The Use of Transport Models in Transport Planning and Project Appraisal

August 2014

JASPERS Appraisal Guidance (Transport)

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Joint Assistance to Support Projects in European Regions

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JASPERS aims are to improve the preparation of major projects to be co-financed by the Cohesion Fund and the European Regional Development Fund (ERDF) in the new Member States. JASPERS is involved in some of the IPA Countries under the regulations of the EU IPA Fund, supporting the candidate countries through gradual improvements in the practice and processes required for absorptions of the EU Funds.

In order to support these activities, JASPERS has produced a series of Guidance Notes which set out generic advice and recommendations with regard to specific areas of strategy or project preparation. This advice is intended to provide an early understanding of the requirements and expectations of JASPERS key experts.

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Contents

Part A

Guidance for the Managing Authority

1. Introduction to this Guidance

1.1. Overview

A Transport Model is a computer-based representation of the movement of people and goods (trips) around a transport network within a defined 'Study Area' having certain socio-economic and land-use characteristics. It is intended to provide an indication of how trips will respond, over time, to changes in transport supply and demand. These changes may be due to changes in the demand for transport and/or due to changes in the transport network itself (i.e. the building of new transport infrastructure).

The outputs from a Transport Model can provide essential insight into the understanding of an existing or future transport problem, thereby supporting infrastructure design and operational planning. A transport model can also identify the likely impacts that will result from a proposed project, strategy or Transport/Environmental Policy. As such, the Transport Model plays an essential role as a decision-support tool, providing relevant and accurate information into planning and decision making.

Given the breadth of applications for Transport Models, it is natural that there is a wide range of guidance available for their construction and application. Guidance is currently published by a number of National Authorities, and adherence to such national guidance is generally mandatory for public investment in transport infrastructure.

1.2. Purpose of this Guidance

In some JASPERS countries of operation, transport modelling and planning is a relatively young discipline with little detailed guidance, and which is still finding its way towards a strong and stable position in the planning process. Although there is currently no detailed guidance at EU level for the development and application of transport models, there are a number of basic principles that are common across many examples of National Guidance which reflect the basic principles of modelling. JASPERS draws from these common principles when providing support in the preparation and application of transport models.

This document has been prepared by JASPERS to provide guidance on the development of Transport Models for use in the development and appraisal of transport projects where a suitable national guidance document does not exist. It is presented in two parts and is intended for use as a starting point aide by:

- **Part A: Guidance for the Managing Authority** to assist in the understanding and definition of modelling requirements during the procurement process, and subsequently to review work that has been undertaken during project preparation; and

- **Part B: Guidance for the Expert** to demonstrate how a transport modelling exercise will align with the views of JASPERS experts for the nature of project under consideration. It is also a reference for those in the Managing Authority who are seeking a greater understanding of the processes involved in Transport Modelling.

This document sets out key requirements that should be considered during the scoping, development and application of transport models for use both in the preparation of transport projects, and in the development of local, regional and national Transport Strategies.

It is intended that this guidance will support an improved quality of modelling tools, which will improve their capability to provide the relevant information to design teams and policy makers in the conception, assessment and appraisal of transport projects and policies. The document is not intended to be a substitute for experience in defining modelling requirements. In this regard, Managing Authorities should always ensure that their beneficiaries and consultants have sufficient experience to procure and develop models that are fit for purpose.

For guidance on the processes related to the development of Transport Strategies, readers are also directed to relevant JASPERS Advice Notes[1].

[1] *Methodology for Preparation of National Transport Strategies, JASPERS, June 2013*

2. The Role of Transport Models in Planning and Project Appraisal

2.1. Functions and use of a Transport Model

A Transport Model is the tool providing a quantitative and qualitative output of the likely impacts of alternative solutions (hypotheses) formulated at planning level (*"What if ?"*). This then provides the analytical input to the planning and decision making process. The model can be used in many different ways to inform this process, including:

- Understanding the function of existing infrastructure in terms of passenger groups, freight types, trip types and origins and destinations;
- Identifying bottlenecks in the network and understanding the need for additional capacity;
- Providing demand data for appropriate options analysis, design and dimensioning of new infrastructure and operational service (e.g. public transport timetables) responding to real forecast traffic and functional requirements;
- Understanding the impact of a new transport scheme on transport flows through the modelled network (multi-modal if necessary), showing how demand responds to the new infrastructure and the resulting conditions that will exist;
- Understanding how transport conditions will change in the future in response to changes in population, employment, economic activity, car ownership and development patterns;
- Understanding the passenger and revenue impacts of changes in routing, frequency, speed or accessibility of public transport services; and
- Understanding the relationship between changes in land use and the resulting transport demand.

Ultimately, the outputs from the transport model provide quantitative information that informs scheme design, Cost Benefit Analysis, Financial Analysis, and Environmental Assessment. Modelling teams should be aware that those end-users of transport modelling outputs rely on robust transport forecasts. Weaknesses in a transport model can therefore reduce the ability to support those other specialists.

As such, a good quality model, based on an appropriate dataset will generate a good quality set of concept and design inputs and assessment outputs. This will in turn allow a more informed design and appraisal.

2.2. The Transport Modelling Process

Transport Models incorporate significant volumes of information which describe large numbers of transport movements over a specified period (e.g. a single hour or a single day) over a transport network. A typical city model might include in excess of one million trip movements during a morning peak period.

Models also generally incorporate information on the transport network (road, rail, air and waterway modes) and on its dynamics (e.g. timetables, interconnections, etc.). Data is typically coded in the form of attributes for each transport link in the network, including speed, quality, and the travel modes that use each link. Public transport service information can also be included in the model.

The Transport Model then undertakes the process of predicting the travel choice made by each individual user travelling through the network, and loading the resulting trip movements to the modelled network based on selection of most likely routing (and where necessary the mode share) for each trip. The Transport Model then describes the loaded transport network after this process has been completed.

A Transport Model can also define the state of the transport network in future years on the basis of growth in travel demand, committed network changes, and changes in socio-economic data. The future years usually coincide at least with the opening year and a distant forecast year which is used for assessment of long-term capacity needs or is the end year of economic evaluation.

In order to achieve this, the transport model often requires substantial (often time consuming and expensive) input data derived from standard statistics and special surveys for building a representation of trips, a model of the network and for understanding current traffic flows and demand structure for the purpose of model calibration. This is essential for the model to be sufficiently accurate and have credibility for planning and decision making. The phrase '*Rubbish In = Rubbish Out*" well summarises the variability of models regardless of software quality.

2.3. Transport Modelling Outputs

For the most basic models, outputs can be restricted to traffic flows and delays at a single junction on a road network. For larger models, outputs can include reports of flows on roads, public transport demand by route and location, freight activity, delay at junctions, mode share, emissions, and overall statistics that describe network efficiency. Sophisticated and well supported software packages are available which automatically produce a number of such outputs as part of their user interface. However all model platforms require appropriate data inputs to make them a serious tool.

The Transport Model effectively 'automates' the process of populating the transport network with transport demand, thereby generating the outputs for the user. This automation allows a variety of transport schemes, or scheme options, to be tested on a consistent basis and in rapid succession.

2.4. The Principle of Proportionality

The modeller must always remember that studies are carried out to help design and enable investment decisions to be made and explained, as well as to inform the environmental appraisal of the scheme, and any work that does not further these objectives is wasteful. The practitioner also has a duty to the planner and decision maker to provide information that is robust and levels of uncertainty are clearly stated and considered in any studies. They must also ensure that any differences identified between alternatives are real and not a product of the techniques used in the appraisal.

Furthermore, it is important that the scope for using existing models and data is carefully considered and that new models and data are up to the task. The modelling approach selected must be balanced and careful consideration should be given, before resources are committed, to the nature of the options that are likely to be designed and tested, the likely key impacts that are to be appraised and thus the required level and focus of detail of the analyses. In short, the model must be fit for purpose in terms of scope and input data quality being not too simple for the required purpose but avoiding unnecessary complexity.

An example might be the design and appraisal of modernisation of major rail corridors where major speed increases are considered, there is strong competition from bus and road and significant mode shift is expected. This will likely require a multi-modal corridor or wider network model with a well calibrated mode-choice model.

3. Management of Transport Modelling Projects

3.1. Institutional basis for modelling

Modelling can be a resource and time consuming process which can be greatly improved for individual projects if relevant starting data is collected and organised on a regular and stable basis by the public sector. This may include centralised development by a dedicated team that oversee:

- Regular national, regional or city wide traffic and passenger counting / travel time surveys
- Regular major household transport behaviour surveys (every few years)
- Regular freight operator / shipper behaviour surveys
- Research to inform modelling parameters etc.
- Development of regular national/city demand forecasts
- Regular processing of other existing data (e.g. census data)
- Maintenance of a central database with all relevant transport modelling data
- Maintenance of official national, regional or city transport models

3.2. Overview

Whilst transport model development can be undertaken in-house by authorities who possess the required level of skill, the development and manipulation of transport models is often subcontracted to external specialists, or undertaken by specialised Transportation Institutes. This places a requirement on the contracting authority to ensure that the project is successfully delivered. A number of suggested mechanisms for successful management of a modelling project are outlined here.

3.3. Preparing Terms of Reference

The Terms of Reference (ToR) are a key document which sets out the basis structure and requirements of the transport modelling. As such, it is necessary to ensure that all basic requirements are fully understood so that they can be adequately set out in the ToR. A number of key areas to be considered are outlined below:

Technical Support in Preparing Terms of Reference

It is recommended that the Managing Authority seek the correct skills when preparing Terms of Reference for a modelling project. The relevant individuals should have knowledge of the subject, but should also have considerable experience in preparation of Terms of Reference, and the preparation of proposals in response to Terms of Reference. In this way, it will be possible to ensure that the resulting requirements meet the needs of the contract and do not place unrealistic burdens on the supplier, or unrealistic expectations on the Contracting Authority.

Theoretical knowledge of modelling in itself is not sufficient to demonstrate the ability to oversee the preparation of ToR. JASPERS is available to Managing Authorities to support in the process of preparing Terms of Reference, or in the process of engaging a third party advisor to provide Technical Assistance.

Preliminary Model Scoping within Terms of Reference

The scoping stage is generally the first stage in a transport modelling project. Whilst the full detail of scoping might not be required prior to tendering, it is generally necessary for the contracting authority to have formed a view on what type of transport model is necessary, and its required functionality. Tendering in the absence of some preliminary scoping should be avoided, as it places an incentive to adopt the least-cost approach to transport modelling. The terms of reference should therefore set out basic requirements, such as:

- If an existing transport model can be modified/adapted for use;
- If a network model is desired/required;
- Transport modes to be included;
- The modelled Study Area;
- Whether variable demand responses are to be modelled;
- The number of user classes and journey purposes; and
- Time periods and the number of forecast years.

Transport modelling projects should be fully scoped to the point where it is possible to use a fixed-price contract specifying technical terms of reference and a defined project programme.

Allowing for Data Collection

The costs of data collection should not be subject to competitive tendering, as this creates an incentive for minimising on data. This invariably leads to a reduction in model quality and should be avoided. For the purpose of tendering, it is better to specify a fixed value for inclusion in the pricing to cover the cost of surveys. With this approach, the survey plan can be developed by the specialists and tendered to third party suppliers for inclusion as an expense within the allowable fixed sum.

The level of expenditure on data collection can be difficult to estimate in the absence of a scoping exercise, as it varies significantly between different models. As a general guide, the budget for data collection might be up to 20% of the overall cost of model development, although it is not unusual for the final expenditure to be above this limit. The final value will depend on whether there are existing sources of data that require infilling, or where limited data is available.

Capacity Building

During the early stages in defining the management of a modelling exercise, it is recommended that the contracting authorities consider mechanisms to build skill and expertise in the sector. For example, the contracting authority may place an obligation on specialist teams to engage at least one local trainee to support in the model development project, working under the supervision of a skilled member of the specialist team.

Alternatively, the contracting authority could make one member of staff available to work with the specialist team for a defined period to support in the model development task. JASPERS can assist in defining such terms to be included in contract documentation.

Reference to Transport Modelling Guidelines

During project procurement, the Terms of Reference should include a reference to the appropriate guidance documentation to be used in Transport Modelling. Where national guidance exists, such documentation can be referenced. Where National Guidance does not exist, a statement could be added stipulating a requirement for the supplier to undertake Transport Model Development in accordance with "*Jaspers Appraisal Guidance (Transport): The Use of Transport Models in Transport Planning and Project Appraisal*"

Requirements of the Supplier

The selection of a supplier for modelling tasks must ensure that the correct level of skills and experience are available. Transport modelling is normally undertaken by small teams, with different individuals working on various elements of model development. The team is overseen by a Team Leader who guides the overall process, checks and approves outputs, and assists the contracting authority with interpreting the results. As such, there is a requirement to ensure that all members of the team are appropriately skilled, and not just the Team Leader.

The level of skill and size of a team will differ for each modelling project, but as a rule it is suggested that a Team Leader should have at least 10 years' experience in Transport Planning and Modelling Studies and have delivered at least one project of a similar scale to the intended project in the previous 5 years. Other key members of the modelling team should have at least 5 years' experience in their selected skill area. The remainder of the team will generally support the key members of the project team and although they should possess a qualification in a technical discipline, no significant experience is generally necessary.

Contracting authorities are recommended to request nomination of the full modelling team with curricula vitae for each project, along with a resource plan for delivery of the work.

In selecting a supplier, it is strongly recommended that the modelling team is selected on the basis of a price/quality weighting. The quality score for a tender proposal should be determined on the basis of:

- the project team and experience;
- proposals for integration with available data and other transport models;
- the proposed functionality of the models;
- the application of well-tested methods with low technical risk;
- proposals for supporting the objective of knowledge sharing;
- innovative proposals on methodology/approach (where these will add value to the project); and
- proposals for communicating with the design team and CBA team.

Duration of the Contract

The transport modelling work plays an inherent role in the selection of the correct project variant and the demonstration of its economic case. During the latter stages of a project, it is common that a need may arise for a review of parameter values, network coding and matrix definition if the subsequent analysis highlights difficulties with the models. As such, it is important that the transport modelling team is retained throughout the project preparation stage until the relevant application is submitted/approved. Likewise, it is important that the modelling team remains available to undertake the relevant modifications as part of any JASPERS input to improving the quality of the application.

Finally, it is common that subsequent users of a model have difficulty in interpreting how the model developer has constructed some elements of the model. Although this should be fully documented in the Model Manual, such documentation is not always clear. It is beneficial to prolong a consultancy engagement through any envisaged handover period.

3.4. Technical Reviews

Where necessary, contracting Authorities are encouraged to engage an individual or entity to support their procurement and ongoing review and management of a modelling project. That individual can support the contracting authority in interpreting outputs from different stages of model development and advise on the overall quality/direction of the work. This person should have substantial experience (ideally more than 10 years) in the preparation of transport models AND their application to the planning process and in the preparation of major infrastructural projects. As already noted, theoretical knowledge of modelling in itself is not sufficient to demonstrate the ability to oversee a modelling team. For project supported by JASPERS, support is available to Managing Authorities during the process of engaging a third party advisor to provide Technical Assistance.

The absence of a skilled individual to oversee such work can lead to inadequate ToR, a consultant-driven approach and substantial deviations from the terms of the project to go unnoticed. Likewise, the use of an individual with sound theoretical knowledge but limited practical experience can lead to over-complication of a transport model, or an exercise that fails to focus on the more important aspects.

Technical reviews may take the form of periodic review of outputs, or using a more hands-on approach where the reviewer is in general communication with the modelling team. It is important that the reviewer is independent of the modelling team and is in a position to make unbiased judgements.

3.5. Intellectual Property and Model Maintenance

Where a project concerns the development of a transport model that has an ongoing role in the strategic planning of transport projects, an allowance should also be included for ongoing maintenance of the transport model which should include ongoing capacity building activities. In this case, a clear individual should be identified within the Contracting Authority who shall have ultimate responsibility for overseeing the model maintenance (including subsequent model updates). That individual would also manage the dissemination of the model to other consultants or authorities for work on related projects where appropriate.

The Terms of Reference should state clearly that the transport model developed under any commission will remain the property of the Managing Authority. This shall include any licenses where they are purchased within the contract.

3.6. Summary of Requirements

On the basis of the above, the information in Table 3-1 presents a summary checklist for the Managing Authority to achieve a successful outcome in the preparation and application of transport models.

Table 3-1: Checklist of Management Requirements

Item	
Clear definition of the purpose and objectives of the project	
Procure Technical Support to assist in preparation of Terms of Reference	
Institutional obstacles to acquiring older models and/or available data from other government ministries/authorities have been overcome	
Technical Manager appointed within Contracting Authority to manage external Technical Support and oversee instructions to the Consultant	
For strategic models, appoint a Technical Manager within Contracting Authority to oversee future maintenance of the transport model, and its dissemination to third parties	
Consider opportunities for Capacity Building within the Managing Authority/Beneficiary	
Preliminary scoping of modelling activities prior to preparing Terms of Reference	
Appropriate allowance (time and funds) for Data Collection	
Clearly defined and sufficient expertise for Modelling Team	
Include requirement that Model is handed over to Contracting Authority following project	
Include requirement for Model Manual	
For strategic models, Include requirements and provisions for model maintenance	
Programme Technical Reviews of models by Competent Expert	
Include reference to JASPERS Appraisal Guidance (Transport) in Terms of Reference	

3.7. Reporting Requirements

It is crucial that any transport model is not a “black box” for project justification. The modelling process, input data, assumptions and outputs should be transparently justified and documented to allow external review and understanding. The anticipated deliverables from a Transport Modelling exercise are outlined in detail in Chapter 13 of this document, and are summarised as follows:

- A Transport Modelling Report;
- A copy of the Transport Models, plus a shapefile version of all modelled scenarios where network models are employed; and
- The Model Manual.

Note that the above deliverables should be prepared in addition to any Feasibility Study or Cost Benefit Analysis reports that may be produced as part of the project preparation.

4. Common Problems and Recommendations

4.1. Overview

Effective management of a project will lead to a well-designed model providing high quality and appropriate outputs. It is therefore essential to understand the potential pitfalls that occur in modelling projects. A summary of the most prominent problems and risks based on JASPERS experience is provided below along with an outline of possible solutions. Correlations between them are mostly self-evident.

4.2. Procurement Stage

Problems:

- Terms of Reference not fully scoped, leading to misunderstanding of project requirements, and very high variations in tender prices, with a risk of under-bidding;
- Poor response from tenderers due to unclear terms of reference, unrealistic work programmes, or uncertainties regarding availability of data;

Solutions:

- Strong scoping exercise during pre-tender stage to allow specific work requirements to be documented;

4.3. Project Preparation Cycle

Problems:

- The model is used only as an input to economic appraisal and not for scheme concept design and options analysis. This can lead to a design that is not consistent with the demand forecasts;
- Model outputs that are not robust, and generate poor quality data for environmental, economic and financial analyses;

Solutions:

- Changes to project preparation process including an institutional requirement of needs-based planning in an options-based feasibility study at the beginning of the project cycle;
- Greater technical diligence during the model development and testing, achieved through use of a Technical Reviewer;

4.4. Model Ownership, Data Access and Documentation

Problems:

- Consultant ownership of models leading to poor transparency and lack of continuous access and controlled model maintenance;
- Poor documentation of modelling work, leading to difficulties in undertaking assessment or reviews, or for subsequent users of the model;
- Difficult access to other models (e.g. official city models) which form important input to a project;
- Blocked access to data owned by third parties including state owned transport operators;

Solutions:

- Ensure contractually that model files and full documentation should be made available for client and third party use and amendment;
- Ensure that models are developed in widely available commercial software;
- Contracting Authority should seek general agreement on access to data and models owned by third parties such as state owned railway companies (and data publication rules for protection of their commercial interests);
- Contracting Authority should oversee data provision via official requests to other governmental departments/agencies

4.5. Capacity Building, Project Management and Quality/Scope

Problems:

- Lack of experienced/qualified staff or time resources applied to the technical scoping;
- Insufficient time allocated to modelling tasks in Terms of Reference leading to inappropriate/insufficient outputs;
- Tender award based on price only with low qualification criteria, often leading to poorly qualified/experienced contractors, and poor quality outputs;
- Lack of agreement with modelling team on detailed scoping after project commencement;
- Model is not developed based on agreed scope due to poor review process
- Models with insufficient input data, in particular missing local surveys required for model building and calibration, leading to unrealistic outputs;
- Models too simple for scheme considered (e.g. not multi-modal or network scope too narrow);
- Models that are excessively complicated with extremely long run times, resulting from poor management during the modelling process, or excessively ambitious functionality requirements;
- Inconsistency with other related models in parameters and forecast results;
- Poor attention to, oversimplification/politicisation of forecasting process;
- Poor coordination/interlinkage between the modelling and economic analysis tasks;

Solutions:

- Stronger Project Management teams within the Contracting Authority and/or ensuring external support for modelling/economic analysis issues from ToR to model completion;
- Develop standardised modelling approaches, conduct research for modelling parameters, develop standard national /city base model / forecast;
- Educate management on role, importance and requirements of modelling;

The summary of common problems above shows that many can be avoided through careful definition of the project requirements in the Terms of Reference and during the early model scoping stage. This reinforces the requirement for good quality technical support during the early stages of a project to ensure a good foundation for subsequent work.

Part B

Guidance for the Expert

5. Defining Types of Transport Model

5.1. Overview

There exists a wide variety of scheme types that may be subject to appraisal ranging from refurbishment of existing infrastructure to major new road or rail schemes, up to the more comprehensive work of preparation of a MasterPlan. It is clearly not sensible to adopt a 'one size fits all' approach when it comes to developing transport models to assess this range of issues. Furthermore the geographical location and size will also impact on the decision of what type of modelling is appropriate.

5.2. Modelling Methods

In essence, transport modelling can range from the development of relatively simple spreadsheet models which are generally bespoke and constructed by users for a particular calculation, and transport network models which describe a defined Study Area, and consider transport demand as a function of the condition of the transport network.

For example, the number of trips generated by a populated area may also be a function of the quality of the transport supply (journey time to the nearest destination). Similarly, the route chosen will also be a function of the level of congestion on the network. Network Models are generally more complex as they can involve 'feedback loops', where the resulting state of the network can impact on user decisions.

In general, for the planning and appraisal of transport projects, the use of Network Models (supplemented by spreadsheet models where appropriate) is normally necessary.

5.3. The Structure of Transport Models

Transport Models usually comprise a series of individual modules (stages), which operate in a defined sequence. The 'Four Stage Model' describes the standard approach to the modelling of transport impacts to a range of proposals. The process is presented below in Figure 5-1.

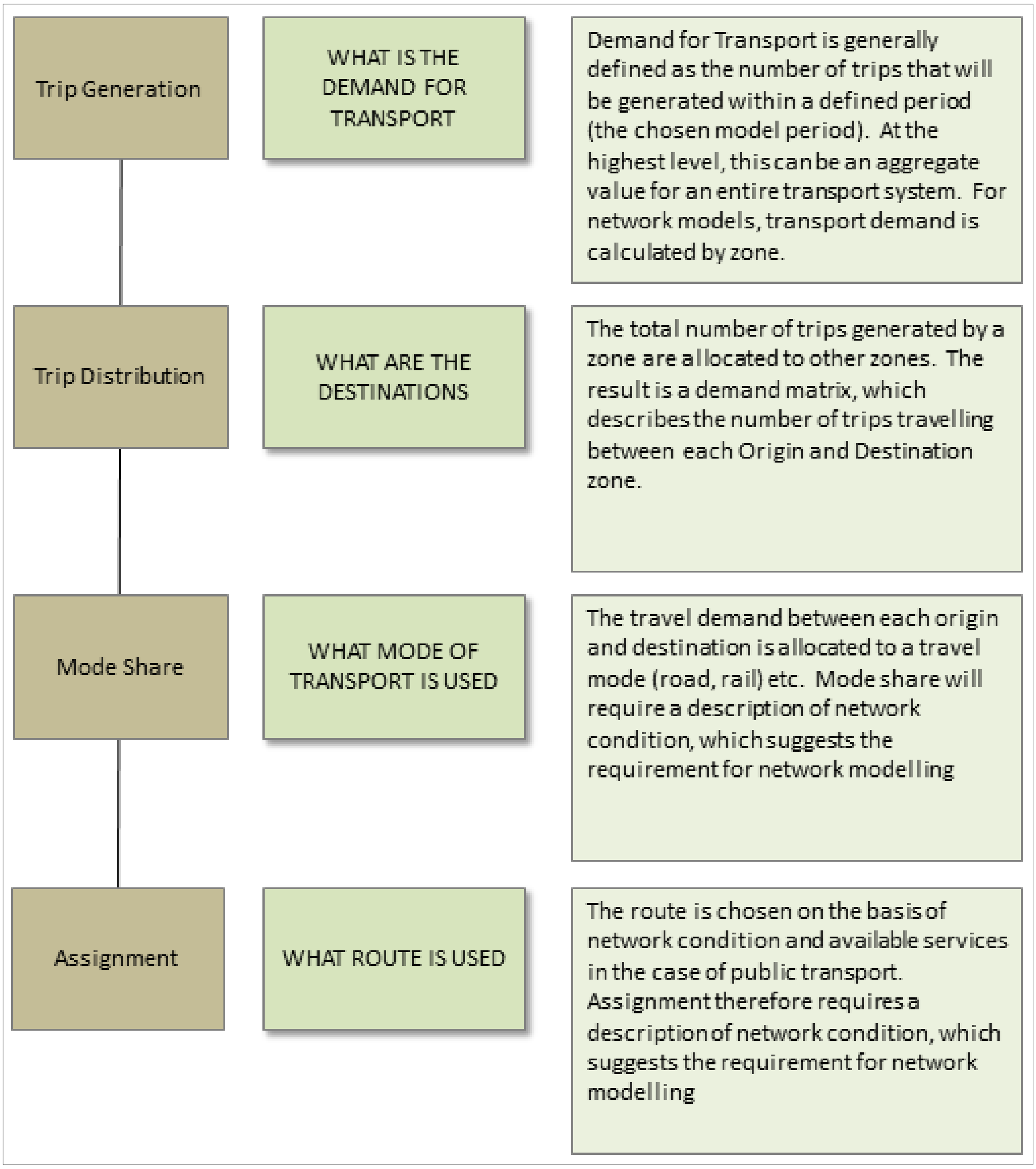


Figure 5.1: Structure of a Four Stage Model

In public transport and freight models, there can also be a final stage where trip volumes (tonnes or passengers) are converted to vehicle numbers following the assignment based on occupancy assumptions. This then allows vehicle/service requirements to be understood. More complex freight models can also have further stages relating to the logistics chain.

For the appraisal of transport projects, a transport model is prepared for at least two scenarios – namely option(s) **with** and **without** the project. In addition, both of these scenarios are prepared for an opening year and a future design year. The impact of the project is defined as the difference between the 'with project' and 'without project' options for each year modelled.

5.4. The Functionality of Transport Models

For each of the four modelling stages, there is often a requirement to include a range of feedback loops into the modelling process. Feedback loops recognise the interdependency of the various stages of the modelling process and hence the need to apply iterative calculation methods. Examples include:

- Where the assignment of demand onto a transport network fundamentally changes the condition of the network (through the onset of traffic congestion), which in turn influences the choice of mode. This therefore requires a feedback loop into the Mode Share stage;
- Where assignment of demand onto a transport network leads to congestion at points in that network, which influences the choice of route. This requires feedback loops within the assignment stage; and
- Where congestion impacts on the choice of destination. This requires network information from the assignment to be fed back into the Trip Distribution stage;

In essence, the functionality of a model is defined by the presence of such feedback loops which increase the ability of a model to forecast real outcomes. The varying levels of functionality are defined as follows:

Simple Models

Where the impacts of an intervention are fully understood and where all outputs are independent of each other (i.e. where the outputs from a calculation do not represent inputs to that calculation, and hence where there is no requirement for a feedback loop), the user may consider the use of Simple Models. In Simple Models, the calculation can be undertaken using spreadsheets or proprietary software products.

For the analysis of Transport Networks, caution should be exercised in the use the use of Simple Models, and should be only restricted to those locations where there is no interdependency between network condition and the resulting transport demand. The use of Simple Models to undertake assignment is not recommended other than in very simple and uncongested rural networks. Examples of Simple Models include:

- Network rehabilitations where there is no change in demand using the rehabilitated/upgraded section, and where the model is required to calculate journey time and/or accident impacts using simple functions (such as speed-flow functions). In this case, the scheme should have no impact on Trip Generation, Distribution, Mode Share or Assignment;
- The projection of existing demand forward through the application of growth rates to reflect increases in population, employment, economic activity or other demographic/economic parameters. In such case, the user applies defined functions to existing demand to define the change in Trip Generation;
- Assessment of transport networks with multiple junctions where re-routing is not considered to be a likely response (i.e. the assessment only considers journey time, safety and other relevant impacts);
- Assessments of individual junctions, where models calculate queuing and delay on the basis of a fixed demand and a specified junction layout;

Assignment Models

Assignment Models are Network Models that assess a fixed transport demand (with a fixed daily demand profile) on a defined transport network. In Assignment Models, the outputs from the Trip Generation, Trip Distribution and Mode Share modelling are undertaken externally, and are inputs to the Assignment Modelling process.

The main function of Assignment Models is to calculate the rerouting response to new transport services or new/improved infrastructure. This is done starting from a schematic representation of the network by means of links and nodes, and demand is expressed through an Origin - Destination matrix. Assignment to the alternative routes is undertaken using route choice algorithms which describe users'' choice behaviour based on route "costs" (in general all the cost is reduced to travel time).

Assignment models have internal feedback loops - the assignment of demand onto a network will change the condition of the network (the level of congestion and hence journey time). As such, the network state is recalculated after each assignment and the assignment then repeated until a stable condition is reached.

Due to the complexity of the calculations, assignment models are usually undertaken using specialist modelling software. Assignment modelling using spreadsheet models is not deemed to be acceptable other than in very simple and uncongested rural networks.

Applications of Assignment Modelling include:

- Network rehabilitations where rerouting of existing demand is expected, but where no change in travel mode or transport demand is anticipated;
- Service improvements on public transport systems, where there may be rerouting within the public transport network, but where overall public transport demand will not change. In cases where there is competition between rail, tram and bus the use of Assignment Modelling may not be appropriate, and Mode Share Modelling may be necessary to fully capture the effects;
- Transport Policy proposals which impact on potential routings through a transport network.

For road transport models, assignment models do not attempt any calculation of changes in transport demand or change in travel mode. As a result, they are only applicable for the appraisal of a road scheme where the measurement of these responses is not required. It is noted that demand or travel mode responses can often define the case for a project, and their omission can fail to capture many of the benefits or impacts of an investment.

For road transport models, the assignment can directly influence the condition of the road network, as the travel time is a function of the volume of traffic using any part of the network. It is for this reason that a number of feedback loops are built into assignment modelling such that each subsequent assignment can be based on the network condition from the previous loop. The final assignment is defined as the point when the difference between subsequent assignments is below a specific threshold (convergence).

Assignment modelling in public transport models is generally done based on the 'lowest cost path' (All or Nothing assignment or more commonly stochastic assignment to many routes based on relative generalised route costs). The cost of a path is calculated as a combination of travel time, fare, access and egress time, waiting time, and sometimes an in-vehicle comfort weighting.

The level of congestion is normally only used as a factor in the assignment algorithm within public transport models in those areas where crowding is a particular feature of the public transport system.

It is noted that in assignment based public transport modelling, assignment models generally assign demand between different public transport modes, based on the principle that all public transport modes are perfectly interchangeable from a user perspective. In some cases this is an unreasonable assumption, especially when the PT modes are of significantly different quality and interval character (e.g. where railways areas are included). In such cases, a mode share model should be used, see below.

Mode Share Models

As a further elaboration of the functionality of a transport model, Mode Share modelling can also be included in addition to Assignment Modelling. Mode share modelling examines the generalised cost (including financial and non-financial costs) of travel on all available modes, and uses this to allocate demand between modes. The assignment is subsequently undertaken for each mode.

In Mode Share modelling, the network condition following the assignment of all transport modes is then fed back into the mode share calculation for trips between each origin destination pair. The mode share calculation therefore iterates until a stable assignment is reached.

Applications of Mode Share Modelling include:

- Network rehabilitations where rerouting of existing demand is expected, and where change in travel mode is anticipated;
- Service improvements on public transport systems, where there may be rerouting within the public transport network, and where overall public transport demand will change;
- Changes to public transport networks or services where demand may switch between road and rail based public transport modes or between urban PT modes and standard rail
- Transport Policy proposals which will impact on travel mode, but will not impact on the overall demand for travel.

Note that Mode Share modelling does not consider changes in overall transport demand. For inter-urban networks where road carries a significant proportion of the existing travel demand, variable demand responses (see variable demand models below) can sometimes be significantly stronger than the mode share responses. As such, the consideration of mode share effects alone can often underestimate the resulting demand for proposed infrastructure.

Mode share models might require a high level of computing capacity, in particular for big networks where a real competition among different modes is to be expected. The use of spreadsheet model for anything but very simple mode share calculations on single routes is unlikely to achieve a realistic output in congested networks.

For uncongested networks, it may be feasible to combine the results of the two separate assignment models for different transport modes to a simplified Modal choice model (not iterative), basically based on the output travel cost (time and financial costs).

Variable Demand Models

Variable Demand Models represent a broad functionality of transport models. Usually in addition to assignment and mode share modelling, they also include the Trip Generation, Trip Distribution modules of the Four-Stage Models as part of the modelling process, with feedback loops into those stages. Variable Demand Models can therefore model the following responses:

- Changes in overall transport demand including the assessment of transport volume induced by the assessed project in terms of the impact of cheaper travel;
- Changes in trip patterns and
- Changes in the timing of travel;

Variable Demand Models are therefore driven by the land use pattern, socio-economic profile and network condition within the study area, and can therefore allow the responses to changes in these properties to be understood.

Typical scenarios requiring Variable Demand Modelling include larger towns and cities with congested networks, scenarios where there is a substantial change in travel time or cost and/or in the structure of land use and of the related economic activities, or regions that have traditionally suffered from poor transport accessibility.

Variable Demand Modelling is a powerful tool in the assessment of the impacts of transport/environmental policy or changing economic circumstances on travel. Examples that are not otherwise quantifiable through assignment or mode choice models include:

- fuel price changes;
- road user charging;
- public transport fare changes;
- parking levies;
- new population/development patterns;
- major traffic management schemes;

In these cases, the Variable Demand response is a fundamental element in the valuation of a project. As such, the relevant demand responses need to be captured to understand the impact of the project.

Variable Demand Models can require a very high level of computing capacity, in particular for big network models where variable demand, mode choice and route choice equilibrium is being sought simultaneously.

Simple Models can however be developed which examine individual elements of Variable Demand. For example, elasticities or logit functions can be used to determine transport demand effects for a single zone or region. Nevertheless, this information is normally combined with network information in order to run the final mode share and/or assignment, and hence the majority of Variable Demand Models used for planning or appraisal of transport infrastructure are correctly built using Network Models.

5.5. Choice of vehicle modelling methodology

Broadly speaking, vehicle/passenger modelling methodologies fall into three categories:

- Macrosimulation models. For assignment, these models calculate the cost of using different routes on the basis of an aggregate calculation of journey time on each section of the network as a function of the traffic flow using that network. They provide good visual representations of demand across a network for a defined period. Modern macrosimulation models also encompass the Trip Generation, Distribution, Mode Share and Assignment stages, therefore covering all processes within the Four Stage Model;

- Microsimulation models, which tend to undertake assignment modelling only. The assignment model operates on the basis of individual vehicles/pedestrians, measuring the behaviour of vehicles/pedestrians on the basis of vehicles/pedestrians around them. The condition of the network is then measured by effectively undertaking ‘surveys’ of the network within the model. They provide a good visual tool to understand network operation in real time and are suitable for accurate modelling of delay build-up in road networks or pedestrian movements, particularly for singular or groups of congested junctions; and

- Mesoscopic models, which provide a functionality mid-way between Microsimulation and macrosimulation models, although these are not common.

Although Macrosimulation models can be time and resource consuming, they allow numerous “what-if” scenarios to be tested during a project preparation or strategy development exercise. In addition, they provide outputs that are compatible with the requirements of a traffic and environmental impact assessment, as well as economic and financial appraisal.

Microsimulation Models are most appropriate for the assessment of road networks in urban areas, or where the nature of the road layout makes the modelling of conflicts difficult using Macrosimulation Models (e.g. merges, weaving, complex junctions). Microsimulation models can also be used to a wider scale e.g. on motorways in order to model users’ response to traffic management and users’ information strategies and systems (ITS). More advanced techniques also permit to use Microsimulation models for road safety analyses. Where Microsimulation models are used, the method of generating outputs for the CBA should be considered in advance. The use of Microsimulation models for interurban road projects and for large complex urban networks can be problematic and can be very consuming in terms of computing capacities. City-wide Microsimulation for large cities or complex motorways networks is an extremely challenging task and is generally not recommended.

Software available on the market either focuses on one of these methods, or increasingly includes some or all of them allowing detailed micro or mesoscopic modelling of smaller areas within a broader macro model. This can allow a 3 or 4 stage approach that allows the strengths of each modelling approach to be harnessed (e.g. mode shift or timing of travel might be the main response to road congestion, and would not be captured through the sole use of a Microsimulation model).

The requirements of this Guidance, particularly with regards to scoping, calibration, validation and future year forecasting are relevant regardless of the choice of model software. However, for micro-simulation the validation/calibration of travel time will generally be a more important task.

5.6. Summary

A summary of the above categories is presented overleaf. The summary also specifies whether or not network-based models are necessary for a robust analysis.

Table 5-1: Summary of Model Functionality and Applications

Simple Models	Assignment Models	Mode Share Models	Variable Demand Models
SHORT RUN TIMES NO ROUTE CHOICE NO NETWORK EFFECTS NO MODE SHARE RESPONSES NO DEMAND RESPONSES	LONGER RUN TIMES INCLUDES ROUTE CHOICE INCLUDES NETWORK EFFECTS NO MODE SHARE RESPONSES NO DEMAND RESPONSES	LONGER RUN TIMES ROUTE CHOICE RESPONSES MODE SHARE RESPONSES NO DEMAND RESPONSES	LONGEST RUN TIMES ROUTE CHOICE RESPONSES MODE SHARE RESPONSES INCLUDES DEMAND RESPONSES
• Capacity analysis of single or multiple junctions with no route-switching. • Analysis of road sections or small networks for Accident Forecasting where no change in demand, mode share or route switching is anticipated. • Application of growth rates to forecast future transport demand on a transport link or from a transport zone. • Can often be done without network modelling software	• Small Network Changes where mode share effects are not expected. • Impact of new and upgraded roads in areas with Limited Public Transport or potential for variable demand responses • Rerouting impact of service changes in a public transport model where no mode share responses are expected. • Needs network modelling software	• Small Network Changes where mode share changes are likely to occur. • Mode share and assignment impacts of service changes in an overall transport model where mode share responses are expected between public transport and road. • Mode share and assignment impacts of service changes in a public transport model where complex mode share responses are expected between different public transport modes with qualitatively different characteristics or where mode share changes need to be economically analysed. • Needs network modelling software	• Major Network Improvements which lead to significant changes in travel time and/or accessibility. • Major urban areas where congestion exists, or will exist within the study period. • Areas where population and/or employment patterns are expected to result from changes to the transport network. • Significant Public Transport Service Changes. • Analysis of Impact of Policy on Network Condition. • Strategic Planning models. • Needs network modelling software

5.7. Timeframes for Modelling

The timeframe required for a modelling exercise depends on the functionality that is required of the model (see Table 5-1), as well as the geographical scale and complexity of a transport model.

Variable Demand Models developed at regional or national level work with large volumes of data and can require up to 12 months or more to develop. Assignment models are generally less complex, requiring anywhere from 1 month to 6 months to develop, depending on the size of the model and the level of zonal and network detail that is required. Simple Models, on the other hand, can be developed within a number of weeks, although this is a reflection of the limited scale of outputs that they generate.

Figure 5-2 provides an indication of the timescales that can be involved in modelling projects. Note that timescales are highly dependent on each situation, and the advice of an expert advisor is important to identify the time that is required for transport modelling within a project preparation cycle.

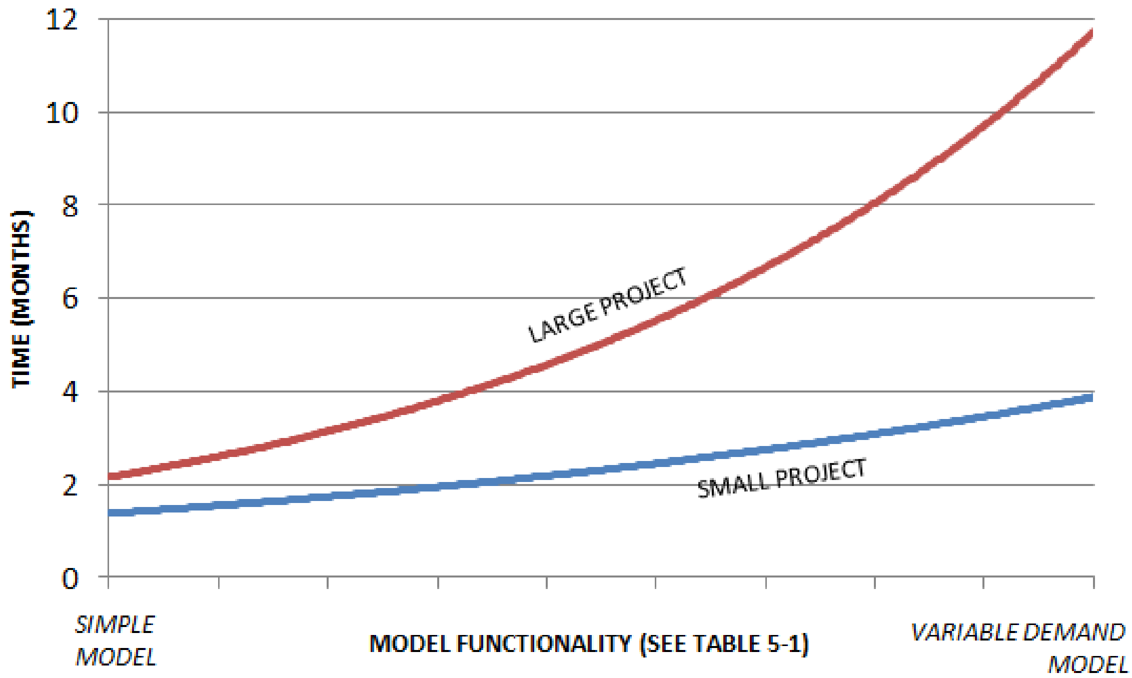


Figure 5.2: Typical Time Required for Transport Modelling Projects

6. Developing a Transport Model

6.1. Overview

Regardless of the functionality and method of modelling chosen, the procedure for developing a Transport Model is relatively consistent. The steps to be followed in model development are presented here, and should be followed in this sequence during the development of any transport modelling tool.

6.2. Steps in Model Development

Prior to undertaking any transport modelling exercise, it is necessary to fully understand the requirements and functions of that model. This will ensure that the model delivers output that is relevant to the project and enables a good project appraisal. The Scoping Stage of a modelling exercise examines the type of model that is required, the level of detail that will be input, and the method for undertaking the calculations.

Following the Scoping, the data collection stage involves the collection of all the necessary data as outlined in the scoping report. Because of the number of movements and the complexity of a transport network, it is not possible to measure every transport movement for inclusion in a transport model. As such, the data collection stage seeks to identify a statistically representative sample of transport movements. The data collection stage also allows the necessary data to be collected for the calibration and validation stages, and the future year model development stages.

The base year Transport Model involves the expansion of the data collected into a full dataset of transport movements using aggregate indicators. This demand is then loaded onto a transport network and transport services (in the case of public transport) that is also constructed as part of this stage, using an initial set of mathematical algorithms.

The calibration and validation process seeks to ensure that this synthesised dataset then matches observed conditions on the transport network. It provides an opportunity for the practitioner to modify the transport network, transport services, transport demand and mathematical algorithms such that the model outputs better reflect existing observed transport activity on the network (journey times, traffic flows at individual locations, observed mode share on selected corridors etc.). This stage also provides an opportunity to correct any errors in the model development which may become clear.

Following this stage, future year forecasts of the Transport Model are developed which incorporate changes to the network and to the factors driving transport demand (e.g. population, employment, car ownership, economic activity). This provides a picture of the future year transport conditions that will exist in defined years, and represents the background against which a project is evaluated.

Finally, transport infrastructure and policy and/or land-use interventions are tested in future year versions of the transport models. This allows impacts and benefits to be assessed for the future year in question, and forms the input to design and the subsequent project appraisal. This process is outlined in Figure 6-1.

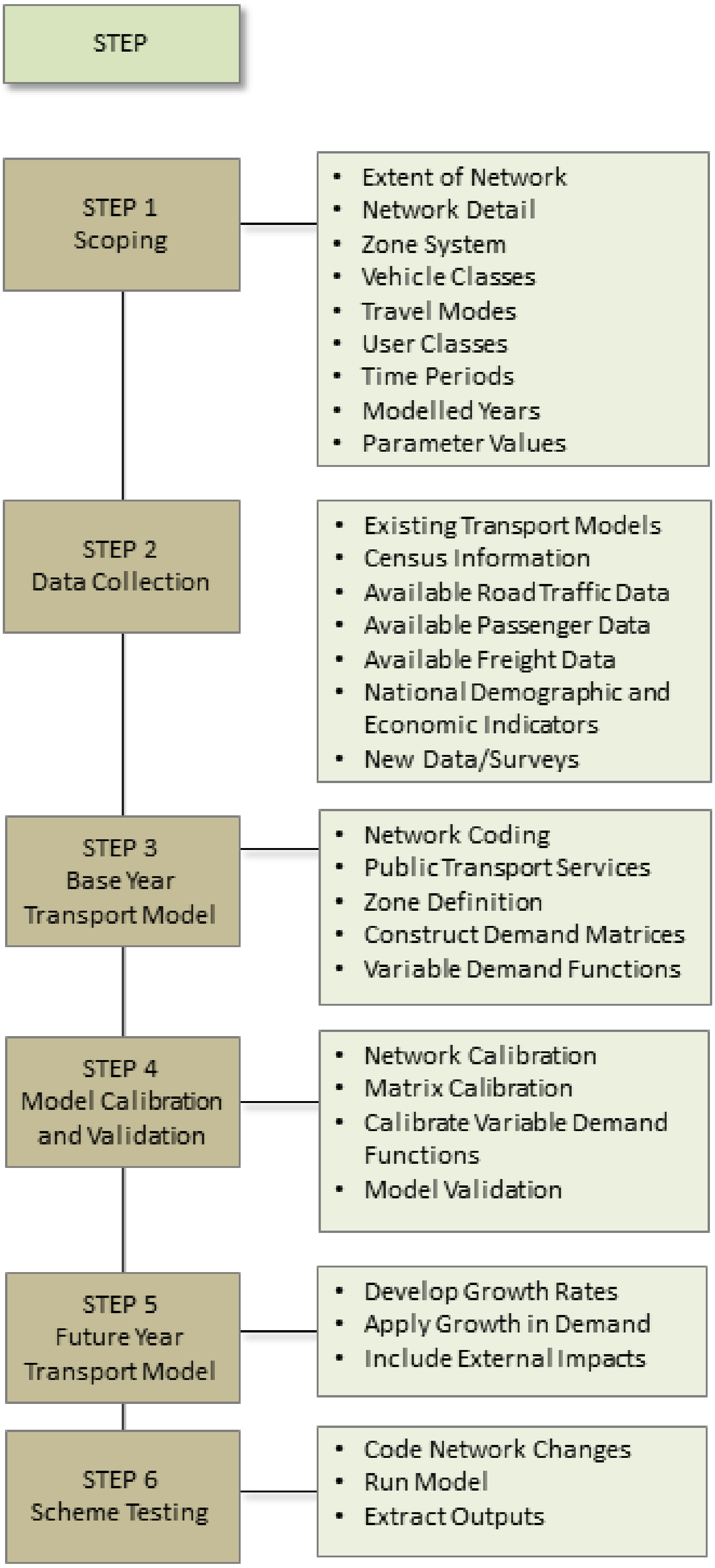
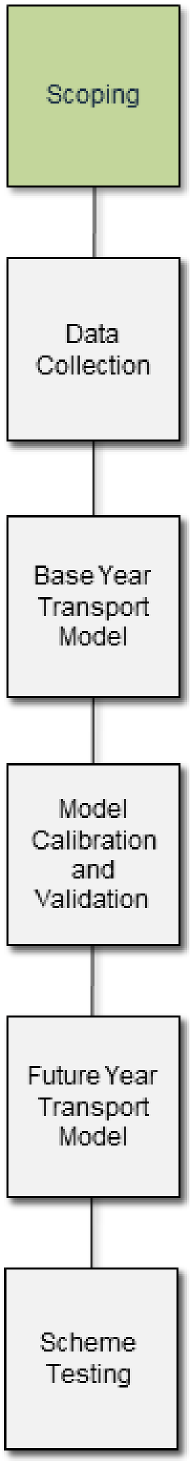


Figure 6-1: Structure of Model Development

7. Step 1 - Scoping a Transport Model



7.1. Type of Model

The nature of the scheme will provide the first indication of what type of modelling is required, although it will also be important to consider the location and the prevailing environment. As an example, a fairly major junction improvement in a rural area with a sparse road network and limited demand responses is likely to only require a Simple Model. The same kind of scheme in a dense urban environment may cause significant re-routeing effects, growth in transport demand and impact on other modes. As a consequence, an Assignment, Mode Share or Variable Demand Model would be required.

Ultimately, the choice of model will be dictated on the information that is required for inclusion in the appraisal. If the appraisal is only required to capture rerouting, then an Assignment Model is sufficient. If the appraisal also requires capture of mode share, travel demand and induced demand effects then a Variable Demand Model is essential. This is even more relevant when the transport model is used in the context of planning activities such as preparing a MasterPlan or planning, as it will have to capture the potential impacts also of changes to policies and wider area level phenomenon.

7.2. Elements of the Scoping

The scoping exercise should consider the major factors that define the final model, its functionality and its complexity. Although scoping is the responsibility of the modelling team, the exercise should involve discussion with those involved in economic, financial and environmental assessment, as well as with the design team. This will ensure that the model can be structured in a way that supports the needs of those other specialists who are dependent on such outputs. The following are considered most relevant to the scoping exercise:

Extent of the Transport Network

The extent of the Transport Network should be, as a minimum, that area and modal scope within which significant impacts are expected. One of the main purposes of a network model is to investigate the extent and impact of changes of route or mode as a consequence of a scheme. Therefore the network must be of sufficient extent to allow all reasonable and significant responses to occur.

If there is an existing network model of the area, even if it is quite old or of a coarse nature, then it should be possible to code in a representation of the improvement scheme to identify the extent of any responses and thereby the area of influence. The magnitude of the effects from an older model may not be quite correct but the pattern is likely to be reasonable. If there is no existing model then the area of influence will need to be determined by judgement and local knowledge.

Level of Detail of the Transport Network

The level of detail required for the Transport Network will probably vary across the network. For new transport infrastructure, the highest level of detail is required in close proximity to the scheme. This should include all feasible alternative routes where transport demand is likely to be affected, either in the base year or in future years.

Network Models should include detailed junction modelling in those areas where junction delays have a significant impact on demand. The inclusion of Junction Modelling within a Network Model in congested areas ensures that delay is more accurately represented, and is preferable to the use of only link-based speed-flow curves. Where an appraisal makes use of an existing model (national or regional model), it may be necessary to 'infill' the level of detail in that model in the vicinity of a proposed scheme to ensure that all effects of the scheme can be fully captured by the Network Model.

More strategic wider area models can be developed at a lower level of network detail, although in such cases more localised models may be necessary to fully define the impact of individual projects on their locality.

Definition of the Zoning System

The size and number of model zones is a critical factor in determining the realism and accuracy of a network model and also how long the model takes to run. If zones are too large, the model will be unable to reflect changes in transport demand to the required level of accuracy, however good the quality of the data. On the other hand, if the zones are too small, this increases the level of work that is required to develop a functional model and greatly increases model calculation times, which can be a problem when many scenarios and options are being tested.

It is noted that intra-zonal trips (i.e. those taking place entirely within the same zone) are not assigned onto a model network. If zones are too large, this may lead to a significant underestimation of transport flows, both on links and at junctions, and this in turn could seriously distort the pattern of flows and delays given by the model. Similar distortions, particularly in the modelling of junction turning movements and boarding/alighting forecasts at public transport stops can also occur if zone sizes are not compatible with the level of network detail included in the model. In this sense, special care needs to be taken in wider area models with major nodes which are often the source of major bottlenecks, which will not be reflected in the model if the zoning is too big.

For public transport networks, care should be taken in situations where a single zone covers multiple public transport boarding/alighting points, as the model may assign all demand to a single stop or equally without consideration of relative accessibility. In such situations, it is advisable to further disaggregate zones such that each zone is associated with a single stop on each public transport route.

In a similar fashion to the network, zones sizes should generally be smallest towards the centre or focus of the model area and increase in size the closer to the model boundary they become. They should also seek to follow, or be capable of being aggregated to, administrative boundaries as this can prove useful when using other data such as population or household information.

Vehicle Classifications

For Assignment Models, the models should be able to distinguish between different vehicle types. For road transport, the assignment should be able to distinguish between cars and goods vehicles, with 5-axle Heavy Goods Vehicles defined as an additional subset. For public transport, vehicles should be defined insofar as is appropriate, with classifications including heavy rail, metro, bus, light rail, trolleybus and taxi. Each of these categories should be subdivided further if it is considered that the vehicle type has a significant impact on user preferences.

Travel Modes

For Mode Share models (and often for Variable Demand Models), it is necessary to construct transport demand individually for each travel mode. In this regard, it is important to understand those travel modes to be included. Possible travel modes are as follows:

For Passenger Transport

- Private Car (Driver);
- Private Car (Passenger);
- Rail (subdivided by heavy rail, metro, light rail where necessary);
- Bus (again, subdivided where necessary);
- Air Transport;
- Water Transport;
- Bicycle; and
- Pedestrian

For Goods Transport

- Road
- Rail
- Air
- Waterways

It is suggested that any mode where an impact is anticipated as a result of a scheme proposal should be included as a transport mode in the analysis. In this way, the impacts on that transport mode can be accurately measured and incorporated into the assessment of scheme benefits.

Careful consideration should be made in urban public transport systems including rail modes on whether to treat modes separately in the Mode Share models. If all PT modes are considered equivalent in the assignment model, then intrinsic differences in mode quality cannot be reflected in the assignment process.

User Classes

In the modelling of user behaviour, there are substantial differences between behavioural responses for different types of demand. In order to allow these differences to be reflected in the analysis, it is therefore common to segregate demand into different user classes to which different parameter values are applied. The following user classes are recommended as a minimum:

For Passenger Transport

- Commuting Trips (travel to and from work and school);
- Business Trips (travel during work time to/from meetings etc.);
- Leisure Trips (including shopping, visiting friends etc.); and

For Goods Transport

- Freight Volumes

In practice when considering modal split a distinction should be made between users with access to a car and those without access (those without access to a car obviously cannot choose the car mode), as this is essential for accurate mode split modelling for public transport projects.

The distinction between Business and Commuting is especially relevant, as there are large differences in the perception of travel time and in value of time for CBA, and quality requirements between these user classes. Where schemes involve tolling, disaggregation of demand into income segments may also be warranted.

Freight Modelling

When considering freight, it should be considered at the outset whether freight impacts are an important part of the assessment. If changes to freight transport are envisaged as a result of a scheme, then the modelling of freight as a distinct user class as shown above is required. This will allow freight to be considered separately in terms of the mode used. Freight demand can be further disaggregated into commodity type if it is necessary to reflect the limitations and preferences of different categories of goods.

Where freight impacts are not anticipated, freight may be expressed simply as a vehicle class in the assignment. This is a far simpler process and assumes that the only impacts on freight will be changes in journey time, single mode routing or cost of existing freight transport activities.

Demographic Groups

A further disaggregation of demand may be achieved by defining those with/without car availability. This can be a useful further classification where there might be a significant proportion of people who will not be subject to the consideration of mode share between private and public transport. It is important that this distinction is made in projects where a major mode share impact is anticipated.

Time Periods to be Assessed

As the modelling process will inform the design of the scheme as well as contributing to the appraisal, the model periods should cover the times when the impact of the change is likely to lead to user benefits. For rural areas, it may be acceptable to consider a full day for the description of transport demand (it is noted that some modelling software have embedded different typical standard distributions of traffic during the day based on which the actual assignments can be done).

In urban areas or anywhere with congested network bottlenecks, the time periods should include separate representations of morning and evening peak periods, with further periods defined as necessary to cover the afternoon period and, in certain circumstances, busy periods during the weekend.

The choice of which hour(s) to use in each case should be informed by an analysis of transport data in the area. This analysis should also inform how the demand during each period should be combined in order to provide daily or annual flow estimates. For areas where seasonal traffic is a significant factor in the selection of interventions, seasonal flows should be modelled.

Data Availability

The scoping stage should examine what datasets are available to support the modelling process. This might include survey data from other studies, existing transport models, or data from national databases. Data collection represents a significant investment in the development of many transport models. As such, it is important that existing data is used effectively, new data is collected correctly, and the model development plan is consistent with the data that becomes available. The input from a skilled technical advisor is imperative in developing the data collection plan.

Choice of Modelled Years

All transport modelling should begin with the definition of a Base Year, for which conditions have been measured. Forecast years need to include, in addition to the base year, the scheme opening year and suitable forecast years. Additional years may be required if there are significant changes to the network or trip patterns in the intervening period.

Parameter Values

All functions that describe a range of behavioural responses, ranging from customer reaction to new rolling stock to the impact of economic growth on car ownership require the definition of parameter values. Parameter Values are usually defined by national transport guidance, or may be available from published international research. Where national guidance prescribes such values, these should be used. Where reference to international research is used, there is a preference for the referencing of multiple research outputs where available which describe the range of such parameter values, and an informed selection of such values is made for the project/region in question.

Mathematical Functions

Many generally accepted mathematical functions can be used in transport modelling, including elasticity models, logit functions and traffic flow theory. For software packages (in the case of, for example, junction analysis, pedestrian simulation, rail runtime simulations) the functions are inherent in the software. For more bespoke analyses, it may be necessary to derive a series of mathematical functions through research. For derived functions, it will be necessary to demonstrate that they are appropriately validated for use.

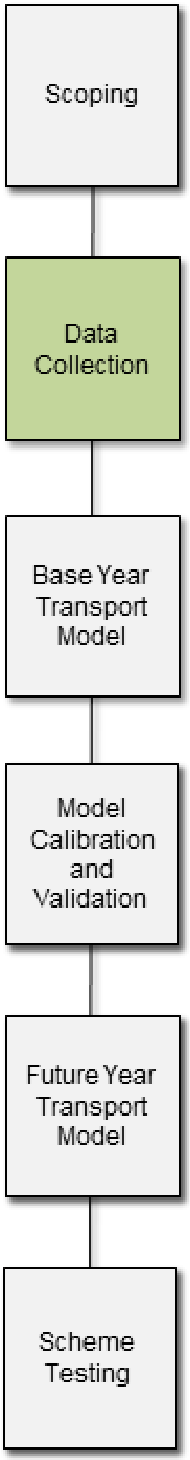
7.3. Scoping Report

The importance of a scoping exercise cannot be underestimated. The effort required to undertake the modelling task at hand may be considerable, and a good scoping exercise will ensure that the level of subsequent wasted effort can be minimised. As such, the scoping should consider all potential applications of the final model to ensure that the model structure and functionality can accommodate these.

The scoping stage should be reported in the form of a Scoping Report which will set out the outcome of the consideration of the above items. A good scoping report will present a justification for each decision, demonstrating why the modelling team considers the proposed approach to best reflect the task at hand. The scoping report should also set out the structure of the model, and its functionality. For Simple Models, the method of analysis should be described, whereas for Variable Demand Models the scoping report should set out which responses are to be modelled and the processes for achieving this. Flowcharts should be included where possible to support the understanding of the process. Finally, the scoping report should present the anticipated applications of the model and relevant inputs/outputs.

The scoping report presents the main form of communication amongst the various parties involved in the project or strategy. It represents the blueprint for subsequent model development and should be agreed with the Managing Authority prior to proceeding with model development.

8. Step 2 – Data Collection



8.1. Overview

Data collection is a relatively major element of any modelling exercise, which fulfils a number of functions:

- It provides the necessary inputs for the construction of the Base Year Model (Step 3);
- It provides the data that is required for the Base Year model Calibration and Validation (Step 4); and
- It provides the input parameters that are necessary to develop a Future Year Transport Model (Step 5).

As such, the data collection stage will generate information that will be used during each subsequent stage. It is therefore important that the requirements are fully understood such that additional data collection can be avoided at a later stage in the project, leading to delay.

Data Collection is a specialist area and is covered at a relatively high level here. In particular, the design and execution of transport surveys requires good understanding of the various techniques that are available and those that are most appropriate for a given environment. For more detailed guidance readers are advised to refer to national guidance documents where available, or seek specialist technical advice.

8.2. Sources of Transport Data

Before developing a Transport Model, it is important to fully understand the extent to which data may already be available as this can significantly reduce the required work in model development. Model development therefore typically begins with an audit of available data which may include:

- Data from any existing transport models;
- Census information on economic activities, distribution of GDP per capita (if possible), population, employment and the Journey to Work;
- Traffic count data from National, Regional or Local Authorities;
- Public transport data from operators;
- Freight data from Eurostat or National databases; and
- National statistics on car ownership, vehicle kilometres travelled, fuel consumption, freight tonnage carried by mode

When considering data from existing transport models, it is important to understand whether data emerging from those models is fit for purpose. Use of data from existing models does not imply that the data is fit for purpose. In such instances it is still necessary to undergo the necessary calibration and validation as part of the model development process.

8.3. Data Collection Techniques

The various data collection methods outlined below represent the most typical approaches used to compile the data that is necessary for a modelling exercise. Ultimately, the survey schedule should be carefully considered to ensure that the following requirements are met:

- The volume of data is sufficient to allow a model to be constructed; and
- The data is relevant to the subsequent applications of the model – for example, a model which will be required to measure subtle differences in journey time should have good journey time input data).

It is important that data collection is properly considered and well specified. Failure to collect sufficient data will lead to significant difficulties during the model calibration stage, or during the subsequent scheme testing.

The Transport Network

The transport network describes the road network, and the public transport network upon which services are operated.

The road network does not need to include all roads in the study area, only those which carry a significant volume of traffic and/or are relevant to the level of analysis to be carried out. Nevertheless, it should incorporate sufficient detail to reflect route choice within the area and may therefore incorporate minor roads which may be impacted by the proposed interventions. If an existing model is not available then a network will need to be built based on a combination of available data, and information gleaned from aerial photos or site visits. Information from navigation systems providers and Google earth/maps should be considered for this purpose. Data should be collected as dictated by the model software requirements, and typically includes:

- Length of each road link in the network;
- Speed limit, and free-flow running speed;
- Number of Lanes and capacity;
- Class of road;
- Applicable tolls;
- Restrictions on any vehicle types; and
- Other information as dictated by the chosen analysis methodology

For public transport networks, it is necessary to collect information on all public transport links in the Study Area, in addition to the locations of stations and stops. Information on links should include:

- Type of Link bus, metro, rail, light rail, waterway, etc.)
- Length of each link;
- The operating speed; and
- Other information such as timetables as dictated by the chosen analysis methodology

Databases of public transport authorities and operators can provide important sources of information. In addition, it is noted that in some locations Google maps now has embedded algorithms for public transport routes identification and provides direct information in those areas where PT operators and authorities do not have a modern database system in place.

Turning Count Surveys

Turning count surveys are designed to provide the turning movements at a road junction. Their complexity reflects the nature of the junction that is being surveyed. Turning movements at simple junctions can be counted by a small number of enumerators on site who directly record each movement in a given time period (typically 15 minute intervals) and according to a specified vehicle classification, or by video surveys with post-production analysis.

More complex or large-scale junctions may require automated Number Plate surveys or Bluetooth matching techniques in order to obtain an accurate result. In each case, observations are made on all arms into and out of a junction, expanded to total flows as necessary based on control total counts. Proprietary software can then match the numbers to provide a matrix of movements through the junction. All results obtained should be divided into maximum periods of 15 minutes and should allow classification into passenger car units. It is a normal practice to present turning count surveys by vehicle type. A typical classification might be:

- Motorcycles;
- Cars;
- Light Goods Vehicles (commercial vehicles with 2 axles);
- Medium Goods Vehicles (commercial vehicles with 3 or 4 axles);
- Heavy Goods vehicles (commercial vehicles with 5 or more axles); and
- Public Transport Vehicles (possibly divided into bus, tram).

The methodology chosen for the turning count surveys should reflect the required classifications by vehicle type.

Turning Count Surveys can include public transport vehicles (buses, trams, trolleybus) and are therefore equally important in validating the assumed public transport service information fed into the models. For improved validation of the transport model, the turning count surveys can measure persons on board public transport vehicles – either through on-board manual counting or a visual estimation or through more advanced techniques such as weight measurement devices on vehicles. Alternatively, surveys can use Bluetooth detection although in such cases a validated method for expanding the sample to a full count is necessary.

Queue Length Surveys

This type of survey is typically undertaken to calibrate a junction model or a micro simulation model. They are also sometimes undertaken to provide a proper estimate of traffic conditions at a junction which is operating in excess of its capacity. In this instance, a standard turning count would effectively measure throughput or capacity (i.e. how much traffic can get through the give way line or stop line) rather than demand. So the addition of the queued vehicles in each time period provides a more accurate picture.

Whilst these surveys are simple in principle, they can be difficult to undertake with any degree of consistency. It can be very difficult for an enumerator on site to distinguish between slow moving and queuing traffic. It is also often the case that the queue will grow quickly as capacity is exceeded, in busy situations, and it can be hard for the enumerator to determine where the end of the queue is. This difficulty is of course compounded when queues tail back through upstream junctions. Nevertheless, queue information must be collected to permit validation of junction models.

Trip Generation Surveys

Trip Generation surveys measure the volume of person-trips or vehicles that are generated by a defined area over a given period. Trip Generation Surveys might be undertaken to allow trip generation to be measured for an individual zone in a transport model, or might be used to develop generic 'Trip Generation Rates' to apply to future development expectations. Trip generation surveys that consider all transport modes are possible in certain circumstances, and can be valuable when considering multi-modal models. Household surveys provide an excellent form of Trip Generation surveys.

Link Counts

Link or passing counts are the simplest form of survey and can be undertaken manually or automatically. In the manual method, an enumerator records each vehicle or passenger passing their location by direction and according to the agreed classification.

Automatic Traffic Counts (ATC) measure the number of vehicles passing a location on a road network, and can be temporary or permanent. Where the requirement is to collect a few weeks of data, pneumatic tubes are laid across the road, either singly or in pairs. A counter at the side of the road then records when a vehicle passes over the tube by detecting the pulse of air. Where a pair of tubes is used, at a known distance apart, this type of survey can also record speeds.

A permanent ATC involves cutting loops in the road which are then connected back to roadside cabinet containing the traffic counting equipment. Depending on the nature of the loop arrangement, and the capability of the traffic counter, these installations can record vehicle number, type (either a simple length classification or a more complex profile) and speed. This type of survey is usually undertaken to assist in long term monitoring of traffic activity. Either type of ATC can provide useful supplementary information to a turning count or roadside interview (which are usually undertaken on one day only) as they can indicate whether that survey day was typical or not.

Public transport surveys can also measure the number of passengers passing a location on the network. This can be undertaken through the placement of enumerators at key points on the road network (for bus, trolleybus, light rail) or at railway stations (for metro or heavy rail). Care should be taken to ensure that enumerators capture the number of passengers passing a particular location, and not confusing this with boarding/alighting surveys.

Journey Time and Speed Surveys

Much of the economic benefits of improvement schemes typically come from time savings. It is therefore important that models accurately reflect the speed observed in reality. Knowledge of the prevailing journey speeds on links is also important when trying to code model networks such that subsequent assignments reflect route choices accurately.

Journey time information can be obtained either using number plate, mobile phone tracking or Bluetooth matching techniques as described earlier (each number plate is time stamped) or by moving car methods. The latter is more common and simply involves a survey team travelling a route at the prevailing speed of traffic. A number of timing points, usually significant junctions in the network, are chosen in advance and the time from the start to each point is recorded. On networks where there are significant differences in journey time between different vehicle types (e.g. mountainous areas with high gradients), then journey time should be measured for different vehicle classifications.

For public transport services, such information is normally collated from timetables, although some verification that timetables reflect actual travel times should be sought.

Origin Destination and Traveller Behaviour Surveys

Origin Destination (OD) and Traveller Behaviour surveys involve obtaining detailed information about individual trips in order to set up and calibrate model parameters such as trip generation and distribution parameters and also OD movements. Such surveys can take a number of forms or be part of the following including:

- Registration Plate/Bluetooth matching/Mobile phone tracking;
- Roadside Interview surveys (RSI);
- Public Transport surveys; and
- Household surveys including revealed preference surveys
- Stated preference surveys

Registration Plate/Bluetooth surveys involve the collection of registration plate details or the detection of mobile telephone signals of passing vehicles at a number of pre-determined locations at specific time periods. This allows an origin-destination matrix of movements to be generated including transit trips.

RSI surveys involve stopping drivers at the side of the road and questioning them about their trip hence the term roadside interview. They provide the best sort of data for building assignment models including transit trips but can be costly and difficult to implement safely in certain situations e.g. high-speed roads. As the survey involves stopping vehicles at the roadside, the location and layout of the survey site is extremely important and the permission and assistance of authorities will need to be sought.

Public Transport surveys to establish the origin and destination of passengers can be undertaken through interviews and/or counts on board vehicles and at stops/stations. They can also be arranged for self-completion by passengers.

Household surveys are similar to RSI surveys except the trip maker is asked to record their own trip information including quite detailed information on trip chains and motivations. Such surveys should generally be required regularly at regional or national level, motivations but are not generally used for the purpose of appraisal of an individual project. When carefully set up with the required detail, household surveys can be set up as revealed preference surveys, which can be used not only to establish O-D movements but also to set up and calibrate model parameters, such as trip generation rates, gravitational model coefficients, generalised cost model weights or modal shift scaling parameters. National census data contains significant data on origins and destinations of regular trips, which can be a solid base of data for models. Such surveys do not provide information on transit trips external to the population sample.

Interview surveys capture a sample of the population in the study area and obtain detailed information about the nature of their trip. For interview methods, surveys will generally include questions about:

- Trip origin;
- Trip destination;
- Trip purpose;
- Travel time (start, end)

- Travel Mode(s)/full travel chain; and
- Number of people in the vehicle (in the case of cars);

In addition, it has been found that some free text to collect opinions and suggestions from people can be useful. In the case of self-completion questionnaires the ability to provide such information can increase the response rate.

One of the main benefits of interview techniques is the ability to capture data on trip purpose. Accurate information on trip purpose is essential where it is intended that higher values of time are to be applied to those involved in Business Trips. Benefits to such users can represent a significant element of the economic case for a project.

The number and scope of questions in an interview survey will depend however on the information needs, the mode of survey and method of support. More detail will mean a lower questionnaire return rate without more follow up support from the interviewer.

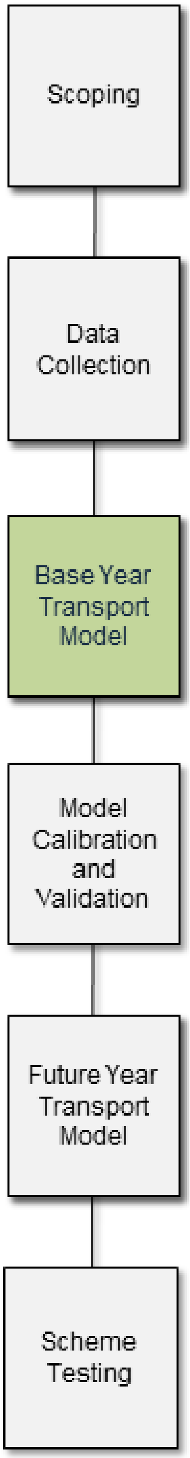
Surveys undertaken using interview methods must ensure that the questionnaire is structured in a way that allows declared origins and destinations to be related to zones as defined in the transport model. The size of the sample shall be determined according to standard statistical methods and the desired/expected level of accuracy.

Stated Preference surveys provide information on the hypothetical intentions of trip makers when presented with a number of choices to make. Stated Preference Surveys are normally undertaken in order to set model parameters such as relative values of travel time or modal shift sensitivities and inform behavioural models such as willingness-to pay, most relevant in the planning of tolling schemes. These studies are undertaken with a controlled group of pre-selected interviewees and require careful and expert execution in order to reveal likely actual behaviour. In general outcomes of stated preferences surveys can be optimism-biased, and sometimes unreliable when surveys are not correctly designed and/or managed.

Common across all origin-destination survey techniques is the requirement for a control total. This control total is necessary to allow the sample to be extrapolated to a full dataset which can then be used in model development. For example, a survey of passengers boarding at a railway station may capture 300 users during a single day, which will represent only a proportion of the overall total for that day. A count of the full volume of passengers for that day is necessary such that the dataset of 300 responses can be expanded to represent the full population.

9. Step 3 - Constructing the Base Year Transport Model

9.1. Overview



Where transport models are intended to estimate changes that will occur as a result of transport interventions, the construction of a base year model is a normal requirement. This involves the development of a representation of existing demand established through surveys or research, and forms the basis for testing the impacts of transport or policy interventions. The advice presented here provides an overview of the key activities when developing a Base Year Transport Model.

9.2. Network Building (For Network Models)

Network descriptions for Assignment Models or Variable Demand Models will often need to include details for both public and private transport networks. Network links are generally described in terms of:

For the Road Network

- Nodes at each end of the link (i.e. junctions or changes in standard);
- Geometric information on the link, as captured from the network surveys;
- The speed-flow relationship (if any) appropriate for the link;
- Link capacity (if not defined by speed-flow relationships or junction details); and
- Any restrictions to particular vehicle types using the link.

For the Public Transport Network

- Nodes at each end of the link;
- Geometric information on the link, as captured from the network surveys;
- Public Transport Systems using the Link;
- Service speeds; and
- Stop Locations;

The requirements for junction coding may arise in urban areas or on congested networks, and should include:

- Junction type (traffic signals, roundabouts, priority);
- Number of approach arms, and their order (in terms of entry link references);
- Number and width of traffic lanes on each junction approach, and the lane discipline adopted (including prohibited turns); and
- Any additional data required to describe the operational characteristics of the junction (e.g. saturation flows, signal timings and phasing, turning radii and gap acceptance characteristics).

Coding a network can be a large undertaking, particularly for larger models. It is therefore recommended that any existing models should be considered for use as a starting point in coding the transport network – it is generally possible to import networks between software packages. Alternatively, it is possible to purchase network information as vector maps from commercial suppliers.

9.3. Public Transport Services (For Network Models)

Public transport services are coded to network models on the basis of paths (including stops) and either timetables or frequencies. With timetabled data, travel time is established by the models using the timetables. With frequency data, the travel time is established through the interrogation of link speeds and defined dwell times at stations.

Care should be taken when deciding on the preferred approach – the use of timetables can require significant recoding of timetables in order to assess the impact of a speed increase on one section of line. On the other hand, coding headways cannot reflect irregular timetables which can exist on public transport routes (both long and short distance).

9.4. Zone System (For Network Models)

Where network models are used, there is normally a requirement to overlay the model zone system onto the transport network, and define the zone connectors. The zone connectors identify those locations where demand arising from a zone will appear on the transport network.

In a simple example where a zone represents a single development site with a single access to the road network, then the definition of the zone connector is relatively straightforward. For typical situations, however, where a zone represents an area of mixed development and a number of roads and public transport services, a number of zone connectors may be necessary to distribute demand across the network in the vicinity of the zone. Zone connectors should not be connected directly into modelled junctions, unless a specific arm exists to accommodate that movement.

9.5. Matrix Building

Transport models generally represent transport activity in the form of demand matrices. The construction of a demand matrix from first principles is challenging, and is generally more difficult than the construction of a demand matrix where some existing or partial dataset is provided. In general, there are three approaches available in developing the demand matrix:

- To construct the demand matrix directly from survey data where good origin-destination information is available (e.g. on railway networks or on road networks with good coverage of survey information);
- To start with an existing demand matrix (e.g. an older matrix or a matrix from a different model) and to manipulate that matrix until it reflects current conditions. This manipulation is undertaken using a tool available within many Macrosimulation models and uses survey data to achieve the final outcome (see Task 3 – Calibration and Validation); or
- To develop a demand matrix from first principles, using the survey data to assist with the development of the trip generation, distribution and mode share functions. This option is particularly relevant in the case of Variable Demand Models;

The development of a matrix from first principles involves a number of stages as set out below. Whilst presented separately, it may be possible to combine or skip the various stages depending on the data that is available. In such case, it is necessary to demonstrate that each of the specific requirements has already been fulfilled.

Trip Generation

Trip Generation involves a calculation of the total number of trips departing each transport zone, and arriving into each transport zone, sometimes referred to as ‘Trip Ends’. Separate trip end calculations may be undertaken for each trip purpose / demographic grouping pair. Trip Generation may be established using demographic and economic parameters and network condition, applying Direct Demand functions to convert these into Trip Ends at zonal level. This form of representing demand is the accepted method of modelling demand where there is a requirement for Variable Demand Modelling (where the condition of the network is also an input to the Trip Generation calculations).

Alternatively, for smaller or more localised networks, Trip Generation can be developed through an estimate of the quantum of different development types (residential, commercial, leisure) and the application of Trip Rates. This gives a static representation of demand, and is therefore not suitable for Variable Demand Models.

Whichever approach is used to derive Trip Ends, the parameter values used must be verified either with reference to academic literature, previous studies of a similar nature, or with reference to survey data. In deriving Trip Generation, at least the following trip purposes should be adopted in the appraisal of transport projects:

- Commuting Trips (Journey to/from work/school);
- Business Trips (journey in the course of work);
- Leisure Trips (shopping and personal business); and
- Transport of Freight (expressed as tonnes).

In the case of Variable Demand Modelling, this schedule of trip purposes/demographic pairs may be increased to suit the requirements of the final transport model.

Also, note that where Demographic Groups are defined (e.g. car available/car non-available) then the trip purposes for passenger transport need to be defined by demographic group.

There may be cases where large datasets on Trip Generation are provided directly from available data (e.g. census information). In such cases, validation of the data is not required, although it is necessary to demonstrate that the dataset is complete. For example, census information might provide information on commuting only, and National Household Travel Surveys can provide information on all trips, they only include a sample of the population. In both cases, further work is required to derive a dataset that represents all trip activity.

Note that Trip End calculations will include double counting. For example, a trip between Zone A and Zone B will be recorded as a Trip End for Zone A and Zone B. This double counting is normally removed during the Trip Distribution Stage of matrix development.

Trip Distribution

Trip Distribution describes the process of allocating Trip Ends for a particular zone to all other zones.

Although a number of methodologies exist, the ‘Gravity Modelling’ approach is a common one, which defines probabilities of travel to alternative zones on the basis of the relative attraction of each zone (total Trip Ends) and the impedance of travel between those zones (the distance or travel cost). It is stressed, however, that whilst gravity modelling is theoretically sound, that the development of an accurate gravity modelling function is extremely difficult. The development of synthesised Trip Distribution requires survey information to enable the various parameters to be calibrated, and is a necessary input to produce a robust demand matrix. In this regard, Origin Destination Surveys provide a good means of establishing trip distribution.

Ultimately, the construction of the demand matrix requires a combination of survey data (which provides a partial dataset and can be used to set key parameters), and matrix manipulation. Matrix manipulation allows a partial dataset to be expanded to represent a full dataset, and can use a number of approaches as follows:

- Data factoring, whereby the incomplete matrix is scaled to Trip End totals for each zone;
- Matrix infilling, which relates to the estimation of unobserved trip movements, either by using parts of another matrix, or by the use of a synthesised model (e.g. gravity model); and
- Other matrix manipulations required to obtain origin to destination matrices for assignment such as matrix estimation techniques.

The actual method used for matrix building will depend on the quality and completeness of the available datasets, and based on an examination of how they can best be combined to produce a full demand matrix.

Ideally, the trip purposes defined in the Trip Generation stage should also be carried through the Trip Distribution and the subsequent matrix construction processes.

During the Trip Distribution stage of matrix development, it is necessary to remove the double counting. This process leads to the translation of the demand matrix from a ‘Production Attraction Matrix’ to a ‘Trip Matrix’. This can then be assigned to the transport network and results compared with observations of network condition (see model calibration and validation).

Mode Share (For Mode Share Models)

Where Mode Share Modelling is included in the model functionality, there is a requirement to establish the base year transport demand by each transport mode. Mode Share modelling can use one of two approaches:

- **Absolute Mode Share Modelling**, where a mode share function allocates demand between each origin destination pair to individual modes on the basis of the generalised cost of travel for each mode option and the sensitivity of Mode Share to differences in generalised cost; and

- **Incremental Model Share Modelling**, where the Base year mode share is calculated directly, and the model seeks to reallocate demand between different travel modes on the basis of the relative change in the generalised cost of travel for each mode option and the sensitivity of Mode Share to changes in generalised cost. This form of modelling is more appropriate when the changes in travel costs are relatively small.

Whichever approach is chosen, the user is required to establish the existing travel demand by each relevant mode between all origin-destination pairs. The resulting analysis produces a demand matrix for each of the travel modes which can be used to inform the development of the mode share functions.

Variable Demand Functions (For Variable Demand Models)

In the case of Variable Demand modelling, the functions that influence demand are important in the matrix development process. Typically, Variable Demand functions draw information on the state of the network following an assignment and use this to modify Trip Generation, Trip Distribution, Mode Share and sometimes the timing of trips. Variable Demand Modelling is a challenging process and would normally seek available literature or comparable models in the development of the relevant functions. The scope of the variable demand responses should include all those where impacts are to be quantified for the project appraisal. In developing the functions, reference should be made to academic literature or to national guidance in the selection of parameter values.

Freight Modelling

The basic steps of modelling in the guidance (data collection, networks, calibration and validation, testing) apply to freight as well as non-freight.

Where modelling of freight responses is required, freight matrices can also be constructed. In the preparation of Trip Generation and Trip Distribution for freight, it is normal practice to segregate freight by commodity and by type of transport (e.g. container/bulk), with the distinctions set on the basis of the specific model purpose and availability of data. This segregation can allow the specific preferences associated with different types of freight to be reflected in the mode choice and assignment stages, and in the variable demand functions (if any).

The means of segregating and assigning demand will differ from project to project. JASPERS can offer project-related support on a case by case basis or point users to more comprehensive guidance.

9.6. Running the Models (Assignment)

Once the matrix has been constructed, the next stage is to 'assign' or 'load' the trip matrices on to the network. This can include the Mode Share and Variable Demand processes if relevant to the model.

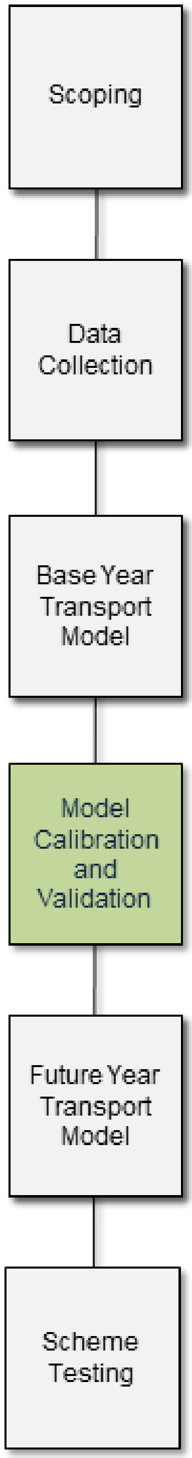
Within the assignment module, each trip will choose the best route through the network for its relevant travel mode based on a combination of time and cost – which in general is reduced to a generalised cost function which uses time as a common measure. The results of this assignment then define the network condition.

Clearly, as more trips are loaded on to the road network, speeds will fall and the choice of mode and route may change (as might the Trip Generation and Distribution). For this reason, the results of the assignment are fed back to the Trip Generation, Trip Distribution and Model Share stages of the model and the process is repeated

The model outputs from this step provide the first representation of network conditions in the Base Year transport model, but may not necessarily reflect reality. It is for this reason that a further Calibration and Validation stage is required which aligns the base year model with actual base year observations.

10. Step 4 – Base Year Model Calibration and Validation

10.1. Overview



Validation and calibration are separate concepts although they are frequently confused with one another. Two accepted definitions are as follows:

- Calibration – the estimation of the parameters of a chosen model by fitting to observations; and
- Validation – the assessment of the validity of a calibrated model, either by the comparison of estimates produced by the model with independent data, or by the direct estimation of the accuracy of model estimates.

It is necessary that the information used in calibrating the model, including count data for matrix estimation, is kept separate from that used for validation if the validation is to be a true independent test of the model.

In reality these two elements are part of an iterative process. If the results of the validation checks are not satisfactory, then the modeller should review the inputs and coding within the model and re-calibrate as required in order to achieve a better representation of reality. The number of iterations required is usually proportional to the complexity of the model.

10.2. Model Calibration

Overview

For a junction model, calibration may involve adjustments to theoretical saturation flows and/or junction geometry to ensure that observed queues and delays are reflected in the model. In the case of more complex assignment, mode share or variable demand models the number of parameters and data elements clearly increases. The following represent some of the more common elements that may require adjustment as part of model calibration:

Road Network

- Road capacities
- Detail of the road network
- Traffic signal timings
- Speed flow relationships
- Junction capacities
- Location of zone connectors
- Representation of tolls
- Route Quality Indices

Public Transport Network

- Public transport mode constants
- Waiting, interchange and in-vehicle weightings
- Representation of fares
- Location of zone connectors

Demand Matrices

- Demand matrices for each transport mode

Other Elements

- The generalised cost function
- Economic parameter values (if permitted)
- Zone sizes

It is good practice to avoid manipulation of the demand matrices until all other possible modifications have been made. In this way, the modeller can be assured that the network coding and the relevant mathematical functions are operating correctly. This will avoid a situation where a matrix manipulation seeks to find a matrix that hides errors in the network coding or assignment functions.

The adjustment of the demand matrix is often undertaken using matrix estimation techniques available as part of most assignment software packages. These techniques take a prior estimate of the trip matrix and then adjust that in order to match a set of 'target' observed counts as obtained from the survey data. Care must be taken with this sort of approach as matrix estimation will almost inevitably result in a solution but it is rarely a unique one. It is therefore necessary to ensure that sufficient count data is held back from this process to enable an independent check to be undertaken as part of the validation process.

Calibration Standards

Following a calibration exercise, it is necessary within network models to compare how the model reflects the calibration data that has been input (link flows, journey times etc.). In undertaking the comparison, the magnitude of the observed volume is clearly important when deciding on what is a reasonable error. Therefore, in addition to considering percentage or absolute differences, the GEH statistic (a form of the Chi-squared statistic) is also used as it incorporates both relative and absolute errors. The GEH statistic is defined as:

$$GEH = \sqrt{\frac{(M - C)^2}{0.5 \times (M + C)}}$$

where M is the modelled flow and C is the observed flow.

The criteria and associated acceptability guidelines to be used in the calibration of models are outlined in Table 10-1. The units for comparing modelled and observed flows may be vehicles, passengers or freight tonnage on links.

Table 10-1 Calibration Criteria

Criteria and Measures		Acceptability
Comparison of Assigned Demand		
1	Individual vehicle, passenger or freight demand within 15% of observed counts.	More than 85% of cases
2	Total screen line flows to be within 5% of observed counts.	
3	GEH statistic: (ii) individual flows : GEH < 5 (ii) screenline totals : GEH < 4	More than 85% of cases
Comparison of Journey Times		
4	Times within 15% or 1 minute if higher.	More than 85% of cases

It is accepted that achieving the above results may not always be possible in very complex or more strategic models. In such cases, it is possible that the data is insufficient or of poor quality, or there are inherent deficiencies in the model. Nevertheless, the inability to meet these targets does not always suggest that the model is not fit for purpose.

10.3. Model Validation

Overview

The process of model validation determines how well the model estimates compare with reality as reflected by observations made on the ground.

When presenting validation evidence, the estimated accuracy of the survey observations should be quoted whenever possible and that of model estimates where available. Providing information on the estimated accuracy will allow meaningful conclusions to be drawn (e.g. the average of the model estimate lies within the 95% confidence interval of the independent observation).

The output from the model run assignment model can be used to assess the performance of the whole modelling process although it should be remembered that any poor performance may be due to a number of factors including:

- Errors in the trip matrix;
- Coding errors in the network; and
- Incorrect route choice parameters.

The types of validation checks which may be undertaken on a model are dependent on the model form but typical examples include the comparison of model outputs and observed data for:

- Average trip length and trip length distribution (for validation of the gravitational distribution model)
- Total demand by travel mode;
- Flows on individual roads and public transport links;
- Passenger, vehicles or freight flows across screenlines or cordons;

- Passengers boarding and alighting at key stops/stations;
- Journey times along critical routes; and
- Routeing through the network.

It is stressed that if a model is to be used for measuring journey time savings, then a robust journey time validation is necessary. Likewise, a model that will estimate mode share impacts will require a robust validation of Mode Share results for the Base Year model. Any intended function of a model requires that function to be validated during this stage of the model development process.

Validation Standards

The two elements of assignment validation are comparisons with traffic counts and journey times. The count comparisons can be done at an individual link level or by looking at groups of links as screenlines. The units for comparing modelled and observed flows may be vehicles, passengers or freight tonnage on links. Criteria are outlined below.

Table 10-2: Validation Criteria

Criteria and Measures		**Acceptability**
Comparison of Assigned Demand		
1	Individual vehicle, passenger or freight demand within 15% of observed counts.	More than 85% of cases
2	Total screen line flows to be within 5% of observed counts.	
3	GEH statistic: (ii) individual flows – GEH < 5 (ii) screenline totals – GEH < 4	More than 85% of cases
Comparison of Journey Times		
4	Times within 15% or 1 minute if higher.	More than 85% of cases

It is important though to note that these are purely guidelines. A model that does not meet these criteria may still be considered acceptable if the discrepancies are within survey accuracies and the more significant discrepancies can be shown to be not important to the scheme. Similarly, a model that meets the criteria but which has significant discrepancies on the key links may be considered unacceptable. The onus is on the modeller to use the Transport Modelling Report as a means of making the case in the Transport Modelling Report that the results of the modelling work are robust and fit for purpose.

In addition to the above criteria, a supporting analysis of the representation of travel patterns, routing, response to changes in the network coding and sensitivity within a model can demonstrate that a model is of suitable quality. In this regard, it is necessary to provide a demonstration of such outputs as part of the reporting (see 'Reporting').

Fitness for purpose will be influenced by the stage the project has reached. As an example, at pre-feasibility, the model must be capable of providing a platform whereby alternative schemes can be assessed on a consistent basis. At feasibility stage, when the model is to be used to determine the preliminary design, and the requirements of land acquisition, the ability to identify the detailed impacts of the scheme will be more important.

In all cases, data used for model validation should use a dataset that covers the full network, with increasing intensity in those areas of particular sensitivity or significance.

Realism Testing

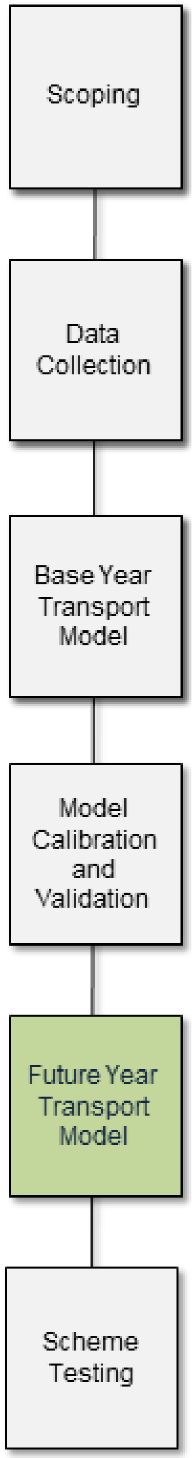
Realism Testing describes the process by which a defined scenario is tested in a transport model to generate outputs that can be used as part of the Validation. The use of Realism Testing allows the operation of the Assignment, Mode Share and other Variable Demand Responses to be tested in a situation where there are substantial changes to transport supply or demand. Validation of the outputs of Realism Tests can be achieved through comparison with historical observations, reference to published literature, or benchmarking with other studies. Realism tests include:

- Provision of major new road/rail routes;
- Introduction of road pricing/tolling on key corridors;
- Changes in public transport fares;
- Changes in fuel price;
- Significant change in public transport services.

Where data exists, it is beneficial to undertake the validation as per the guidance provided above. Where historic data is not available, outputs can be benchmarked against other studies, or against anticipated responses based on international research. Obviously, the testing of actual historic projects as part of the Realism Testing provides a good context for demonstrating the robustness of a model.

11. Step 5 – Developing Future Year Transport Models

11.1. Introduction



Whilst a Base Year Model provides a reflection of current conditions, it is normally necessary to understand the impact of transport investments or policies some years into the future.

In developing future year model scenarios, the user normally seeks to develop a 'Do-Minimum' or 'without project' model. The 'Do-Minimum' describes the most likely scenario that will exist in a defined future year, without the proposed policy intervention or investment. Comparing this Do-Minimum against a scenario with the proposed intervention or intervention options (known as the Do-Something[s]) then provides a picture of the impacts of a project on the transport system.

There are various elements which need to be considered when constructing a Future year Transport Model. These include:

- Changes in travel demand;
- Changes in the transport network and transport services; and
- Changes in modelling and policy/economic/land-use parameters that influence user behaviour.

11.2. Growth in Travel Demand

Forecasting of transport demand should be based on a logical explanatory model of the world and not just an extrapolation of the past. In this regard, there are a number of factors which drive growth in travel demand such as population growth, general economic growth and increases in car ownership.

The structure of a transport model will dictate how such growth is incorporated into the model. For models that are based on Trip Matrices, growth resulting from such changes is calculated externally and input to the models in the form of changes to the trip matrix. More complex Variable Demand Models use Direct Demand equations, where growth is incorporated to the model through increases in population, employment, car ownership, economic activity, GDP etc. In both cases, the factors applied must be derived based on past experiences in sufficiently similar conditions (e.g. using multi-variate regression analysis) or through more theoretical models which should be backed up with sufficient evidence or consensus opinions.

Assessing the growth in travel demand requires the modeller to be aware of likely growth in demographic and economic inputs. In this regard, the use of information on factors driving growth in transport demand (population, employment, car ownership, GDP, etc.) from official sources is beneficial. For regional or local models, population and economic growth rates can sometimes be overestimated, leading to an unrealistic representation of the future scenario. The modeller should seek apply growth forecasts that have been derived from national assessments of growth. This will avoid situations whereby individuals regions make excessively optimistic assumptions regarding their ability to capture a high share of national population or employment growth.

Incorporating growth in demand is normally done at zonal level. In this way, the future trip matrix is achieved either through re-running the Trip Distribution models, or through manipulation of the base year trip matrix to achieve target trip ends (where Production Attraction Matrices are not used).

In areas where growth is likely to be uneven across the transport network, the use of global matrix growth factors to develop future year trip matrices generally does not provide an accurate representation of how growth might occur, and should not generally be the basis of scheme appraisal. Examples might comprise projects in areas where growth is anticipated in specific development zones.

Forecasting is a very uncertain business and it is common in more advanced modelling / design / appraisal exercises to form demand forecast scenarios or high/low forecasts expressing likely upper and lower forecast bounds as the basis for CBA risk analysis.

11.3. Changes to Transport Supply

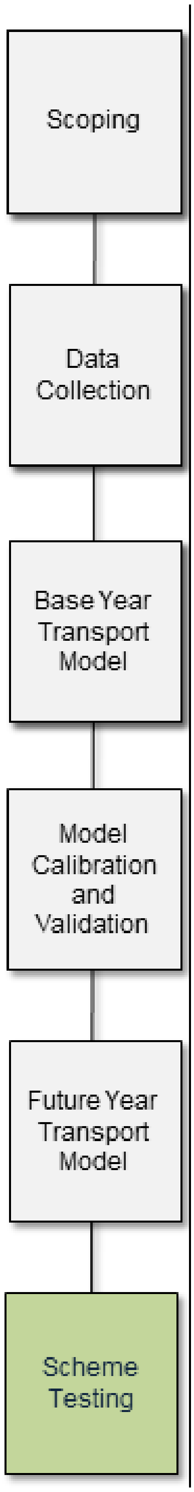
In addition to the scheme which is being appraised, there will be invariant future changes to the transport network and/or public transport services which are forecast to occur irrespective of whether or not the scheme progresses. It is important that these changes are reflected in any network coding so that the Do-Minimum is properly reflected.

11.4. Parameter Changes

Most of the parameters which are subject to change over time, such as the price of fuel, are generally of more direct importance to economic appraisal rather than modelling per se. However, if any of these have been used in the development of the base model, e.g. to determine the appropriate balance of time and distance for route choice parameters in assignment models or trip generation based on generalised costs, then changes to these should be reflected in the future year assignments.

12. Step 6 – Scheme Testing and Outputs

12.1. Procedure for Scheme Testing



Testing of transport investments and policies normally begins after the completion of the future year models. A well-developed model will facilitate a more efficient testing stage, as it is more likely to deliver sensible and reliable outputs. Where scheme testing highlights unusual behaviour in the transport models, this behaviour should be investigated as it may point towards some flaws in the demand matrix, transport network, or calculation methods.

12.2. Model Outputs

The testing stage of a project generates outputs which are used in the assessment of impacts and in the Cost Benefit Analysis.

Assessment of Impacts

Impact Assessment describes the process by which the positive and negative impacts of a proposal are quantified. Impacts may be global (network wide), or may be local. Although global impacts are generally quantified as part of Cost Benefit Analysis in order to understand the economic case, project impacts should also be understood in order to understand firstly how a project is meeting its objectives, and secondly whether there are any significant impacts that require mitigation. Impacts might include:

- New traffic flows on a proposed road, or passenger/freight volumes on a proposed transport corridor;
- Changes in vehicle, passenger or freight flows on the entire network;
- The emergence or dissipation of any bottlenecks elsewhere on the transport network;
- Significant changes in travel patterns, mode split and or generalised journey costs / journey times;
- Emerging desire lines along corridors or between specific transport zones; these represent the basic input for analysis of new potential corridors to be served or to be increased in capacity; and
- Any significant increases or decreases in noise and/or emissions.

The Impact Assessment will generally support the preparation of a discussion on the impact of the proposed measure within a Feasibility Study, and can form the basis for the Environmental Assessment for a major project, or for the Strategic Environmental Assessment in the case of a Transport Plan or Programme.

Cost Benefit Analysis

The transport modelling outputs that feed the Cost Benefit Analysis will depend on the scheme being examined, and the range of inputs that are to be assessed. In addition, the format of information will depend on the chosen approach to CBA. For example, economic modelling tools which offer good compatibility with transport models will require output skim matrices and demand matrices from the transport models. Generally, the more relevant, direct information (such as OD-relations, matrices of travel times, generalised costs etc.) that can be transferred automatically from a well calibrated transport model to the economic model, the better, as it avoids the need for less accurate estimates of the economic modelling team.

Typically, standard outputs would include the following data for each time period:

- Travel demand by mode and by users category;
- Generalised cost or journey time information, expressed either as a skim matrix or as a global network total for journey times, expressed by user class and travel mode;
- For public transport modelling, generalised cost or journey time information should be presented separately for access time to stations/stops, waiting time/interval convenience time, in-vehicle time, egress time by mode and user class;
- Total network person km or vehicle km, expressed either as a skim matrix or as a global network total for journey distance, expressed by travel mode;
- Total emissions (where these are calculated in the model); and
- Total accidents (where these are calculated within the model).

It is essential that the form of the model outputs to undertake the CBA is defined in the Scoping Report for the Transport Model, and agreed with the team undertaking the CBA.

Further guidance on the preparation of Cost Benefit Analysis is set out in the *"Guide to Cost Benefit Analysis of Investment Project: European Commission: July 2008*". Note that an update to the European Commission CBA document is anticipated during 2014.

13. Reporting Requirements

13.1. The Need for Documentation

It is crucial that any transport model is not a "black box" for project justification. The modelling process, input data, assumptions and outputs should be fully and transparently justified and documented to allow external review and understanding. The following deliverables should be generated from a transport modelling exercise:

- A Transport Modelling Report;
- A copy of the Transport Models, plus a shapefile version of all modelled scenarios where network models are employed, where the models are to be handed over to the contracting Authority; and
- The Model Manual where the models are to be handed over to the contracting Authority

Note that the above deliverables are produced in addition to any Feasibility Study or Cost Benefit Analysis reports that may be produced as part of the project preparation.

The reporting should contain as much graphic outputs as possible from the model, e.g. zoning, network, counting/surveys, traffic flows, main O/Ds, traffic flows, validation results.

It is preferable that Intellectual Property associated with any modelling project (i.e. the Transport Models) is handed over to the Contracting Authority following the project. This reflects the significant expenditure of the contracting authority in the collection of data and the development of the model, particularly where the Terms of Reference includes a budget for model development.

13.2. The Transport Modelling Report

The Transport Modelling Report is the key deliverable that sets out the work associated with the development of the Transport Model. The Transport Modelling Report should be structured as follows:

- Introduction – an overview of the context of the project/proposal and the purpose of the transport model. This might include a discussion on the background of the selected study or investment, and the current stage of the project (pre-feasibility, feasibility or implementation stage). This section should also set out the software proposed for developing the model, and the proposed functionality of the model (see Table 3-2 of this document);
- Data Collection – define the study area, the surveys that were undertaken, and the result of the surveys. Also refer to other data that is used in the development of the demand forecasts. Survey information should be provided in an appendix to the report or on an accompanying CD;
- Transport Network – describing the transport network that is being examined in the analysis of demand. This should be shown clearly, as it defines that area within the effects of the proposal are captured in the CBA;
- Transport Demand – a report setting out how the base year transport demand has been derived, including details of all calculations, processes and a summary of key inputs and outputs. Naming conventions used in defining matrix files should also be set out;

- Calibration and Validation – the process used to verify the quality of the base year models, including a table showing the comparison of observed and modelled information, and a report on the realism testing;
- Traffic Forecasting – the process used to generate future year demand for use in the testing of projects, either through land use changes, population growth, and the effects of other projects. Network plots or schematic diagrams should be included showing vehicular and passenger flows on links within the relevant study area; and
- Summary – a summary of key data from the models, setting out matrix totals, network vehicle kilometres, network passenger kilometres, and network journey time. This information should be displayed for each of the modelled years, and should be presented for each time period, user class, vehicle type and travel mode as appropriate.

13.3. The Transport Model and Shapefiles

The Transport Model should be provided in digital form along with relevant instructions for opening and running the model. For network models developed using specialist software, shapefiles should be prepared for each model scenario and supplied along with the model. Shapefiles for transport zones should include all demographic and economic information within each zone that has been used in the analysis.

13.4. The Model Manual

For the more complex models there may be a requirement for a model manual. The manual will set out the procedure for opening and running the model, and for the modification of parameters. This document is essential where models combine analysis from different software tools and where there is a requirement for the modeller to manually undertake each stage of the modelling exercise. Where scripting is used to drive the model (e.g. Python), this should be included in the Model Manual, along with a non-technical explanation of each section of code.

Recommended Further Reading

MOTOS Handbook containing guidelines for constructing national and regional transport models: Transport Modelling – Towards Operational Standards in Europe, May 2007
http://www.transport-research.info/Upload/Documents/200909/20090928_091637_67695_MOTOS%20-%20Handbook.pdf

Transport Appraisal Guidance Unit 3.1: Modelling: Department for Transport (UK): June 2003 to June 2005
http://www.dft.gov.uk/webtag/documents/expert/unit3.1.php

Methodological support to the Preparation of National and Regional Transport Plans and the related Ex-Ante-Conditionality to the 2014-2020 Programming Period : JASPERS, June 2014
http://www.jaspersnetwork.org/plugins/servlet/documentRepository/displayDocumentDetails?documentId=221

Glossary of Terms

It is recognised that the terminology for transport modelling terms may differ between different jurisdictions. As such, a glossary of technical terms is provided here.

Links	Individual section of the transport network (i.e. section of road, rail or waterway) in a transport model, and which contains all relevant information on the characteristics of that link
Transport Zones	A geographical area within a transport model where transport activity may start or finish
Zone Connectors	The mechanism for connecting zones to links in the transport network
Origin Destination (O-D) Matrix	A means of representing individual trips between origin and destination zones in a transport model. The total of all cells in an Origin Destination Matrix will be equal to the number of trips undertaken in a transport system.
Generalised Cost	A means of representing the “cost” of travel between two points, which incorporates the value of travel time including time in and out of vehicles and waiting/inconvenience time, along with fares/tolls, all converted into a single comparable trip costs. Used as the basis for assignment of trips to destinations, routes and modes. In simple cases is often reduced to travel time or distance.
Do-Minimum	A term used to describe a future situation where only committed projects are assumed to occur, and against which a with-project scenario is compared
Trip Generation	The method of deriving the total number of trips generated by a transport zone
Trip Distribution	The method of allocating trips to an OD matrix
Mode share calculation	The splitting of trips between modes for each OD relation based on probability models reflecting the generalised cost of relation per mode
Route assignment	The method of allocating network routes for trips between transport zones
Static Demand	Models which do not assume any change in the quantum of travel demand as a result of transport infrastructure or policy interventions
Variable Demand	Models which measure a change in the quantum of travel demand as a result of transport infrastructure or policy interventions
Calibration	The process of adjusting the various elements of a base year transport model such that it will fit sufficiently with observed data
Validation	The process of comparing a calibrated base year transport model with independent observed data to understand if it sufficiently reflects reality
Prior Matrix	The demand matrix that is developed using data from surveys and other sources, but prior to undertaking calibration
User Classes	Categories of journey purpose, normally including commuting, business, leisure and freight as a minimum
Vehicle Classes	Categories of vehicle type
Matrix Estimation	The process of manipulating a matrix such that the output is consistent with observed data
Matrix Factoring	The application of global factors to increase or decrease a demand matrix
Matrix Infilling	The process of adding data to a demand matrix where there are gaps in the data within the matrix
Synthetic Matrices	Matrices constructed using theoretical relationships with limited reliance on survey data.