	0.54	0.73	1.59	1.11	1.50	2.09	1.46	1.97	2.37	1.66	2.24	1.68	1.18	1.59
E - Buggy	0.04	0.04	0.08	0.10	0.12	0.23	0.05	0.06	0.12	0.14	0.17	0.31	0.08	0.10	0.18
Total	3.05	2.25	2.91	7.65	5.67	7.32	10.67	7.75	10.20	12.13	8.83	11.68	8.24	6.03	7.90

INNER SUBURB	AM peak			Inter peak			PM peak			Weekend			Average		
% Passengers by PRM Category	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)
A - Wheelchair	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B - Physical mobility Impairment	0.28	0.31	0.16	0.75	0.84	0.43	0.38	0.43	0.22	0.49	0.55	0.28	0.48	0.53	0.27
C - Medium encumbrance	1.65	2.02	1.94	4.38	5.37	5.16	6.71	8.22	7.89	7.52	9.23	8.86	4.98	6.10	5.86
D - Large encumbrance	0.62	0.77	0.73	1.28	1.59	1.50	1.68	2.09	1.97	1.91	2.38	2.24	1.36	1.68	1.59
E - Buggy	0.09	0.09	0.08	0.24	0.24	0.23	0.13	0.13	0.12	0.32	0.32	0.31	0.19	0.19	0.18
Total	2.64	3.19	2.91	6.66	8.05	7.32	8.90	10.87	10.20	10.25	12.47	11.68	7.00	8.51	7.90

OUTER SUBURB	AM peak			Inter peak			PM peak			Weekend			Average		
% Passengers by PRM Category	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)
A - Wheelchair	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B - Physical mobility Impairment	0.49	0.56	0.16	1.32	1.51	0.43	0.67	0.77	0.22	0.86	0.98	0.28	0.84	0.96	0.27
C - Medium encumbrance	1.41	2.46	1.94	3.75	6.54	5.16	5.73	10.00	7.89	6.43	11.22	8.86	4.26	7.42	5.86
D - Large encumbrance	0.52	0.90	0.73	1.08	1.87	1.50	1.42	2.45	1.97	1.62	2.79	2.24	1.15	1.97	1.59
E - Buggy	0.15	0.12	0.08	0.42	0.32	0.23	0.22	0.17	0.12	0.57	0.44	0.31	0.33	0.25	0.18
Total	2.58	4.04	2.91	6.58	10.24	7.32	8.05	13.39	10.20	9.48	15.43	11.68	6.57	10.61	7.90

SHOPPING	AM peak			Inter peak			PM peak			Weekend			Average		
% Passengers by PRM Category	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)
A - Wheelchair	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B - Physical mobility Impairment	0.19	0.18	0.16	0.52	0.48	0.43	0.27	0.24	0.22	0.34	0.31	0.28	0.33	0.30	0.27
C - Medium encumbrance	3.41	1.35	1.94	9.05	3.58	5.16	13.85	5.47	7.89	15.54	6.14	8.86	10.28	4.06	5.86
D - Large encumbrance	1.22	0.50	0.73	2.53	1.03	1.50	3.32	1.35	1.97	3.77	1.53	2.24	2.67	1.08	1.59
E - Buggy	0.04	0.09	0.08	0.12	0.25	0.23	0.06	0.13	0.12	0.16	0.34	0.31	0.09	0.20	0.18
Total	4.87	2.11	2.91	12.22	5.33	7.32	17.49	7.19	10.20	19.81	8.32	11.68	13.37	5.65	7.90

TERMINUS	AM peak			Inter peak			PM peak			Weekend			Average		
% Passengers by PRM Category	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)
A - Wheelchair	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B - Physical mobility Impairment	0.24	0.25	0.16	0.65	0.68	0.43	0.33	0.34	0.22	0.42	0.44	0.28	0.41	0.43	0.27
C - Medium encumbrance	2.38	2.40	1.94	6.32	6.38	5.16	9.67	9.76	7.89	10.85	10.95	8.86	7.18	7.24	5.86
D - Large encumbrance	0.91	0.92	0.73	1.88	1.89	1.50	2.47	2.48	1.97	2.81	2.82	2.24	1.99	2.00	1.59
E - Buggy	0.06	0.08	0.08	0.17	0.23	0.23	0.09	0.12	0.12	0.22	0.31	0.31	0.13	0.18	0.18
Total	3.59	3.65	2.91	9.02	9.18	7.32	12.56	12.70	10.20	14.30	14.52	11.68	9.71	9.85	7.90

TOURIST	AM peak			Inter peak			PM peak			Weekend			Average		
% Passengers by PRM Category	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)	Entrance	Exit	Av (Int)
A - Wheelchair	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
B - Physical mobility Impairment	0.35	0.18	0.16	0.96	0.49	0.43	0.49	0.25	0.22	0.62	0.32	0.28	0.61	0.31	0.27
C - Medium encumbrance	1.87	1.45	1.94	4.96	3.85	5.16	7.58	5.88	7.89	8.51	6.60	8.86	5.63	4.37	5.86
D - Large encumbrance	0.69	0.54	0.73	1.43	1.11	1.50	1.88	1.46	1.97	2.13	1.66	2.24	1.51	1.18	1.59
E - Buggy	0.07	0.06	0.08	0.18	0.17	0.23	0.10	0.09	0.12	0.25	0.24	0.31	0.14	0.14	0.18
Total	2.98	2.23	2.91	7.53	5.62	7.32	10.07	7.69	10.20	11.51	8.82	11.68	7.90	5.99	7.90

13.5. PRM for step free access schemes

13.5.1. When modelling step free access schemes the appropriate approach to modelling PRM numbers should be agreed with the sponsor and documented.

13.5.2. As more stations become step free the percentage of PRM is likely to increase, hence percentages may be higher than those provided in section 13.4. Therefore, additional testing may be required to sufficiently space proof step free access and waiting areas.

13.5.3. When producing social cost outputs, if additional PRM are added to the model in the scheme option this adds additional social cost to the station, the equivalent of which is not captured in the existing layout model. Additional Legion social cost reports should be provided to show the social cost by entity type. The impacts of this should be clearly documented in the modelling report.

13.5.4. For calculation of improved accessibility benefits of step free access schemes beyond Legion's within-station calculations contact the R&U Transport Strategy team.

14. BCDM Parameters (May 2014)

14.1. Lift parameters from BCDM

14.1.1. Lift speed: 1.4 metres/second. (from BCDM Appendix D1.3)

14.1.2. Stop time/floor: 40 seconds (from BCDM Appendix D1.3)

14.2. Value of Time (VoT)

14.2.1. The value of time is now broken down into three separate values for different journey purposes. The value of time for an individual station will depend on the proportion of passengers of each journey purpose. Generalised Journey Time and Congestion Factor results should be delivered to the project sponsor for conversion into monetary values. Overground uses Rail VoT.

14.2.2. Value for in work time:	LU/DLR	£24.07/hour
14.2.3. Value for non-work – commuting:		£8.06/hour
14.2.4. Value for non-work – other:		£7.16/hour

14.3. Social Cost Weighting

14.3.1. The Global GJT Weightings in Spaceworks reflects the BCDM weightings at the time of writing for the activities available.

14.3.2. Additional weightings: Waiting for Lifts = 2.5, Riding in Lifts = 2.0,

14.3.3. Further information on weightings for elements of LU journey times can be obtained from LU Transport Planning.

15. LU Station types

Station Name	Station Type	Station Name	Station Type	Station Name	Station Type
Acton Town	Outer Suburb	Chalfont & Latimer	Outer Suburb	Finchley Road	Inner Suburb
Aldgate	City	Chalk Farm	Inner Suburb	Finsbury Park	Inner Suburb
Aldgate East	City	Chancery Lane	City	Fulham Broadway	Inner Suburb
Alperton	Outer Suburb	Charing Cross	Terminus	Gants Hill	Outer Suburb
Amersham	Outer Suburb	Chesham	Outer Suburb	Gloucester Road	Inner Suburb
Angel	City	Chigwell	Outer Suburb	Golders Green	Outer Suburb
Archway	Inner Suburb	Chiswick Park	Outer Suburb	Goldhawk Road	Inner Suburb
Arnos Grove	Outer Suburb	Chorleywood	Outer Suburb	Goodge Street	Shopping
Arsenal	Inner Suburb	Clapham Common	Inner Suburb	Grange Hill	Outer Suburb
Baker Street	Tourist	Clapham North	Inner Suburb	Great Portland Street	Tourist
Balham	Outer Suburb	Clapham South	Inner Suburb	Green Park	Tourist
Bank	City	Cockfosters	Outer Suburb	Greenford	Outer Suburb
Barbican	City	Colindale	Outer Suburb	Gunnersbury	Outer Suburb
Barking	Outer Suburb	Colliers Wood	Outer Suburb	Hainault	Outer Suburb
Barkingside	Outer Suburb	Covent Garden	Tourist	Hammersmith (Ham&City)	Inner Suburb
Barons Court	Inner Suburb	Croxley	Outer Suburb	Hammersmith (Picc)	Inner Suburb
Bayswater	Tourist	Dagenham East	Outer Suburb	Hampstead	Inner Suburb
Becontree	Outer Suburb	Dagenham Heathway	Outer Suburb	Hanger Lane	Outer Suburb
Belsize Park	Inner Suburb	Debden	Outer Suburb	Harlesden	Outer Suburb
Bermondsey	Inner Suburb	Dollis Hill	Outer Suburb	Harrow & Wealdstone	Outer Suburb
Bethnal Green	Inner Suburb	Ealing Broadway	Outer Suburb	Harrow-on-the-Hill	Outer Suburb
Blackfriars	City	Ealing Common	Outer Suburb	Hatton Cross	Outer Suburb
Blackhorse Road	Outer Suburb	Earls Court	Inner Suburb	Heathrow T123	Tourist
Bond Street	Shopping	East Acton	Inner Suburb	Heathrow T4	Tourist
Borough	Inner Suburb	East Finchley	Outer Suburb	Heathrow Terminal 5	Tourist
Boston Manor	Outer Suburb	East Ham	Outer Suburb	Hendon Central	Outer Suburb
Bounds Green	Outer Suburb	East Putney	Inner Suburb	High Barnet	Outer Suburb
Bow Road	Inner Suburb	Eastcote	Outer Suburb	High Street Kensington	Shopping
Brent Cross	Outer Suburb	Edgware	Outer Suburb	Highbury & Islington	Inner Suburb
Brixton	Inner Suburb	Edgware Road (Bakerloo)	Inner Suburb	Highgate	Outer Suburb
Bromley-by-Bow	Inner Suburb	Edgware Road (Met&Circle)	Inner Suburb	Hillingdon	Outer Suburb
Buckhurst Hill	Outer Suburb	Elephant & Castle	Inner Suburb	Holborn	City
Burnt Oak	Outer Suburb	Elm Park	Outer Suburb	Holland Park	Inner Suburb
Caledonian Road	Inner Suburb	Embankment	Tourist	Holloway Road	Inner Suburb
Camden Town	Inner Suburb	Epping	Outer Suburb	Hornchurch	Outer Suburb
Canada Water	Inner Suburb	Euston	Terminus	Hounslow Central	Outer Suburb
Canary Wharf	City	Euston Square	City	Hounslow East	Outer Suburb
Canning Town	Inner Suburb	Fairlop	Outer Suburb	Hounslow West	Outer Suburb
Cannon Street	City	Farringdon	City	Hyde Park Corner	Tourist
Canons Park	Outer Suburb	Finchley Central	Outer Suburb	Ickenham	Outer Suburb

Station Name	Station Type	Station Name	Station Type	Station Name	Station Type
Kennington	Inner Suburb	Oxford Circus	Shopping	Sudbury Hill	Outer Suburb
Kensal Green	Inner Suburb	Paddington	Terminus	Sudbury Town	Outer Suburb
Kensington Olympia	Inner Suburb	Park Royal	Outer Suburb	Swiss Cottage	Inner Suburb
Kentish Town	Inner Suburb	Parsons Green	Inner Suburb	Temple	City
Kenton	Outer Suburb	Perivale	Outer Suburb	Theydon Bois	Outer Suburb
Kew Gardens	Outer Suburb	Piccadilly Circus	Tourist	Tooting Bec	Outer Suburb
Kilburn	Inner Suburb	Pimlico	Tourist	Tooting Broadway	Outer Suburb
Kilburn Park	Inner Suburb	Pinner	Outer Suburb	Tottenham Court Road	Shopping
Kings Cross / St Pancras	Terminus	Plaistow	Outer Suburb	Tottenham Hale	Outer Suburb
Kingsbury	Outer Suburb	Preston Road	Outer Suburb	Totteridge & Whetstone	Outer Suburb
Knightsbridge	Shopping	Putney Bridge	Inner Suburb	Tower Hill	Tourist
Ladbroke Grove	Inner Suburb	Queens Park	Inner Suburb	Tufnell Park	Inner Suburb
Lambeth North	Inner Suburb	Queensbury	Inner Suburb	Turnham Green	Inner Suburb
Lancaster Gate	Tourist	Queensway	Tourist	Turnpike Lane	Outer Suburb
Latimer Road	Inner Suburb	Ravenscourt Park	Inner Suburb	Upminster	Outer Suburb
Leicester Square	Tourist	Rayners Lane	Outer Suburb	Upminster Bridge	Outer Suburb
Leyton	Outer Suburb	Redbridge	Outer Suburb	Upney	Outer Suburb
Leytonstone	Outer Suburb	Regents Park	Tourist	Upton Park	Outer Suburb
Liverpool Street	City	Richmond	Outer Suburb	Uxbridge	Outer Suburb
London Bridge	City	Rickmansworth	Outer Suburb	Vauxhall	Inner Suburb
Loughton	Outer Suburb	Roding Valley	Outer Suburb	Victoria	Terminus
Maida Vale	Inner Suburb	Royal Oak	Inner Suburb	Walthamstow Central	Outer Suburb
Manor House	Inner Suburb	Ruislip	Outer Suburb	Wanstead	Outer Suburb
Mansion House	City	Ruislip Gardens	Outer Suburb	Warren Street	Shopping
Marble Arch	Shopping	Ruislip Manor	Outer Suburb	Warwick Avenue	Outer Suburb
Marylebone	Terminus	Russell Square	Tourist	Waterloo	Terminus
Mile End	Inner Suburb	Seven Sisters	Outer Suburb	Watford	Outer Suburb
Mill Hill East	Outer Suburb	Shepherds Bush (Central)	Inner Suburb	Wembley Central	Outer Suburb
Monument	City	Shepherds Bush (Ham&City)	Inner Suburb	Wembley Park	Outer Suburb
Moor Park	Outer Suburb	Sloane Square	Shopping	West Acton	Outer Suburb
Moorgate	City	Snaresbrook	Outer Suburb	West Brompton	Inner Suburb
Morden	Outer Suburb	South Ealing	Outer Suburb	West Finchley	Outer Suburb
Mornington Crescent	Inner Suburb	South Harrow	Outer Suburb	West Ham	Outer Suburb
Neasden	Outer Suburb	South Kensington	Tourist	West Hampstead	Inner Suburb
Newbury Park	Outer Suburb	South Kenton	Outer Suburb	West Harrow	Outer Suburb
North Acton	Inner Suburb	South Ruislip	Outer Suburb	West Kensington	Inner Suburb
North Ealing	Outer Suburb	South Wimbledon	Outer Suburb	West Ruislip	Outer Suburb
North Greenwich	Inner Suburb	South Woodford	Outer Suburb	Westbourne Park	Inner Suburb
North Harrow	Outer Suburb	Southfields	Outer Suburb	Westminster	Tourist
North Wembley	Outer Suburb	Southgate	Outer Suburb	White City	Inner Suburb
Northfields	Outer Suburb	Southwark	Inner Suburb	Whitechapel	Inner Suburb
Northolt	Outer Suburb	St James s Park	Tourist	Willesden Green	Inner Suburb
Northwick Park	Outer Suburb	St John s Wood	Inner Suburb	Willesden Junction	Outer Suburb
Northwood	Outer Suburb	St Pauls	City	Wimbledon	Outer Suburb
Northwood Hills	Outer Suburb	Stamford Brook	Inner Suburb	Wimbledon Park	Outer Suburb
Notting Hill Gate	Inner Suburb	Stanmore	Outer Suburb	Wood Green	Outer Suburb
Oakwood	Outer Suburb	Stepney Green	Inner Suburb	Woodford	Outer Suburb
Old Street	City	Stockwell	Inner Suburb	Woodside Park	Outer Suburb
Osterley	Outer Suburb	Stonebridge Park	Outer Suburb		
Oval	Inner Suburb	Stratford	Outer Suburb		

16. Notations and abbreviations

Legion layers	
ACL	Activity Object Layer
AOL	Analysis Object Layer
RL	Routing Layer

Standard Legion objects	
CDZ	Circular Drift Zone
DM	Direction modifier
DP	Delay point
DZ	Drift zone
EN	Entrance
ES	Escalator
EX	Exit
EZ	Evacuation zone
FDZ	Focal drift zone
FN	Focal node
LE	Level entrance
LX	Level exit
PZ	Populated zone
QG	Queue group
QU	Queue
ST	Stairs
WZ	Waiting zone

Legion model data structures	
AP	Arrival profile
AvP	Availability profile
AL	Analysis line
AN	Analysis
AZ	Analysis zone
DPf	Delay profile
EP	Event profile
EST	Entity supply type
ET	Entity type
RG	Route guide
XP	Exit profile

Standard Legion short forms	
ANA	Legion analysis file
AVI	Audio Video Interleave, format of video files generated by Legion
CAD	Computer Aided Drawing
CHD	Cumulative High Density (plot)
CM	Camera
CMD	Cumulative Mean Density (plot)
DF	Distribution focus
GJT	Generalised journey time
LGM	Legion model file
ORA	Legion model simulation file
RES	Legion simulation result file
SU	Space Utilisation (plot)

Special purpose Legion objects	
AC	Analysis for conditional functioning
AN CT	Analysis for flow count
AN GJT	Analysis for calculating social costs
AN JT	Analysis for measuring journey time
DC	Direction Modifier for conditional functioning

Rail & Underground specific	
BCDM	Business Case Development Manual
BAK	Bakerloo line
CEN	Central line
D&C	District and Circle lines
DIS	District line
ELL	East London line
H&C or HC	Hammersmith & City line
JUB	Jubilee line
LOS	Fruin's Level of Service
LU	London Underground
MET	Metropolitan line
NOR	Northern line
PIC	Piccadilly line
PRM	Person with Restricted Mobility
RODS	Rolling Origin & Destination Survey
SC	Social costs
SDM	Station Demand Modelling
SPSG	Station Planning Standards and Guidelines
TSM	Train Service Model
VIC	Victoria line
W&C or WC	Waterloo & City line
WTT	Working Timetable

Others	
AFM	Advanced Fare Machine
ATM	Cash machine or Automated Teller Machine
FFM	Few Fare Machine
GL	Gateline
GLAP	Gateline attendant's point
LT	Lift
MFM	Multi-Fare Machine
OD	Origin-Destination
PF	Platform
POM	Passenger Operated Machine
PTI	Platform-train interface
QBM	Queue Buster Machine
TH	Ticket hall
TIW	Ticket Issuing Window
TVM	Ticket Vending Machine (front loading)
WAG	Wide Aisle Gate

17. References

- LUL Station Planning Standard 1-371, issued June 2011 (including all appended Written Notices)
- LUL Station Planning Standards and Guidelines, issued May 2012
- Pedestrian Planning and Design, John J Fruin, 1971
- LUL Station Demand Modelling v1.1, issued June 2005
- TfL Business Case Development Manual, issued May 2014
- Legion Spaceworks 5.2 User Guide, 2014
- TfL Street level modelling with Legion—Best Practice Guide, issued 2008
- DfT Quality Assurance of Analytical Modelling, issued September 2014

18. Station model audit checklist

The audit checklist is provided as a guide to the TfL audit process. Models are expected follow the best practice as set out in this guide. Where reasonable alternatives have been agreed by Transport Modelling & Sponsors throughout the modelling process this should be clearly documented.

1. Accompanying Model Documentation	R / A / G	Comments
Assumption Cover Sheet Supplied		
Sources of data adequately documented		
Assumptions documented sufficiently		
Assumptions match model inputs		
Formatted appropriately for ease of use		
Date of site visit documented and on-site observations documented		
Legion Data Template Supplied		
Data template extracted from model matches LDT supplied		

2. Model Builder / LDT	R / A / G	Comments
Agreed model scope modelled		
Agreed model time period modelled		
Agreed Sensitivity % applied		
Model name follows BPG naming conventions		
Inputs		
Sufficient accurate existing station CAD input used in model		
Scheme CAD aligned well with existing CAD		
Appropriate rolling stock CAD for each scenario		
CAD layers as BPG and well labelled		
Realistic / agreed station operation (e.g. one way systems)		
Modelling objects follow BPG naming conventions		
Demand & Profiles		
Entity profiles set up as BPG, including PRMs as applicable.		
Supply Types set up as BPG for station type and movements		
OD Matrix specified clearly		
Colouring by Final Destination as per BPG		
Data profiles specified in appropriate time intervals (15 mins or less)		
Delay profiles specified in LDT for all infrastructure		
Origin Settings – Distribution to cars appropriate		
Origin Settings – TPH, minimum service interval and noise as BPG		
Origin Settings – availability profiles for boarding as BPG		
Unused data / profiles remaining in model (should not be)		
Station non-platform locations		
Street Entrances and exits modelled appropriately		
Ticket hall facilities modelled with BPG delay profiles		

Ticket hall facilities used by appropriate proportion of pax		
Gatelines configured with appropriate arrangement and delay profiles		
Station crowding control modelled as agreed (if applicable)		
Passageways modelled as BPG (entity behaviour realistic)		
Escalators and stairs modelled as BPG		
Lifts modelled as BPG		
'Decision' points appropriately represented		
Platform locations		
Waiting zones drawn with edge effect (500mm from Platform Edge)		
Boarding/alighting behaviour and timings as BPG		
Train capacity/left behind modelled appropriately (if applicable)		
Boarders board specific service at correct time (if applicable)		
Route assignment		
Reasonable/natural route assignment from origin to destination		
Reasonable use of Focal Nodes		
Reasonable use of Direction Modifiers		
Reasonable use of Drift Zones and Focal Drift Zones		

3. Simulations and Analyser Files	R / A / G	Comments
No major errors and warnings while exporting ORA		
Simulation successfully run using exported ORA		
Accessible space confined to public accessible areas		
No error messages generated in simulator		
No significant/prolonged blockages in model		
No unconventional (or irregular) entity movement within model		
Simulated OD matrix extracted and compared (including leftovers) to original demand – within 2%.		
Throughput of escalators and gatelines achieved as SPSG		
Analysis lines / zones and analyses set up appropriately		
Maps set up following BPG		
Social Costs generated using appropriate analyses and BCDM weightings		
Appropriate number of simulation files used in social cost reporting (3-5)		

4. Analysis and Reporting	R / A / G	Comments
CMD maps provided for time periods, and appropriate LOS as BPG		
CHD maps provided for time periods, and with appropriate cut off / accumulation settings as BPG		
Maps provided match reasonably the new simulated file		
Evidence / outputs of other analysis provided for checking		
Modelling Report Supplied		
Key assumptions appropriately discussed		
Appropriate results incorporated		
Discussion of results, limitations, mitigations etc. reasonable.		

Contact

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