Technical Note

Project:	**Milton Keynes Model Update**	Job No:	**60516496**
Subject:	**Public Transport Local Model Validation Report**		
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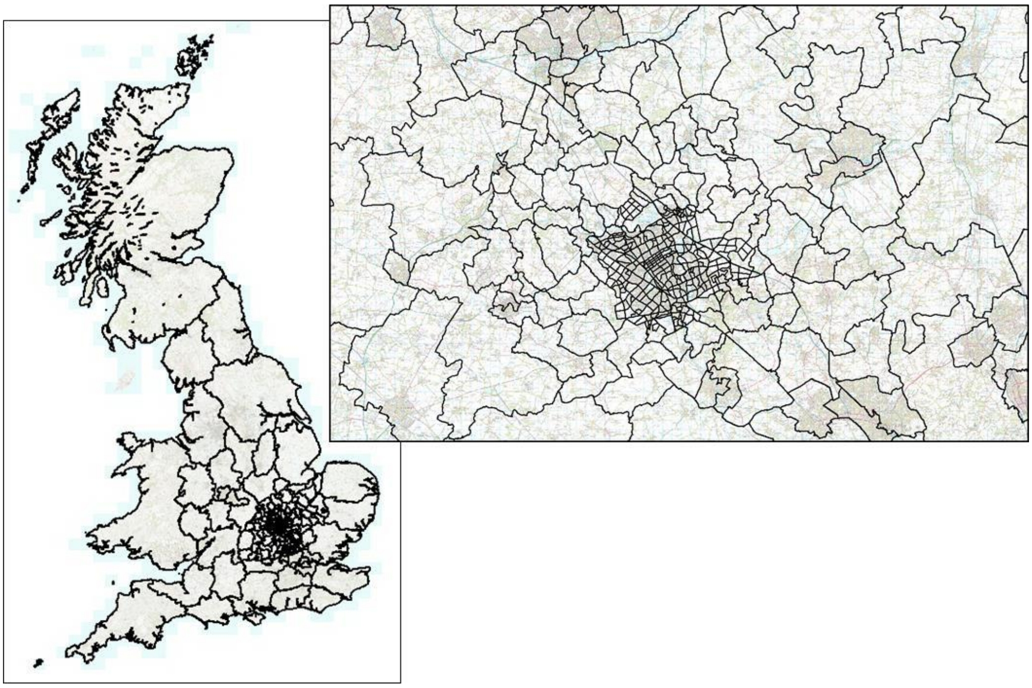
1. Introduction

1.1. The Milton Keynes Multi-Modal Model (MKMMM) public transport model has been developed in INRO's Emme software, and covers both bus and rail modes. It is designed to model public transport in and around the Milton Keynes urban area. Rail services and demand extend across the whole of Great Britain, but in decreasing detail outside of Milton Keynes. Bus services and demand cover only trips from, to and within Milton Keynes urban area.

1.2. MKMMM is a strategic model designed to forecast effects upon broad travel patterns and viability of corridors for investment. It is not a detailed operational model, and cannot produce results down to the level of individual bus stops, for example.

1.3. The public transport model uses the same zoning system as the highway and variable demand models. This zone system consists of a total of 513 model zones, with a decreasing level of detail outside Milton Keynes. This zone system is shown in Figure 1.

Figure 1: Overview of Model Zone System



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Modes of Travel

1.4. Table 1 below shows the transport modes represented within the MKMMM public transport model.

Table 1: Public Transport Modes in MKMMM

ID	Name	Type	Speed	Description
a	Auto	Auto	-	Car mode for traffic assignment. This is used only to enable turning data, with car travel is modelled in the highway assignment model.
b	Bus	Transit	-	Bus services derived from Traveline National Dataset (TNDS)
r	Rail	Transit	-	National rail services
w	Walk	Aux	5 kph	Walk used for access to bus and pure walk trips
e	External	Aux	22 kph	External connectors to railway stations at motorised speed

1.5. The access mode *e* does not represent the speed of a specific mode of travel, but has a speed calibrated to broadly reproduce traveller behaviour as well as possible. *e* is used outside Milton Keynes only, and represents access to external rail stations (by a combination of car, walk, and bus modes).

Time Periods

1.6. The public transport model represents an average hour within three periods during an average weekday in 2016. The three periods are the same as those represented within the highway assignment model; but in the AM Peak and PM Peak an average rather than peak hour is represented. The modelled time periods are therefore:

- an average AM period hour (07:00 to 10:00);
- an average Interpeak hour (10:00 to 16:00); and
- an average PM period hour (16:00 to 19:00).

2. Assignment Method

2.1. The MKMMM public transport model uses a frequency-based deterministic assignment method in which each desired destination is assigned a single optimal strategy. A strategy consists of a decision of what to do at every node in the model network, which may be to take an access / walk mode along a specific link, wait for the first service to arrive from a defined set of services calling at the node, or alight from a service.

2.2. The frequency-based nature of the model is suitable for strategic assessment in relatively high-frequency situations. This describes most local / urban bus services and rail services to / from London fairly well. Because actual timetables are not represented (only the average interval between buses / trains on a service) nor are passengers' desired departure times represented in detail below the 3 or 6 hour periods, this approach is not suitable for detailed operational or timetable planning, nor is it suitable for assessing very low frequency services where interchanges may occur.

2.3. Although rail and bus demand were developed separately (see Section 5), the demand for public transport was combined within the model and mode choices were made within the assignment process, via the *Extended Transit Assignment* module in Emme, which utilises strategies to implement mode and route choices.

2.4. Strategies enable travellers to choose from a set of attractive paths before embarking on a trip, and then lets the mode that arrives first at a stop determine which path (and mode) to take. The optimal strategy is the one which minimises the "generalised cost" of travel between an origin and destination node.

3. Generalised Cost Formulations and Parameter Values

3.1. The generalised cost is a combination of a traveller's travel time and fare. The definition of the generalised cost requires appropriate weights for different components of travel time. Values for these were derived initially from WebTAG and PDFH (Passenger Demand Forecasting Handbook) advice and other models, but many of them have been adjusted to improve the routeing behaviour in the model.

3.2. The final values in the model are shown in Table 2. The "value of time" is used to convert monetary elements, fares, into time equivalents.

Table 2: Public Transport Model Assignment Parameters, 2016 Base

Name	Value	Description
Fares	-	Set as functions of boardings and distance by vehicle type
Value of Time	12.318	Derived by model year from WebTAG advice (p/min, 2010 prices)
Walk speed	5 kph	Average walking speed.
Boarding, bus	7 min	Time penalty (mins) applied to each bus vehicle boarding
Boarding, rail	2 min	Time penalty (mins) applied to each rail vehicle boarding
Transfer weight	3.1	Weight applied to boarding penalties when transferring between services
Wait factor, w_t	5 min	Expected wait time below which travellers turn up at random
Wait factor, w_w	0.25	Factor applied to half-headway to derive wait time beyond the threshold

3.3. The function used to calculate wait time is as follows:

$$w(h) = \frac{h}{2} * \left(\frac{\min(\bar{h}, w_t) + w_w \min(\bar{h} - w_t, 0)}{\bar{h}} \right)$$

where w is the wait time in minutes, h is the headway in minutes for services the traveller might board, $\bar{h}$ is the average headway in minutes for a service calling at the stop, and w_t and w_w are parameters as described in Table 2.

3.4. Rail and bus fares are calculated as follows:

$$Fare, bus(pence) = 71.2 + 4.23 * Dist(km)$$

$$Fare, rail_{NonVirgin}(pence) = 180 + 20 * Dist(km)$$

$$Fare, rail_{Virgin}(pence) = 205 + 23 * Dist(km)$$

Different cost functions have been derived for Virgin train services and all other train services to represent the difference in fares between operators at Milton Keynes.

3.5. All fares are intended to represent average fares actually paid (including all discounts and concessions), rather than the advertised full single fare. Fare functions were derived from ticket sales data in both cases (see Section 5).

4. Relationship between Public Transport Model and Highway Assignment Model

4.1. Highway congestion is not modelled at a link level in the public transport assignment, which uses timetabled travel times. Should changes to bus travel times be anticipated within forecast scenarios, these changes in bus travel times should be coded into the services within the public transport model.

4.2. Bus vehicle flows have been transferred from the public transport model to the highway model to ensure their impact on congestion is fully represented in the base year. There is no direct link between the two models in forecasting; if a bus scheme is considered likely to affect highway congestion, this will need to be coded separately in the highway model.

5. Public Transport Demand Data

Bus Electronic Ticket Machine (ETM) Data

5.1. Electronic ticket machine (ETM) data have been collected from a bus operator (Arriva) in Milton Keynes, which covers around 53% of bus services that operate in the area. The ETM data was provided for the three months April to June 2016. The services for which data was available are summarised in Table 3Table 1.

5.2. Although there is some variation in the format of data provided, the bus operator has provided record-based data, containing one passenger boarding or other event per record. This covers the following:

- bus service number;
- bus journey departure time;
- boarding event time;
- ticket type;
- fare paid;
- boarding stage identifier; and
- alighting stage identifier (certain ticket types only).

5.3. The data in principle cover all passenger boardings, including concessions, use of return tickets, and use of smartcards and other passes, as well as actual ticket sales.

Table 3: Bus Electronic Ticket Machine Data

Service No.	Description
1	Newport Pagnell - Bletchley
2	Newport Pagnell - Westcroft
4	Wolverton - Bletchley
5	Wolverton - Lakes Estate
6	Wolverton - Lakes Estate
7	Wolverton - Bletchley
8	Oxley Park - Walnut Tree
9	Bletchley - Kingston
13	Bradville - CMK
14	Wolverton - Hospital
70	Luton - L.Buzzard - MK
150	Aylesbury - Milton Keynes
300	Magna Park - Station
F70	Luton - L.Buzzard - Milton Keynes
X60	Buckingham - Aylesbury

5.4. The operator provided boarding information at a fare stage level, with each fare stage often covering a group of bus stops in the same general area (such as "Milton Keynes Shopping Centre"). The number of trips associated with each fare stage was used to inform the suitable allocation of zones to stages. For example, where a stage has a high number of trips and is located close to a number of residential or shopping zones, then multiple zones were allocated to a single stage.

Rail LENNON Data

5.5. The rail demand matrices were developed using LENNON (Latest Earnings Nationally Networked Over-Night) rail ticket data obtained from the Association of Train Operating Companies (ATOC) for the whole country. The LENNON data were provided for the month of March 2016. This information is a complete representation of all rail tickets sold, and was therefore used as the starting point for the development of a rail matrix.

5.6. LENNON data contain tickets (including season tickets) sold by type, issuing station, origin station and destination station. They lack a considerable amount of information required to construct rail matrices, which had to be estimated, including:

- trip purpose;
- car availability;
- time periods of outgoing and return trips; and
- actual origin / destination as opposed to merely the origin and destination stations, which may be some distance from ultimate trip-ends.

Household Interview Data

5.7. As the primary data sources for public transport demand are largely ticket-based, they lack many travel attributes that are required for transport modelling, such as trip purposes. These missing elements have been added with the help of household interview data, from the

National Travel Survey (NTS), 2002-2014. NTS data has also been used in the validation of the processed demand data for rail and bus.

5.8. The NTS has large samples overall, with robust bias-correction and data validation.

Trip-End Model

5.9. A trip-end model is used in MKMMM to convert planning data (population, households and employment) at a zonal level into trips made by each mode of transport, by purpose and direction of travel. Our trip-end model is based on version 7.0 of the National Trip-End Model (NTEM), with the zoning altered to represent MKMMM zones inside and around Milton Keynes.

5.10. We have made extensive use of these trip-ends in developing public transport matrices. This is of particular value, as the trip-end model will be used to calculate forecast changes in demand over time, and it is highly desirable that these forecasts are reasonably consistent with the base year demand in the model.

6. Public Transport Calibration and Validation Data

6.1. No observed public transport counts were commissioned as part of this model development exercise. It has therefore been necessary to make the best use of the limited available count data collected for public transport travel in and around Milton Keynes.

Office of Rail and Road (ORR) Station Usage

6.2. The Office of Rail and Road (ORR) (formerly the Office of Rail Regulation) publishes annual statistics on usage of all stations in Great Britain[1]. These data are based primarily on LENNON ticket sales data, and have been used to validate and confirm our processing of the LENNON data.

Bus Passenger Flow Count Data

6.3. Two sets of boarding / alighting counts at bus stops at two different locations within the model area were available. Those locations are:

- Milton Keynes Central railway station – actual bus stops are shown in Figure 2 ; and
- Milton Keynes Shopping Centre (The Point) – actual survey locations are shown in Figure 3.

[1] http://orr.gov.uk/statistics/published-stats/station-usage-estimates

Figure 2: Location of Surveyed Bus Stops at Milton Keynes Central

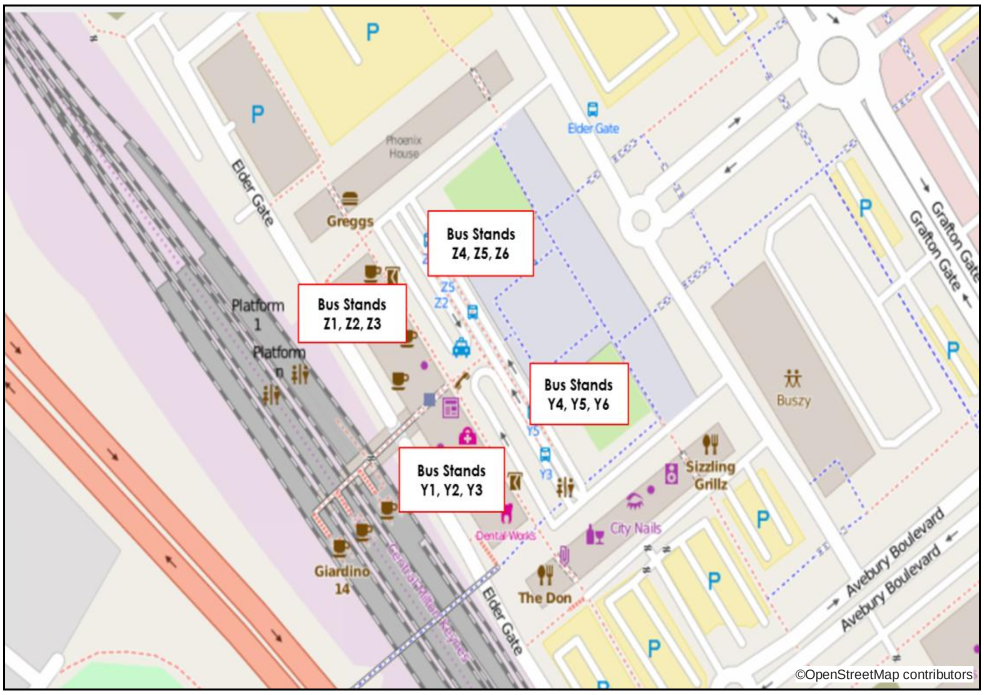
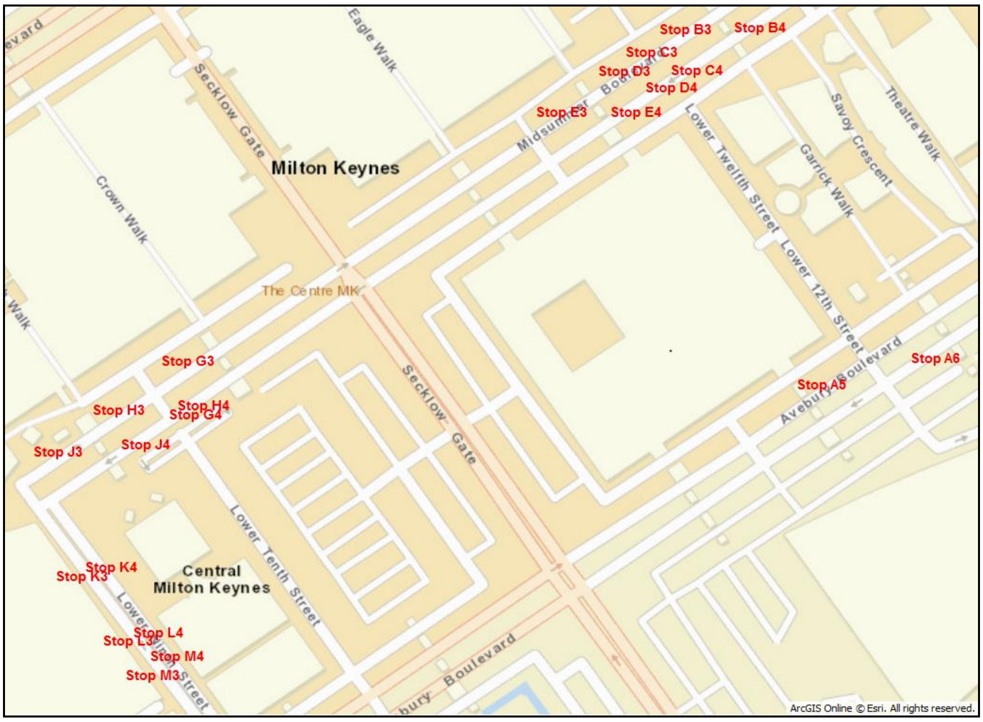


Figure 3: Location of Surveyed Bus Stops at Milton Keynes Shopping Centre



6.4. The count survey at Milton Keynes Central was carried out on a weekday in December 2015, while that at The Point were carried out on two weekdays in September 2016. The survey at The Point was limited in scope, and was undertaken for the purposes of another project and not specifically commissioned for this model development. Analysis of the survey data suggests that the survey did not record the number of boarding / alighting passengers for every service which called at The Point, but recorded the number of boarders and alighters for a sample of bus services.

6.5. In order to make the surveyed number of boarders and alighters at The Point representative of all bus services calling at this set of bus stops, the observed values were adjusted using the proportion of bus services recorded as part of the survey by modelled time period.

6.6. It is understandable that observed count values derived using this approach will be subject to significant error, but we believe this approach to be a valid use of the limited data available. The derived values are shown in Table 4. Note that hourly counts are multiplied by 3, 6, and 3 (i.e. the number of hours in each time period), respectively, in order to obtain count estimates for each time period.

Table 4: Adjustments made to Count Values at The Point

		AM	IP	PM
Passengers per hour	**Boarders**	45	61	70
	Alighters	53	72	53
No. of buses per hour	**Observed**	19	24	17
	Modelled	73	39	65
	Adj. Factor	3.89	1.60	3.93
Passengers per period	**Boarders**	528	590	823
	Alighters	621	687	628

7. Public Transport Matrix Development

7.1. Public transport travel demand has been generated for an average weekday in a neutral week (a week without bank holidays) in Spring 2016. Demand includes both bus and rail travel. Taxi travel is not included in the MKMMM public transport model, nor is travel by air.

7.2. Demand represents travel on scheduled public bus services and national rail. It does not include all education travel on dedicated school buses (though some buses that primarily serve schoolchildren were included in the ETM data), travel on non-scheduled coaches or travel on heritage railway lines.

7.3. Origin-destination (OD) matrices, which represent person trips made between MKMMM geographic zones, have been generated. Each matrix contains an estimate of numbers of trips between every pair of zones, except external-external bus trips, which have not been estimated. Rail external-external trips are included.

7.4. Matrices have been segmented in several ways: by time period, by purpose and direction of travel, by rail / bus, and car-availability of traveller. Each valid combination of these dimensions has resulted in a separate matrix.

7.5. The demand matrices have been developed as trip matrices (stored in OD format) for home-based purposes and non-home-based purposes. The model does not consider tours of linked trips (from home to work and from work to home) or chaining of successive trips across different modes or routes / services.

7.6. Demand matrices have been constructed for the four time periods:

- AM Peak Period: 07:00 to 10:00;
- Interpeak Period: 10:00 to 16:00;

- PM Peak Period: 16:00 to 19:00; and
- Off-Peak Period: 19:00 to 07:00.

7.7. In addition, the demand matrices have been developed for the journey purposes shown in Table 5.

Table 5: Public Transport Purposes of Travel

Representation	Purpose
Home-Based Trips	Commuting
	Employer's Business
	Other
Non-Home-Based Trips	Employer's Business
	Other

Rail Demand

7.8. Estimates of total trips made per ticket issued, by ticket type, were required to create the rail matrices from LENNON data.

7.9. LENNON data contain tickets sold by type, issuing station, origin station and destination station. They lack a considerable amount of information required to construct rail matrices, which were estimated, including:

- trip purpose;
- car availability;
- time periods of outgoing and return trips; and
- actual origin / destination as opposed to merely the origin and destination stations, which may be some distance from ultimate trip-ends.

7.10. With regard to the last point, this is more an issue when developing demand internal to Milton Keynes. It is considerably less of a problem for external demand, partly because accurate representation of external demand is less crucial, but principally, as zones are much larger in the external area, it can be reasonably assumed that the vast majority of travellers' ultimate trip-ends are contained within the same zone as the corresponding station.

7.11. It has been assumed that the LENNON trip-ends represent the actual trip-ends of the trips at most stations outside Milton Keynes.

7.12. Generation of ultimate trip-ends (as opposed to station trip-ends) was performed by a combination of estimating access / egress distance distributions by trip-length of actual rail journey, and by considering proportional levels of total rail demand originating in and destined for each modelled zone.

7.13. Estimates of total trips made per ticket issued, by ticket type, were required to create the rail matrices from the LENNON data. Each ticket type has been classified into either a single trip or a tour, and the number of trips that an average customer makes on the ticket was estimated. Most of these estimates were acquired from databases that are already at AECOM's disposal but some had to be estimated logically. Table 6 shows the number of trips that were assigned to the most frequent ticket types in the LENNON dataset in Milton Keynes. The ticket types in this table account for 92% of ticket sales within the model area.

Table 6: Sales from LENNON by Ticket Type

Ticket Name, LENNON Database	Tickets Sold (Milton Keynes)	Trip/Tour?	Implied Trips/Tours
STANDARD DY RTN 2BAF	265,061	Tour	1
CHEAP DY RTN HI 2BDY	239,825	Tour	1
STANDARD SINGLE 2AAA	105,860	Trip	1
PAYG OPK RAIL UNCP 2OCI	85,729	Trip	1
PROMOTION 9ZWM	75,818	Trip	0
PAYG PK TT UNCP 2OCH	73,277	Trip	1
PAYG PK RAIL UNCP 2OEH	63,497	Trip	1
PAYG OPK TT UNCP 2OCJ	44,311	Trip	1
7 DAY SEASON 2MQA	34,422	Tour	5
STD CHEAP SNGL 2ADA	21,928	Trip	1
CARNET PEAK 5 2ATA	16,807	Trip	5
AI SEAT RESVTNS 2ZYM	15,700	Trip	0
PAYG PK MIXJNY TT UNCP 2OCL	13,971	Trip	1
SEASONS VB 1 2MTA	11,930	Tour	20

7.14. The distance distribution of access and egress trips was extracted from the National Rail Travel Survey (NRTS), 2005. This is an old source, but other data sources (the National Travel Survey) did not appear to contain reliable information on access distances due to reporting biases and omissions.

7.15. In addition to a distance-distribution, weightings were also required to reflect levels of rail travel to / from each model zone. These were derived from the MKMMM trip-end model and were thus based on local planning data.

7.16. The zone weights and distance distributions were used to create a function to allocate demand by access / egress zone, of the form:

$$D_{ijab} = D_{ab} k_{ab} P_i A_j d_{ia}^{\,l_{l1}-1} e^{\eta_1 d_{ia}} d_{bj}^{\,l_{l2}-1} e^{\eta_2 d_{bj}}$$

where

- i is the production zone;
- j is the attraction zone;
- a is the production station zone (from LENNON data);
- b is the attraction station zone (from LENNON data);
- D_{ab} is the demand (from LENNON data);
- P_i and A_j are the production and attraction factors, from the trip-end model;
- d_{ia} and d_{bj} are the distance from origin zone i to origin station a, and from destination station b to destination zone j. These are crow-fly distances.
- l_{l1} and η_1 are calibrated parameters for access, by trip-length band l (from a to b);

- λ_{l2} and μ_{l2} are calibrated parameters for egress, by trip-length band l (from a to b); and
- k_{ab} is a factor to control total demand from a to b to the total in the LENNON matrix.

7.17. The λ and μ parameters were calibrated using Excel's "Solver" function to maximise the fit of the output data to the distance distributions observed in the NRTS data.

7.18. Demand was then aggregated over ultimate production and attraction zones i and j. The final demand matrices were not stored by station production and attraction, so that:

$$D_{ij} = \sum_{ab} D_{ijab}$$

7.19. Station origin and destination zones (i and j) were considered for a given set of modelled zones (a and b) only if they fell into a defined "catchment area" for each station. In the case of stations within and around Milton Keynes, the catchment area for each station was defined as a set of zones surrounding each station. In total, catchment areas were defined for 13 national rail stations in and around Milton Keynes.

7.20. The LENNON data do not contain any indication of travel purpose or of time of day. It is possible that time of day information can in principle be obtained, but in any case this would be based on the purchase time of the ticket, which in the case of return and season tickets would not identify the time of travel.

7.21. These characteristics have therefore been inferred using the trip-end model. The household interview data (NTS) do not contain enough geographic detail to enable reliable purpose / period splits to be obtained across the modelled area. However, overall purpose splits have been compared with the NTS proportions to validate the approach.

Bus Observed Demand

7.22. The first task in processing Electronic Ticket Machine (ETM) data was the allocation of the stages provided by operators (usually related to fares) to MKMMM zones. Stage information is generally in the form of a numeric ID, and a corresponding text description, for example, "1 – Newport Pagnell - Bletchley". Where provided, the alighting stage has also been used to ensure that all possible stages have been allocated.

7.23. This allocation was carried out by service, using GIS software. Bus service route maps and timetables were used to map service routes into GIS, along with a base street map and the MKMMM zone system. Boarding stage numbers and descriptions were used to identify the order and general location of each stage on the route. The MKMMM zone layer was used to allocate zones to stages.

7.24. These were chosen on the assumption that travellers will generally not walk much more than 250m to a bus stop, that they will choose the closest bus stop on the service in question, and will choose the most convenient bus corridor where there is a choice. More zones were required for urban centres where zones are smaller. The number of trips associated with each stage has been used to inform the selection of multiple zones in more populous areas, such as residential or shopping zones.

7.25. Although most of the ETM data contain alighting stage information, these data are accurate only for certain kinds of ticket; generally singles and returns. For concessionary fares, multi-day tickets, season tickets and other passes, these data were generally either missing or coded arbitrarily (either to the same point as the boarding or to the last calling point of the service). Around 25% of passengers detailed in the ETM data have associated alighting information that we believe to be correct.

7.26. As a result, it was necessary to estimate alighting points where these data were not available. Analysis has also been undertaken to identify incorrect alighting points. The assumption has been made that for all trips whose boarding and alighting points are the same the alighting stage is incorrect. This will not be true for all trips, but there should be relatively few trips short enough to remain within a single stage for their entire journey.

7.27. In order to estimate alighting points, those ETM entries with accurate alighting points were used as a basis for distribution of trips within the same service, for the same boarding point and time of day. Accurate alighting points were available for single and return tickets. This has been carried out at a stage level.

7.28. The ETM alighting points are likely to be biased towards journey patterns for less frequent travel (which are more likely to use singles and returns). It is considered that this is not a major inaccuracy.

7.29. A number of spot checks by service were carried out to check the plausibility of OD matrices after alighting points had been estimated. The matrices by stop-to-stop movement were extracted for around 10 services selected at random. Checks were made to inspect the patterns of travel to ensure broad tidality and symmetry across the day, and that the key boarding points appeared plausible.

7.30. Zone-based matrices were created by distributing each ETM record among the zones allocated to the boarding and alighting stages, using the MKMMM trip-end model forecasts as weights. Given the relatively short distances involved, it was not deemed necessary to construct a full gravity model to take account of the relative distances to the bus stops from model zones.

7.31. Records not referring to passenger boardings were ignored as part of this process. These include bus start times, fare stage changes, incidents and refunds; not all operators use each or any of these. Records referring to a cancellation of a ticket issued in error were considered as negative trips, as these should cancel out an earlier (mis-sold) ticket within the dataset.

7.32. Data were aggregated by origin to destination movement following this process. Checks were undertaken on the output demand matrices by studying demand desired lines from the matrices in Emme modelling software. This allows confidence that ODs reflected a pattern of travel that would be expected when considering the service routes.

7.33. The above process used an implicit assumption that a bus boarding and a bus / public transport trip are the same thing. Multi-leg trips, either using more than one bus service or using both bus and rail, are not explicitly considered. A small proportion of multi-leg trips will have been correctly captured, because some of the ticket data includes through tickets that involve interchanging onto another bus, but this occurs only where the journey can be made using a single ticket and the same operator runs both services.

7.34. National Travel Survey (NTS) data suggest that approximately 9% of bus trips in the East of England involve more than one bus boarding. This is sufficiently low that it is not expected that any significant forecasting or demand interaction issues will arise through treating each bus journey as a separate trip, as the above matrix-development process has done.

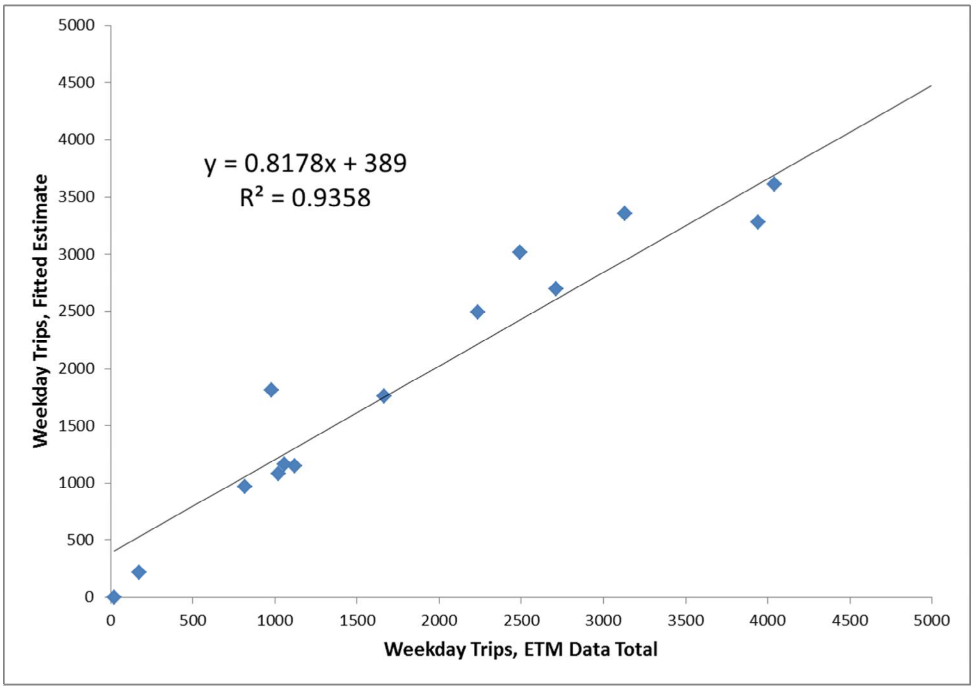
Bus Synthetic Demand

7.35. With the ETM data being provided for approximately 59% of services within Milton Keynes, albeit for most of the services in the central focus area of the model, it was necessary to develop synthetic demand matrices to account for the remaining bus trips.

7.36. All Milton Keynes bus services were identified from the Traveline National Dataset (TNDS). These were compared against the services for which data had been provided to establish for which services data were missing. Demand for these services has been synthesised based on those services with observed ETM data and the relationship between observed trips and service frequency being used to control the total number of trips in the synthetic matrix.

7.37. The daily frequencies of all services, and the length of the bus route, were extracted from the Traveline National Dataset (TNDS) and for those services with ETM data, the number of passenger trips on an average modelled weekday was fitted as a function of the frequency and length of the route. Figure 4 shows the fitted estimates of total trips against the actual ETM data trips for those services for which ETM data are available.

Figure 4: Fit of Estimated Function - Synthetic Bus



7.38. The function used is shown below:

$$T = 0.4149F^{1.25}L^{1.006}$$

where:

- T is the number of trips on the service in an average weekday;
- F is the total of bus journeys made per day by the service; and
- L is the route length of the service in kilometres.

7.39. The total population of zones within the bus route catchment area was also considered for informing the estimated function, but this was not used, as the comparison showed a weaker correlation.

7.40. In addition to the parameters derived from the length versus trip relationship, it was necessary to calculate a trip-length distribution for services with ETM data. The trip-length distribution was calculated at 1.5km bands up to 30km using the observed data for Arriva services across all time periods.

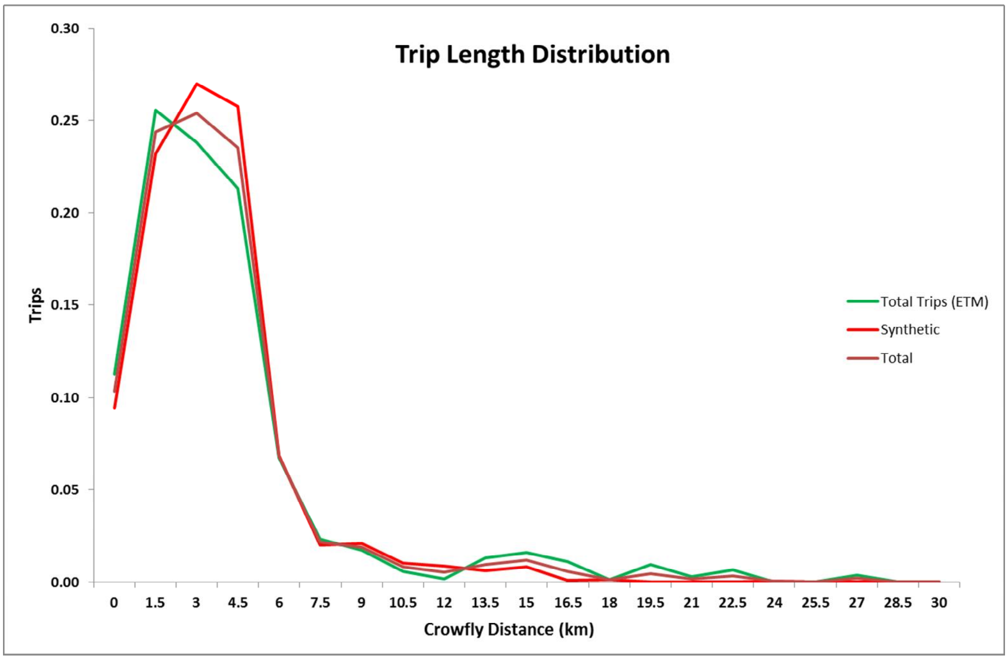
7.41. The expression for the fitted curve of the trip-length distribution was used as the basis of the alpha (α) and beta (β) parameters of the following equation, which was used to influence the distribution of trips within the synthetic matrix:

$$ABe^{-aD}D^{b}$$

where A and B are land-use weights of MKMMM zones, taken from the MKMMM trip-end model (estimates of zonal origin and destination trips) and D is the crow fly distance in kilometres between zones.

7.42. After a number of iterations, the trip-length distribution (alpha and beta parameters) of the synthetic matrices was calibrated to correspond with that of the observed ETM demand matrices, as shown in Figure 5.

Figure 5: Synthetic Trip-Length Distribution



7.43. Synthetic trips have a lower proportion of short distance trips and there is also a peak between 3 and 6 km, which does not match the ETM data. A large proportion of bus services with synthetic demand run just outside Milton Keynes (located between 3 and 6km from the centre of the model area), and this explains the discrepancy.

7.44. The final synthetic matrices were then combined with the observed demand matrices to create total OD demand matrices for each time period.

Bus Demand Disaggregation

7.45. Following the above process, trip-based zonal matrices were split by travel purpose and direction in addition to time period. The direction of travel refers to whether the trip is from-home, to-home, or non-home based.

7.46. This was achieved by taking land-use weights according to these directions / purposes for each zone from the MKMMM trip-end model. Proportions for each were then applied over the total demand matrices. The proportions used for purpose splits are shown in Table 7 along with the outturn purpose splits in the model bus demand matrices.

Table 7: Purpose Proportions, Bus Demand, Milton Keynes

Purpose	MKMMM Trip-end Model	MKMMM Bus Matrices
HB Commuting	17%	19%
HB Employers' Business	1%	2%
HB Other	74%	74%
NHB Employers' Business	0%	1%
NHB Other	8%	5%

Note: Values rounded to the nearest percentage

8. Public Transport Matrix Validation

Purpose Splits

8.1. For bus, a series of checks were undertaken to ensure that purposes derived from the MKMMM trip-end model were in line with local and regional statistics from other sources. This involved extracting bus trip purpose data from the NTS and NTEM and comparing proportions with that of the model, and is shown in Table 8.

Table 8: Validation of Purpose Splits, Bus

Purpose	MKMMM Bus Matrices	NTS (Milton Keynes)	NTEM (Milton Keynes)
HB Commuting	19%	32%	18%
HB Employers' Business	2%	0%	1%
HB Other	73%	65%	72%
NHB Employers' Business	1%	0%	0%
NHB Other	5%	3%	8%

8.2. MKMMM agrees fairly well with the NTEM data for Milton Keynes, and shows a similar purpose split as NTS data but there are larger differences than when comparing with NTEM. In terms of the comparison with NTS, within the model we have notably less commuting demand and more home-based other bus demand in MKMMM than NTS. This may partly be genuine as commuting demand in Milton Keynes is quite heavily dominated by rail.

8.3. NTS is generally a very reliable source, but since the NTS factors were derived only for Milton Keynes Borough, the sample sizes may not be large enough to give confidence in the derived factors.

8.4. For rail, MKMMM agrees fairly well with NTS for the Milton Keynes Borough, and slightly less well with the purpose splits from the trip-end model, as shown in Table 9. Again the sample sizes in for NTS does introduce some uncertainty in the proportions derived from NTS.

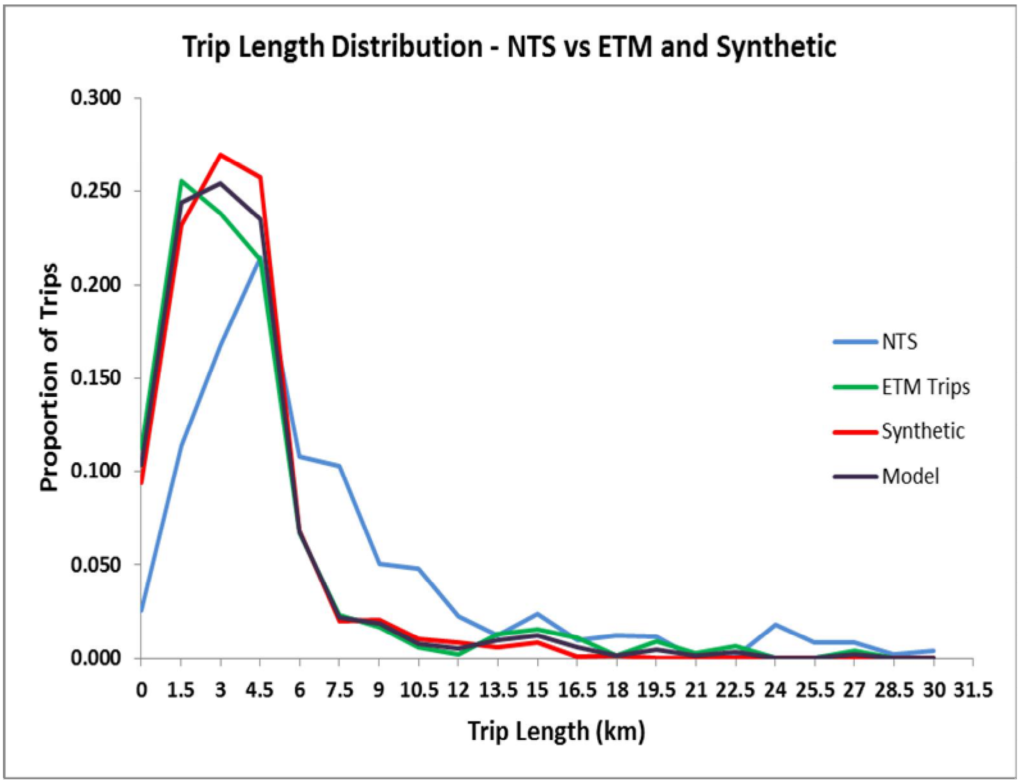
Table 9: Validation of Purpose Splits, Rail

Purpose	MKMMM Rail Matrix	NTS (Milton Keynes)	NTEM (Milton Keynes)
HB Commuting	56%	66%	38%
HB Employers' Business	12%	8%	6%
HB Other	15%	17%	41%
NHB Employers' Business	3%	7%	3%
NHB Other	14%	3%	11%

Trip-Length Distributions

8.5. Trip-length distributions were derived for bus trips from both the NTS and compared against the trip-length distribution of the MKMMM demand matrices, shown in Figure 6. This was carried out in order to verify the quality of the total demand matrix.

Figure 6: Bus Trip-Length Distributions, Validation



8.6. The overall shape of the modelled trip-length distribution largely corresponds with that derived from the NTS. There is a higher proportion of short distance trips in the model than in NTS, as well fewer long distance trips. This could partly be explained by the fact that trip chaining has not been considered when developing the demand matrices, so a small number of journeys which changed mode or route have not been picked up as a single trip. This should not have an impact on overall demand.

8.7. The difference between the actual observed demand and the synthetic demand can be explained by the fact that a greater number of the services from the operators which did not provide ETM data, which generally service to areas just outside of the Milton Keynes urban area.

8.8. The model trip-length distribution for rail is heavily dominated by the distance between Milton Keynes and London (which represents the substantial majority of rail demand in the area). It is therefore difficult to compare this meaningfully with any other source of trip-length data for rail.

Rail Demand Data Processing

8.9. The rail demand matrices were developed from LENNON ticket sales data through AECOM's own established process. It is desirable to check this by comparing the results with the official ORR station usage statistics, also derived largely from LENNON.

8.10. Unfortunately, the ORR data provide only annual station usage. Factors were derived from the NTS to estimate average weekday patronage from annual, and the conversion factor applied to all stations. This introduces some uncertainty, as some stations may have slightly different weekly and annual profiles from others.

8.11. The stations within Milton Keynes, and those in the immediate vicinity of the model area, have services running 7 days a week, but along the Bedford to Bletchley line there are no Sunday services. Therefore, the variability in those small stations will be more than the observed in the largest stations of the model.

8.12. The validation in general terms is very good, with the two sources agreeing within 1% in terms of overall station usage. In terms of the WebTAG criteria for flow validation within a public transport model, we are seeking differences between modelled and observed flows of less than 25%. The exception to this is where passenger flows are less than 150 per hour, in which case WebTAG suggests that the 25% criterion is not applicable.

8.13. All stations compare well between the processed matrices and the ORR data, with only four stations failing the WebTAG criterion of 25%. Three of these have low observed flows, and therefore the 25% threshold is not applicable, with the remaining station being Berkhamstead which is outside of the model area. These results are shown in Table 10. Note that there two rail stations are within the same MKMMM zone, these stations are combined within this analysis, such as Lidlington and Millbrook.

Table 10: Validation of Rail Demand Data Processing

Station	MKMMM Matrix	ORR Daily	Difference
Milton Keynes Central	10,159	10,352	2%
Wolverton	626	646	3%
Bletchley	1,516	1,610	6%
Fenny Stratford	41	42	3%
Bow Brickhill	47	65	39%
Woburn Sands	60	68	12%
Aspley Guise	9	14	55%
Ridgmont	52	56	7%
Lidlington Millbrook	48	63	33%
Stewartby Kempston Hardwick	71	70	-2%
Bedford St Johns Bedford Midland	5,913	5,801	-2%
Northampton	4,167	4,597	10%
Leighton Buzzard	2,739	2,709	-1%
Cheddington	107	118	10%
Tring	1,224	1,278	4%
Berkhamstead	3,519	2,634	-25%
Hemel Hempstead	3,032	3,000	-1%
King's Langley	1,164	1,107	-5%

8.14. It is perhaps worth acknowledging here that the use of LENNON as a source implies that ticketless (i.e. illegal) passengers on rail will not be included in the matrices. The ORR data also explicitly exclude ticketless travel for the same reason. This is not likely to be a significant issue at major stations in Milton Keynes, as ticket gates are in operation during the day. However, some smaller stations do not have ticket gates. It is quite likely that total passengers are understated by the ORR data and the model at these stations.

Trip Rates

8.15. Although bus data processing has not been validated in the same way as the rail, the matrix totals have been compared with plausible trip rates and knowledge of the population of Milton Keynes. Trip rates have been taken from the NTS and applied to the population of Milton Keynes, and compared to the base model results. Two sets of NTS trip rates were considered: (i) trip rates for the East of England; and (ii) trip rates for the Milton Keynes Borough.

8.16. Note that although NTS (and the trip-end model, which indirectly uses NTS data) was used for a number of purposes in building both the bus and rail matrices, it was only ever used to disaggregate demand, never to inform an overall total. This is consequently a genuinely independent validation.

Table 11: Bus Trip Rates Validation, Trips per person, on an average weekday

Source	Trip Rate
MKMMM	0.152
NTS, Milton Keynes	0.161
NTS, East England	0.100

Table 12: Rail Trip Rates Validation, Trips per person, on an average weekday

Source	Trip Rate
MKMMM	0.049
NTS, Milton Keynes	0.061
NTS, East England	0.042

8.17. For bus travel, the match is poor when comparing the model with the NTS trip rates for the whole East of England, but is considerably better against the NTS data for the Milton Keynes Borough.

8.18. For rail travel, there is again a relatively close match between modelled trip rates and those derived from NTS data for Milton Keynes Borough, and a closer match between the modelled trip rates and those from NTS for the East of England.

9. Public Transport Network Development

Base Bus and Rail Network

9.1. The network used by the MKMMM public transport model consists of roads, railway lines and pedestrian access routes, as well as “centroid connectors”, used to allocate model zones to suitable loading points on the road network.

9.2. The road network in the public transport model has been taken directly from the MKMMM highway model, converted from SATURN to Emme format using an automated process.

9.3. To this has been added railway track, which has been coded manually with reference to GIS maps of UK railway lines. All lines within Milton Keynes have been coded in detail. With increasing distance outside the model area, fewer lines have been coded. In general the major station in each zone is represented, and sufficient railway track to correctly link up all coded stations has been added. In a few zones more than one station is represented if there are significant junction stations in the zone. For example, branch lines outside Milton Keynes are generally not coded, railway lines in Scotland north of Edinburgh are not coded at all, nor the Underground layout in central London.

9.4. Walk links connecting railway stations to the road network have been added to this, and centroid connectors have been manually coded, one per zone, connecting each model zone to a suitable point on the road network representing the land-use access within the zone.

9.5. Figure 7 and Figure 8 below illustrate the extent of the rail and road networks in and around Milton Keynes.

Figure 7: Rail Network in and around Milton Keynes

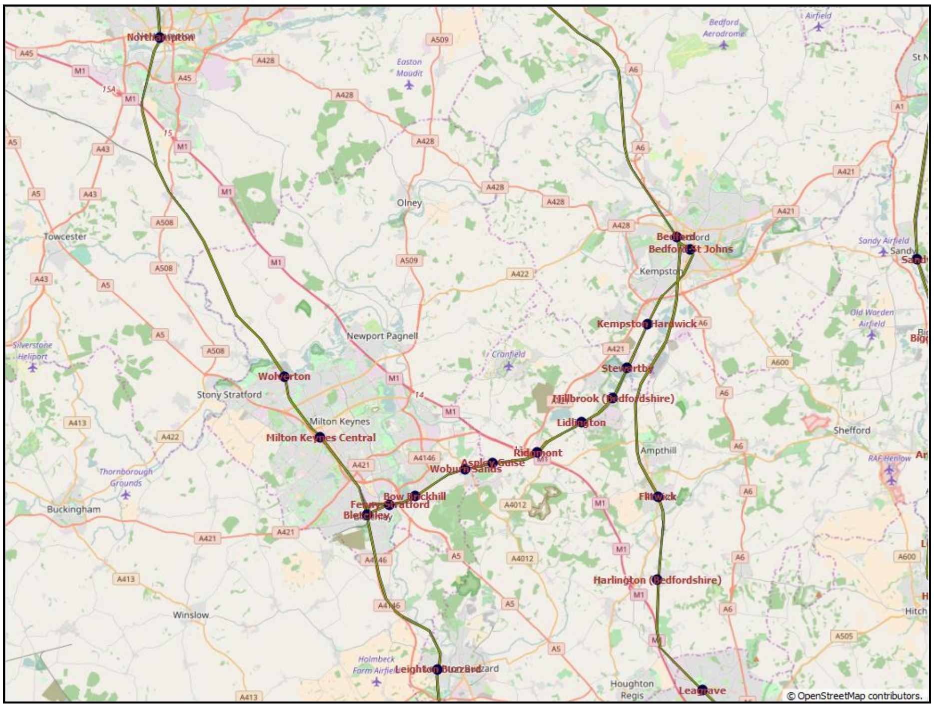
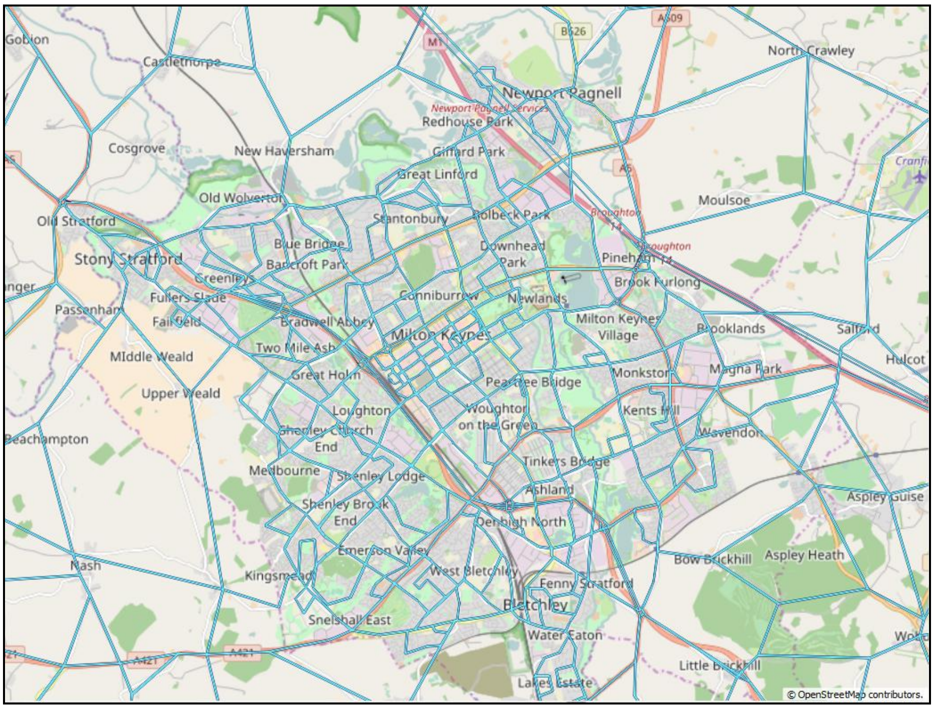


Figure 8: Road Network in and around Milton Keynes



9.6. Table 13 summarises the public transport link types. The auto (car) mode is allowed on link type 10 to enable Emme's representation of turning attributes on such links.

Table 13: Public Transport Model Link Types

Link Type	Allowed Modes	Description	Number in Network
1	r	Railway track	792
10	abw	Highway buffer links, converted from SATURN	5,556
22	wy	Reverse-direction walk-only links for one-way roads	224
23	w	Walk links, connecting highway to rail	228
101	w	Walk links connecting internal model zones to the highway network	952
102	we	External walk links connecting external model zones to the highway network	88

9.7. Nodes in Emme have no "type" as such. Table 14 below summarises the numbering convention adopted for nodes within the public transport model.

Table 14: Public Transport Model Nodes

Range	Description	Number in Network
1-9999	Zone centroids	513
10000-99999	Rail nodes, forming stations or junctions in railway track.	310
100000-999999	Highway nodes, forming part of road network converted from SATURN	2,061

9.8. All of the rail network is "shaped" within the model area. That is to say, each model link connecting two nodes follows the actual curve of the railway line in reality. This can be seen clearly in Figure 7. This shaping has no effect on the model results, but is useful for analysis, plotting and reporting.

Bus Routes

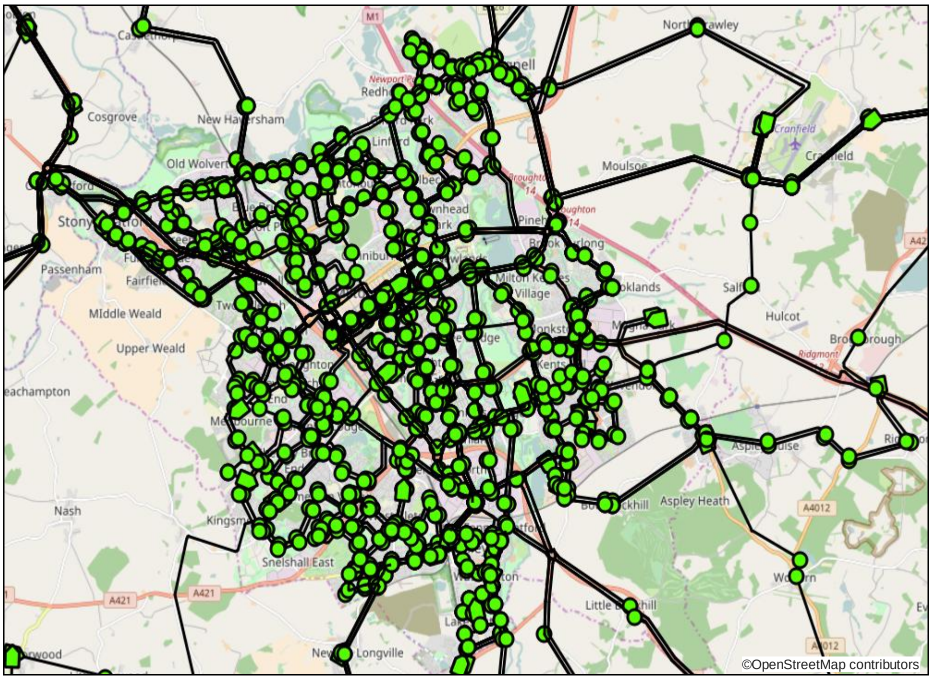
9.9. The base network is only part of the specification of the public transport system. In addition to this, public transport passenger services need to be coded to allow the model to represent the routeing behaviour of passengers.

9.10. Bus and rail services have been coded from different sources. Most of the input data are in the TransXChange format – an xml-based format for sharing public transport service pattern information. These include service timetables in full detail, with all stops and stopping times throughout the year, including differences between weekdays, Saturdays, Sundays and bank holidays.

9.11. Bus data have been taken from the Traveline National Dataset (TNDS). This is updated weekly with information on all bus, tram, light rail and ferry services in Britain. It does not cover rail, coach or underground.

9.12. An example of the bus service coding, in and around Milton Keynes, is illustrated in Figure 9 Green circles indicate stops, while green arrows are service start and end points. Each service is illustrated by a single black line, following its route.

Figure 9: Bus Services in Milton Keynes



Rail Services

9.13. Rail services within Milton Keynes have been coded manually with reference to online timetables.

9.14. Rail services outside of Milton Keynes were not coded in full detail as this would have generated excessively detailed services. Instead, line frequencies were manually coded in a simpler way to ensure broadly correct routes and frequencies, without including detailed representation of stopping patterns.

Centroid Connectors

9.15. Centroid connectors have been manually coded, one per zone, connecting each model zone to a suitable node on the road network representing the land-use access within the zone. An example of these is illustrated in Figure 10 where centroid connectors are shown in blue.

Figure 10: Centroid Connectors in Milton Keynes

Fares

9.16. Public transport fare systems, especially on the national rail network, are complex, with fares varying by time of day, movement, person characteristics, degree of ticket flexibility required, and more. It is neither possible nor desirable to model all of these details, and so the fares used in the MKMMM model are estimates.

9.17. We have, as discussed in Section 3, chosen to model fare functions whereby the fare paid is a function of distance, with longer trips paying more. The intent has been to model an average fare actually paid, including the effect of discounts and concessions.

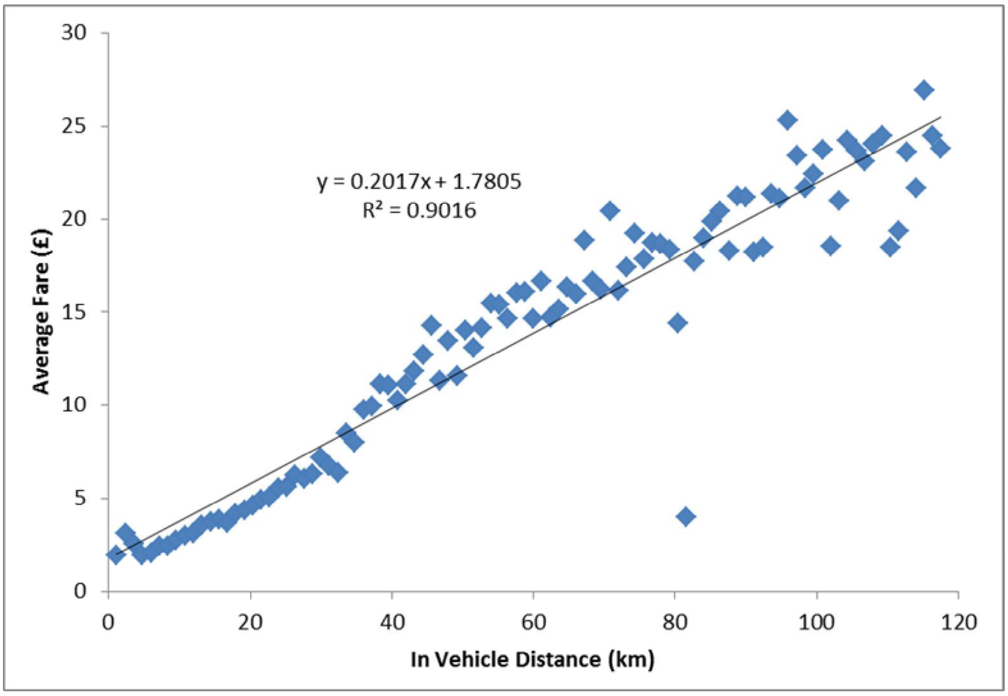
9.18. The preferred source for deriving such functions is complete ticket sales data with associated fares paid. For rail travel this has been used as LENNON does contain revenue data.

9.19. For bus, fare data was received from Arriva and used in a similar way. We have not plotted the raw bus fares data to protect the operators' commercial confidentiality, but the fitted function is quoted in Section 3.

9.20. The rail data used and the function fitted to the data are illustrated in Figure 11. Rail trips originating in Milton Keynes have been extracted from the LENNON data, and the fare recorded in LENNON compared against actual in-vehicle distances calculated using the model. These are plotted, along with the function (black line) fitted to the data and used in the model. This analysis ensures that the rail fares are appropriate for Milton Keynes specifically.

9.21. Fares have been converted to 2010 prices for consistency with the rest of the modelling.

Figure 11: Rail Fare Data and Fitted Function, 2010 prices



9.22. In order to improve the routeing for demand between Milton Keynes and London, Virgin services have been modelled with a higher fare function. It is not possible within the LENNON data to isolate tickets for individual operators, and so the uplift factor has been derived based on an online search of ticket prices.

10. Public Transport Network Validation

Service Pattern Validation

10.1. The automated process for converting TransXChange data to model format, discussed in Section 5, has been used in a number of models and is considered quite robust. However, it does have some weaknesses. One issue relates to allocating bus stops correctly to model network nodes; the process is over 99% accurate here, but a small proportion of bus stops had to be manually corrected. In addition, the TNDS data are not a 100% accurate representation of bus services, though they are in general very good representation.

10.2. Consequently, the service coding was thoroughly checked. This involved checking the following for all services:

- There were no strategically odd routes; in particular services travelling long loops around motorways or major roads. This generally indicates a severe misallocation of a bus stop to the model network.
- There were no highly implausible speeds (either too low or too high) on any service. All bus service speeds average between 10 kph and 55 kph (note that this includes time for stopping and picking up / setting down passengers), and all rail service speeds between 35 kph and 165 kph.
- There were no implausible service frequencies. All services operate between once per day and once every 5 minutes.

- All extreme values on these measures have been independently checked to ensure the high / low speeds or high / low frequencies were correct.

11. Public Transport Route Choice Calibration and Validation

Route Choice Validation

11.1. A randomly selected set of 20 potential passenger journeys boarding or alighting within the model region was taken. These journeys were run through the MKMMM public transport model, and the outputs were compared with the recommendations given by online journey planners for the corresponding trip. The model gave realistic routes and services used for each origin-destination pair, with largely accurate in-vehicle journey time estimates compared with estimates given by journey planners. A small representative set of these comparisons is shown in Table 15 and Table 16 for rail and bus journeys.

Table 15: Modelled versus Journey Planner, Journey Travel Times and Routes, Bus

Origin	Destination	Modelled Time (Mins)	Journey Planner Time (Mins)
Milton Keynes Central	Wolverton Agora	20	24
Shopping Centre	Northampton	56	53
Wolverton Agora	Shopping Centre	24	27
Shopping Centre	Bletchley Station	29	32
Milton Keynes Central	Buckingham	21	20
Bletchley	Walnut Tree	16	15

Table 16: Modelled versus Journey Planner, Journey Travel Times and Routes, Rail

Origin	Destination	Modelled Time (Mins)	Journey Planner Time (Mins)
Milton Keynes Central	Bletchley	4.8	4
Wolverton	Milton Keynes Central	4	5
City of London	Wolverton	50	49
City of London	Bletchley	40	42
Wolverton	Bletchley	9	9
Bedford	Bletchley	38	44

11.2. For rail, the modelled in-vehicle times always match the journey planners to within a few minutes. For bus movements, the validation is not quite as good, although the journey times are still generally close. This is due to the greater complexity of bus movements, especially where interchanges are involved, changes in bus services and timetables between the base year of the model and early 2017 (when the calibration was carried out), and differences between the TransXChange data and journey planner estimates of bus journey times.

12. Public Transport Assignment Validation

Calibration and Validation Approach

12.1. The MKMMM public transport model assignment has been validated by comparing the model results against other available data. Discrepancies were investigated and, where appropriate, changes have been made to the assignment parameters or other parts of the process to improve the model. The following changes were made during model calibration:

- centroid connector coding;
- catchment areas related to some railway stations were modified in order to avoid overlapping and other problems
- interchange weight applied to boarding penalties; and
- auxiliary time weight changed.

12.2. No manual changes were made to the final matrices, although the matrices were altered by applying changes to the inputs of the matrix development process, not the outputs.

12.3. “Matrix estimation”, the technique (used in the MKMMM highway model) for adjusting a matrix of traveller demand to better reproduce observed flow data, was considered, but not used. Given that the demand data is based on ticket data collected over a month or more, and the count data has been collected through a one- or two-day count, it is felt that the demand data are a more reliable data source than the observed count data.

12.4. While some discrepancies in the bus data could have related to the demand matrix, we considered it inappropriate to adjust a demand matrix developed from 3-months of ticket sales data to match a count collected manually on a single day, as the former would generally be considered to be more reliable, and therefore that this demand data should be preserved.

12.5. The validation criteria set out by WebTAG relevant to public transport modelling are shown in Table 17.

Table 17: WebTAG Calibration and Validation Criteria and Acceptability Guidelines

Measure	WebTAG Criteria	Acceptability Guideline
Public Transport Link (and Boarding) Flows	Individual flows within 25% of counts for flows > 150 passengers per hour	> 95% of cases
Public Transport Screenlines	Flows within 15%	> 95% of cases

Bus Validation

12.6. Validation data for bus demand were only available for two sites:

- bus stops outside of Milton Keynes Central railway station (MKC) – data collected for a single weekday in December 2015; and
- bus stops around Milton Keynes Shopping centre (The Point) – data was collected during two weekdays in September 2016.

12.7. Table 18 shows the performance of the public transport assignment model when the assignment is undertaken using only the matrices derived from Arriva ETM data and the synthetic bus demand for unobserved services. This analysis highlights the performance of the bus matrices in isolation.

12.8. This analysis shows that, using an estimate of all-day flows based on the hourly counts and modelled flows, the model provides a good fit in terms of boarders and alighters at both

Milton Keynes Central and The Point. Only alighters at Milton Keynes Central fail to meet the WebTAG criteria of ±25%.

12.9. There is more variation between modelled and observed flows when considering individual average hours represented within the model, with around 50% of counts meeting the WebTAG guidelines. It should be noted that there is significant uncertainty in terms of the observed data as the count at Milton Keynes Central is from a single day, and the count undertaken at The Point provided observed data for only a proportion of bus services at this location.

12.10. It should also be noted that all changes applied to the bus matrices, networks and assignment to achieve the validation results detailed in Table 18 were global (i.e. applied to the whole model). There is reason to expect, therefore, that the model may perform broadly similarly in other areas where we have no validation data.

12.11. Table 19 shows the same comparison, but including the processed rail demand data within the assignment. The results of this comparison are not at the same level as with the assignment of bus demand only, and in particular there is a significant overstatement of bus boarders and alighters at Milton Keynes Central.

12.12. This is due to the specification of the public transport model whereby the choice between rail and bus modes is undertaken within the assignment. This therefore means that motorised access to rail stations is not represented, and access to rail stations must be undertaken either through walking or use of one of more bus services.

12.13. Therefore, the majority of rail demand to / from Milton Keynes Central uses bus to access the station, whereas in reality it is assumed that a significant proportion of this demand would drive to the station. There is also the possibility of double-counting within the demand matrices, as passengers who bought both a rail and bus ticket would be included in both demand matrices.

12.14. If a motorised access mode was coded within the public transport assignment for access to / from railway stations, this would have to be coded with a faster travel time than the corresponding bus services in order to attract demand. However, this mode would be open to all demand and therefore would attract a significant amount of bus demand from bus services onto this motorised access mode.

12.15. On balance, Table 18 demonstrates that the underlying processing of the bus ticket data is valid, but Table 19 shows that there is an inconsistency between the specification of allowed modes within the public transport model and those allowed in reality. This impact of this issue is likely to be greatest at Milton Keynes Central, with a smaller impact away from railway stations.

Table 18: Comparison of Modelled and Observed Average Hour Bus Flows – Bus Matrix Assignment Only

		AM			IP			PM			All Day		
	Site	Obs	Model	Diff	Obs	Model	Diff	Obs	Model	Diff	Obs	Model	Diff
Boarding	MKC	245	173	-30%	117	176	51%	297	307	3%	2,724	2,923	7%
	The Point	528	471	-11%	590	824	40%	823	800	-3%	8,883	10,242	15%
Alighting	MKC	317	191	-40%	171	133	-22%	235	152	-35%	3,139	2,140	-32%
	The Point	621	692	11%	687	917	34%	628	529	-16%	9,207	10,725	16%

Table 19: Comparison of Modelled and Observed Average Hour Bus Flows – Bus & Rail Matrix Assignment

		AM			IP			PM			All Day		
	Site	Obs	Model	Diff	Obs	Model	Diff	Obs	Model	Diff	Obs	Model	Diff
Boarding	MKC	245	532	117%	117	397	239%	297	1,103	272%	2,724	8,523	213%
	The Point	528	586	11%	590	878	49%	823	928	13%	8,883	11,476	29%
Alighting	MKC	317	1241	291%	171	388	127%	235	493	110%	3,139	8,812	181%
	The Point	621	842	36%	687	991	44%	628	644	2%	9,207	12,172	32%

Rail Validation

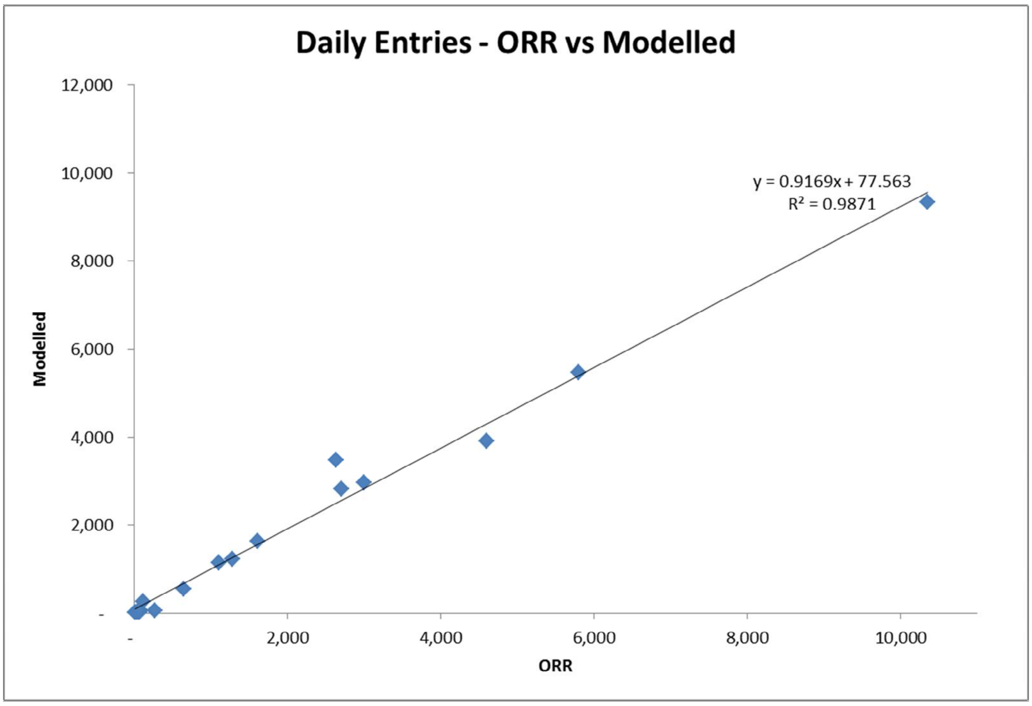
12.16. For rail demand across Milton Keynes, the ORR station usage data are available to confirm that rail passengers, when run in the assignment model, do actually use the stations their tickets were sold at. This does therefore represent a good validation of the assignment itself, but is not a validation of the matrix as such.

12.17. The comparison of the modelled station entries across an average weekday against the ORR data are summarised in Table 20 shows the same results, but shows the correlation between the modelled and observed station entries. Note that an assessment against WebTAG guidelines has not been undertaken where the observed station entries are low, in line with WebTAG guidance. These stations are included in Table 20, but not assessed against WebTAG.

Table 20: Comparison of Modelled and Observed Daily Station Entries

Rail Station	ORR Daily Entry	Model Entry	Difference	WebTAG
Milton Keynes Central	10,352	9,345	-10%	Pass
Wolverton	646	542	-16%	Pass
Bletchley	1,610	1,635	2%	Pass
Fenny Stratford	42	18	-56%	n/a
Bow Brickhill	65	22	-67%	n/a
Woburn Sands	68	30	-56%	n/a
Aspley Guise	14	17	19%	n/a
Ridgmont	56	47	-17%	n/a
Lidlington	63	25	-60%	n/a
Millbrook				
Stewartby	70	87	24%	n/a
Kempston Hardwick				
Bedford St Johns	271	59	-9%	Pass
Bedford Midland	5,801	5,459		
Northampton	4,597	3,918	-15%	Pass
Leighton Buzzard	2,709	2,833	5%	Pass
Cheddington	118	271	129%	n/a
Tring	1,278	1,231	-4%	Pass
Berkhamstead	2,634	3,473	32%	Fail
Hemel Hempstead	3,000	2,960	-1%	Pass
King's Langley	1,107	1,136	3%	Pass

Figure 12: Comparison of Modelled and Observed Daily Station Entries



12.18. The correlation is very strong between the modelled and observed station entries, and the validation good for the all the stations within the model area (i.e. Milton Keynes Central, Bletchley and Wolverton). There are a few stations along the Bletchley to Bedford line with discrepancies, but these are all small stations with a very low number of trips per day, significantly below the 150 passengers per hour recommended within WebTAG.

12.19. Aside from the stations along the Bletchley to Bedford line, the only other locations which fail to meet WebTAG guidelines are Cheddington, where the observed flow is low and below WebTAG recommendations, and Berkhamstead, where the model has 32% more entries than observed in the ORR data. Berkhamstead is not within the modelled area, and the zoning in this part of the model is unlikely to be detailed enough to model the choice between stations in this area.

13. Summary of Model Performance

13.1. The limited available observed count data for the public transport model demonstrates that there is a reasonable fit between the modelled and observed flows, in particular in relation to rail station entries. The performance of the bus matrices is good at an all-day level, but there are discrepancies when considering the individual modelled hours and when including the rail demand within the assessment of bus flows.

13.2. Given that the demand data is based on ticket information from one month for rail and three months for bus, it is felt that these datasets capture the day-to-day variation in public transport demand to a greater extent that the one- or two-day boarding / alighting surveys collected for bus demand. On the basis of this, it is felt that matrix estimation should not be applied to improve the model fit against observed data.

13.3. In terms of the wider model, the demand model makes use of the processed demand matrices developed for the public transport model and the costs of travel between zone pairs from the assignment. As the assignment does not include rail and / or bus crowding, these travel costs are independent of the level of demand assigned. The analysis set out in this technical note demonstrates that the processed demand matrices form an acceptable basis for the demand used in the variable demand model, and the coded services provide a realistic representation of journey times and fares between model zones.