Contents

Volume 4 - Analytical Framework & Model Descriptions: Part B

Part B Road Map

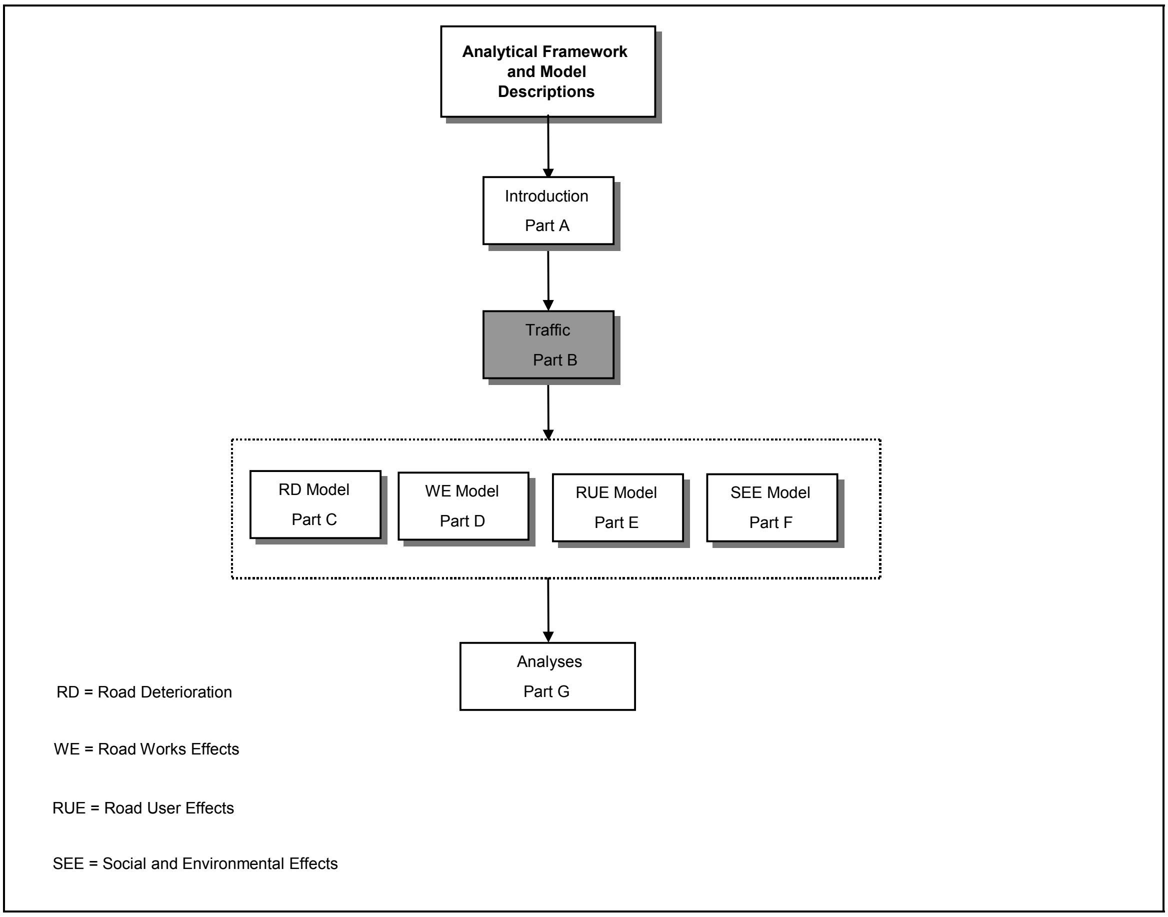

Figure B Analytical Framework and Model Descriptions Road Map

B1 Traffic characteristics

1 Introduction

This chapter describes the traffic characteristics used in HDM-4, and provides details of the traffic data that are required. These include the methods used for calculating future traffic and axle loading together with the approaches for modelling traffic congestion. The traffic data are used in all four sets of HDM-4 models (Road deterioration, Works effects, Road user effects and Social and environmental effects, see Figure B).

As travel demand varies both in time and space, traffic data should be representative averages for a road section. The representation of traffic needs to be at an appropriate level of detail in accordance with the type of analysis (project, programme or strategy) to be performed.

A list of research documents referenced from this chapter is given in Section 8.

2 Representation of traffic

2.1 Purposes of traffic data

The results of economic analyses are quite sensitive to traffic data, and most benefits that justify road improvements arise from savings in road user costs (see Part E). To perform economic analyses in HDM-4, traffic characteristics of roads therefore need to be described and represented at an appropriate level of detail.

Traffic characteristics need to be represented for the following analytical purposes:

- **Project analysis**

  This requires a detailed representation of traffic characteristics on the road being analysed. For each road section, the representation should include data items that describe the details of changing traffic composition and volumes, axle loading, capacity and speed-flow relationships, hourly traffic flows, traffic induced by road improvements, and of demand shifts.

- **Programme analysis**

  The required traffic data for this type of analysis is similar to that for project analysis, with the exception that the data is at a more aggregate level (see Applications Guide). For example; traffic volumes may be specified by vehicle classes, and the data could be used by several representative road sections.

- **Strategy analysis**

  This requires the specification of an aggregate set of traffic data, that is representative of a group of road sections being analysed. Traffic levels should be expressed in terms of daily flows, and may be described as **low**, **medium**, or **high**. The composition of traffic may be expressed as a percentage of daily flow for each vehicle class/type.

For the purposes of representing traffic characteristics both for project and network level analyses, road sections within a network must be categorised according to the following:

- **Road types**

  For example, single lane roads, four-lane roads, motorways, etc. This data is used to determine the parameters for capacity, speed-flow relationship shape, width effects and passenger car space equivalents for each road type.

- **Traffic-flow pattern**

  For example; commuter, recreational, inter-city, etc. This data is necessary for describing the patterns of traffic flow along each road category; commuter routes, for example, tend to have weekday peaks but low weekend traffic, whereas recreational routes have a more peaked distribution.

- **Non-motorised transport factor**

  Measures the effect of non-motorised transport (for example, bicycles, animal-drawn carts, pedestrians, etc.) on motorised traffic speeds.

- **Roadside friction**

  Measures the effect of roadside activity on traffic speeds; this includes the effects of land use, roadside stalls, bus stops, parking, access points, etc.

- **Motorised transport factor**

  Measures the effect of motorised transport on non-motorised transport (NMT) speeds.

2.2 Data types

The traffic data required is incorporated in several modules (or applications) rather than being specified in one place. Traffic data types can be considered under the following headings.

- **Traffic categories** (see Section 3)

  These are **normal**, **diverted** and **generated** traffic.

- **Traffic composition, volumes and growth rates** (see Section 4)

  The traffic composition and volume is specified for each section within a Road Network. Sets of traffic growth rates are defined as part of a Vehicle Fleet and assigned to sections within the individual applications programs (that is, project analysis, programme analysis and strategy analysis) as required by the purpose of the study being performed.

- **Axle loading** (see Section 5)

  Specified for each vehicle type in the Vehicle Fleet folder (see Overview of HDM-4). Provision is made to derive most of the required parameters (for example, equivalent standard axle load factors, etc.) from the user-specified data.

- **Road capacity and speed-flow relationships** (see Section 6)

  Defined according to the road type within the HDM-4 Configuration (see Overview of HDM-4).

- **Hourly flow-frequency distribution data** (see Section 7)

  Required to estimate hourly flow ranges from annual average traffic data. These traffic data types are road dependent and are specified for each road use category within HDM-4 Configuration (see Overview of HDM-4).

The specification for each of these data sets is discussed in Sections 3 to 7 (as referenced above).

3 Traffic categories

Traffic is separated into the following categories in order to assess benefits, *TRRL Overseas Unit (1988)*:

- **Normal** (see Section 4.2.1)

  Normal traffic is defined as traffic that would pass along the project road if no investment took place, including normal growth. It is specified for each road section within the applications programs.

- **Diverted** (see Section 4.2.2)

  Diverted traffic is defined as traffic that changes from another route (or transport mode) to the project road, but still travels between the same origin and destination (this is termed **reassigned** traffic in transport modelling). It is specified together with the road investment option that causes it, and is specified within the relevant applications programs.

- **Generated** (see Section 4.2.3)

  Generated traffic is defined as additional traffic that occurs in response to the road investment (this includes **redistributed** traffic as defined in transport models). Generated traffic arises either because a journey becomes more attractive because of a cost or time reduction, or because of the increased development that is brought about by a road investment. It is specified together with the road investment option that induces it, and is specified within the relevant applications programs.

These categories are each treated separately in an economic analysis (see Part G).

4 Traffic composition, volumes and growth rates

4.1 Basic features

The traffic composition is defined as the proportions of the different vehicle types that use the road. Information on traffic composition is required for several analytical purposes, including:

- **Predicting pavement deterioration**
- **Estimation of vehicle operating costs**
- **Estimation of travel time**
- **Predicting quantities of vehicle exhaust emissions**
- **Calculation of energy use**
- **Economic analysis**

The existing traffic volumes on the road being analysed are specified in terms of **vehicle type** or **class**, depending on the kind of analysis to be performed. The value entered for each vehicle type is expressed as the annual average daily traffic (AADT):

$$AADT = \frac{\text{Total annual traffic in both directions}}{365}$$

This constitutes the baseline flow for the analysis period. It is assumed that seasonal variations in traffic flows have already been accounted for when estimating the AADT from traffic counts carried out over shorter periods.

For **project analysis**, traffic composition data is specified for each section. For network level analysis, several representative sets of traffic composition data can be specified, and each is assigned to a group of road sections with similar traffic characteristics.

In most situations, traffic growth has a major effect on the level of benefits obtained. Specifying different growth rates for each vehicle type/class can effect changes in traffic composition over time. Uncertainties always exist in estimating initial traffic, but there is even greater uncertainty in forecasting future growth rates. Thus, it is recommended that sensitivity analyses be always undertaken on the effects of different forecast growth rates.

Traffic volumes are derived from the baseline AADT and the composition data. The computation of annual road user effects requires the AADT for each road section to be broken down by vehicle types. For normal traffic, the annual average daily traffic for each vehicle type ($AADT_{kn}$) is obtained by multiplying the normal traffic $AADT_n$ by the composition data defined for the vehicle type *k* in the base year. For generated traffic, $AADT_{kg}$ is either specified directly or calculated, based on $AADT_{kn}$ and the traffic growth type used. Volumes for normal and generated traffic are required as separate inputs into the Economic Analysis module (see Part G) to enable the economic benefits of generated traffic to be determined.

The specification of traffic composition data for each section is carried out for each traffic category as described in Sections 4.2.1, 4.2.2 and 4.2.3.

4.2 Composition, volumes and growth rates

4.2.1 Normal traffic

Normal traffic is specified using the following data.

- **Annual average daily traffic (AADT)**

  It is permissible and sometimes convenient to enter AADT, in vehicles per day, for some year before the start of the analysis period. However, it must be ensured that the **traffic start year** is always less than or equal to the start year of the analysis period.

- **Initial composition**

  The AADT of each representative vehicle that uses the road The AADT of all vehicles in the Vehicle Fleet is used to calculate the total traffic volume of the section for the applicable year.

- **Future traffic**

  This is specified as a traffic growth period defined in terms of its relative start year (where year 1 is the first year of the analysis) and by one of the following growth types:

  - annual percentage increase (p)

$$AADT_y = AADT_{startyear}\left(1+\frac{p}{100}\right)^{(y-1)} \qquad \text{...(4.1)}$$

where:

$AADT_y$	annual average daily traffic in year *y* (vehicles per day)
$AADT_{startyear}$	annual average daily traffic in the start year, (vehicles per day)
p	annual percentage increase in AADT (%)
y	relative year of the analysis (1, 2,…., *analysis duration*)

  - annual incremental increase in AADT (vpd)

$$AADT_y = AADT_{startyear}\left[1+VPD(y-startyear)\right] \qquad \text{...(4.2)}$$

where:

$AADT_y$	annual average daily traffic in relative year *y* (vehicles per day)
$AADT_{startyear}$	annual average daily traffic in the start year, (vehicles per day)
VPD	annual incremental increase in AADT (vehicles per day)

  - actual AADT, which must be followed by another traffic growth period, unless the year in which it applies is the last year of the analysis period

  Then, depending on the selected traffic growth type, the growth rate is specified for each representative vehicle. For example, light trucks increasing at 4% per year from 1st to 6th year of the analysis, if annual percentage increase was selected.

Several traffic growth periods may be defined, each with a minimum length of one year. It is important to ensure that the defined traffic growth periods cover consistently each and every year of the analysis period. Therefore, if only one growth period has been defined, this will be assumed to apply to all successive analysis years. A combination of different growth types may be used to specify future traffic over the analysis period.

4.2.2 Diverted traffic

Forecasting diverted traffic can be difficult, particularly where traffic diverts from other transport modes, and for analysis over a complete network. Ideally, estimates of diverted traffic should be made by utilising the results from external traffic demand models. Thus, in a situation where a road works causes diverted traffic, a new set of traffic data representing the net effect of traffic diversion over all the sections affected should be defined for each project alternative.

For each project alternative, a new set of traffic data is specified as follows:

- **Name**
- **Start year**

  The calendar year in which traffic diversion starts, typically this should coincide with the year following the completion of the road works.

- **New AADT**

  The annual average daily traffic in the **start year** for each road section.

- **New composition**

  The traffic composition in the **start year** for each road section.

- **Future traffic**

  Specified by selecting one of the following growth types:

  - annual percentage increase in AADT, calculated using Equation 4.1 above
  - annual incremental increase in AADT, calculated using Equation 4.2 above

Economic comparisons of investment options involving diverted traffic can only be done meaningfully, at the project analysis level, if the following conditions are met:

1 All the road sections from and to which traffic diverts are analysed together with the section(s) being considered under the investment analysis; this implies that a study area be defined to comprise all the sections that are affected significantly by traffic diversion as a result of carrying out the road works.

2 In any given analysis year, the total traffic volume entering the study area equals the total traffic volume exiting the area; this implies a fixed trip matrix.

The analysis of a new section in an entirely new location will always involve diverted traffic.

4.2.3 Generated traffic

The main causal factors of generated traffic are reductions in travel cost or time, or the increased development brought about by a road investment. The amount of generated traffic is difficult to forecast accurately, so the time period over which traffic is generated should be limited.

The recommended approach to forecasting generated traffic is to use demand relationships. The **price elasticity of demand for transport** measures the responsiveness of traffic to a change in transport costs following a road investment.

For each road investment standard, generated traffic is specified as follows:

- **Name**
- **Relative start year**

  The number of years, after the start of the road works, that generated traffic appears. Thus, relative start year *j* means the j^{th} year following the start year of the works that cause the generated traffic.

- **Future traffic**

  The total volume of generated traffic in any analysis year is calculated as follows:

$$AADT_{gen(y)} = AADT_{gen(y-1)} + \Delta AADT_{gen(y)} \quad ...(4.3)$$

where:

$AADT_{gen(y)}$	total generated traffic in year *y* (vehicles per day)
$AADT_{gen(y-1)}$	total generated traffic in year *y-1* (vehicles per day)
$\Delta AADT_{gen(y)}$	annual increase in generated traffic for year *y* (vehicles per day)

The increase in generated traffic is specified by selecting one of the following growth types:

- additional annual percentage increase in AADT (q1)

  the annual increase in generated traffic is given by:

$$\Delta AADT_{gen(y)} = AADT_{total(y)} - AADT_{total(y-1)} - AADT_{norm(y)} + AADT_{norm(y-1)} \quad ...(4.4)$$

where:

$$AADT_{total(y)} = AADT_{total(y-1)}\left(1 + \frac{(p + q1)}{100}\right) \quad ...(4.5)$$

$$AADT_{norm(y)} = AADT_{norm(y-1)}\left(1 + \frac{p}{100}\right) \quad ...(4.6)$$

and:

$AADT_{total(y)}$	total traffic in year *y* (vehicles per day)
$AADT_{total(y-1)}$	total traffic in year *y-1* (vehicles per day)
$AADT_{norm(y)}$	normal traffic in year *y* (vehicles per day)
$AADT_{norm(y-1)}$	normal traffic in year *y-1* (vehicles per day)
q1	additional annual percentage increase in AADT (%)

p annual percentage increase in AADT for normal traffic (%). The value of p is user-specified if the method used for defining normal traffic growth for the analysis year is that represented by equation 4.1. If the method used is the "actual AADT" or that described by equation 4.2, then p is calculated from equation 4.6 using the known values of $AADT_{norm(y)}$ and $AADT_{norm(y-1)}$

- percentage of increase in normal traffic in the current year (q2)

  the annual increase in generated traffic is given by:

$$\Delta AADT_{gen(y)} = \frac{q2}{100} \Delta AADT_{norm(y)} \qquad \text{...(4.7)}$$

where $\Delta AADT_{norm(y)}$ is the increase in normal traffic in year y given by:

$$\Delta AADT_{norm(y)} = AADT_{norm(y)} - AADT_{norm(y-1)} \qquad \text{...(4.8)}$$

and:

q2 increase in generated traffic as a percentage increase in normal traffic (%)

- annual incremental increase in AADT of generated traffic

  the value input by the user is the annual increase in generated traffic $\Delta AADT_{gen(y)}$

- initial AADT of generated traffic

  The value input by the user is the total generated traffic in year y, (i.e., $AADT_{gen(y)}$), (alternatively, the input value could be considered as $\Delta AADT_{gen(y)}$ since $AADT_{gen(y)}$ is zero.) This should be followed by another traffic growth period otherwise there would be no change in generated traffic over the rest of the analysis period.

4.2.4 Changes in vehicle fleet characteristics

If changes in the characteristics of the vehicle fleet are expected to occur in the future, the following procedure should be followed:

Any vehicles that come into use at a future date should be specified in Vehicle Fleet folder, together with those that are already in use. The AADT of future vehicles should be set to zero until the year in which they come into effect. In that year new AADT for the vehicle is defined using incremental increase in AADT, or the actual AADT, followed by another growth period. Negative growth rates can be defined for vehicles that are already in use in such a manner that they are gradually phased out (that is, AADT=0) and replaced by future vehicles.

5 Axle loading

5.1 The need for axle loading data

The following measures of axle load are required to predict the impacts of traffic on pavement deterioration and maintenance effects:

- **Numbers of vehicle axles (YAX)**

  Defined as the total number of axles of all vehicles traversing a given road section in a given year.

- **Numbers of equivalent standard axle loads (ESA)**

  Combines the damaging effects of the full spectrum of axle loading in a common damage-related unit. ESA is considered on each road section, for each year of the analysis period.

5.2 Vehicle axles

For each vehicle type; the number of vehicle axles, YAX_k, traversing a given road section in a particular year is computed as the volume of traffic multiplied by the number of axles per vehicle of the type involved. The total number of all axles, YAX, in a given year is obtained by summing YAX_k for all vehicle types.

$$YAX_k = \frac{T_k * NUM\_AXLES_k}{ELANES * 10^6} \quad ...(5.1)$$

$$YAX = \sum_{k=1}^{K} YAX_k \quad ...(5.2)$$

where:

YAX	annual total number of axles of all vehicle types (millions per lane)
T_k	annual traffic volume of vehicle type k, (k = 1, 2, . . , K)
NUM_AXLES_k	number of axles per vehicle type k
ELANES	effective number of lanes for the road section

The effective number of lanes ELANES is used to model the effect of traffic load distribution across the width of paved roads. This may either be specified by the user or be taken by default as equal to the number of lanes (NLANES) for the road section.

5.3 Equivalent standard axle load factors

The equivalent standard axle load factor is defined as the number of applications of a standard 80kN dual-wheel single axle load that would cause the same amount of damage to a road as one application of the axle load being considered. The value of ESALF for each vehicle type may be specified directly by the user, or calculated from axle load information defined in the Vehicle Fleet folder.

For each vehicle type, $ESALF_k$ is computed using information on the different damaging effects of various axle configurations. Usual axle groups are single-wheel single axles, dual-wheel single axles, dual-wheel tandem axles, wide-single-wheel triple axles, and dual-wheel triple axles. For each type of axle group *j* a standard load, $SAXL_j$, is used to determine the loading ratio. The expression for calculating ESALF is as follows *Watanatada et al. (1987)*:

$$ESALF_k = \sum_{i=1}^{I_k} \frac{P_{ki}}{100} \sum_{j=1}^{J_k} \left(\frac{AXL_{kij}}{SAXL_j} \right)^{LE} \qquad ...(5.3)$$

where:

$ESALF_k$	equivalent standard axle load factor for vehicle type *k*, in equivalent standard axle loads
I_k	the number of subgroups *i* (defined in terms of load range) of vehicle type *k* (*i* = 1, 2, . . ., I_k). Note that *i* may represent each individual vehicle
P_{ki}	percentage of vehicles in subgroup *i* of vehicle type *k*. If *i* represents each individual vehicle then P_{ki} = 100 (%)
LE	axle load equivalency exponent (default = 4.0)
J_k	the number of single axles per vehicle of type *k* (*j* = 1, 2, . . ., J_k). A multiple axle is treated as several separate single axles.
AXL_{kij}	the average load on axle *j* of load range *i* in vehicle type *k* (tonnes)
$SAXL_j$	the standard single axle load of axle group type *j*, for example: = 6.60 tonnes for single-wheel single axle, = 8.16 tonnes for dual-wheel single axle, = 15.10/2 = 7.55 tonnes for dual-wheel tandem axle. = 22.90/3 = 7.63 tonnes for dual-wheel triple axle.

The factor $ESALF_k$ is therefore an average over all vehicles of type *k*, loaded and unloaded, in both directions on the given road section.

The annual total number of equivalent standard axles is calculated as:

$$YE4 = \sum_{k=1}^{K} \frac{T_k * ESALF_k}{ELANES * 10^6} \qquad ...(5.4)$$

where:

YE4	annual total number of equivalent standard axles (millions per lane)

All other parameters are as previously defined in Sections 5.2 and 5.3.

5.4 Light and heavy vehicles

The modelling of some pavement distress modes and the calculations of unsealed road deterioration requires input of the amounts of **light** and **heavy** MT vehicles. Heavy vehicles are categorised as those with operating weight equal to or greater than 3.5 tonnes; other vehicles are categorised as light. The Average Daily Light vehicles (ADL) and the Average Daily Heavy vehicles (ADH) are specified in terms of vehicles per day for each year of the analysis period.

The modelling of the changes in pavement skid resistance requires the specification of the flow of heavy commercial vehicles per lane per day (QCV).

$$QCV = \frac{ADH}{ELANES} \qquad \text{... (5.5)}$$

where:

QCV	flow of heavy commercial vehicles per lane per day
ADH	average daily heavy vehicles (numbers in both directions)
ELANES	effective number of lanes for the road section

The modelling of changes in pavement texture depth requires the specification of the annual number of equivalent light vehicle passes (ΔNELV) over the road section. This is calculated from the following expression:

$$\Delta NELV = 365 * (ADL + 10 * ADH) \qquad \text{...(5.6)}$$

where:

ΔNELV	Number of equivalent light vehicle passes during an analysis year

The number of vehicles with **studded tyres** is required for modelling pavement rutting during freezing seasons.

$$PASS = \frac{365 * ST * AADT_y * 10^{-5}}{NTFD} \qquad \text{...(5.7)}$$

where:

PASS	annual number of vehicle passes with studded tyres in one direction (measured in 1000s)
$AADT_y$	annual average daily traffic (AADT) in year *y* (veh/day)
ST	percentage of annual number of vehicle passes with studded tyres (%)
NTFD	number of traffic flow directions

5.5 Cumulative traffic loading

The cumulative traffic loading parameters are used for modelling road deterioration and as intervention criteria for some road works activities. These parameters are calculated from the accumulated traffic since the time of the last surfacing or construction works on the road section (see below).

The cumulative number of equivalent standard axle loads since the last rehabilitation, reconstruction or new construction works (NE4) is given by:

$$NE4 = \sum_{y=1}^{AGE3} YE4_y \qquad \text{... (5.8)}$$

where:

NE4	cumulative number of equivalent standard axle loads since last rehabilitation, reconstruction or new construction (millions/lane)
$YE4_y$	number of equivalent standard axle loads in year *y* (millions/lane)
AGE3	number of years since last rehabilitation, reconstruction or new construction (years)

6 Road capacity and speed-flow relationships

6.1 Basic concepts

The capability to model the effects of traffic volume on speeds is provided to enable the economic consequences of road capacity improvements to be determined. The factors that determine speed-flow relationships are described below:

- **Capacity**

  The maximum number of vehicles that can pass a point, or traverse a road section, in one hour (total both directions). Capacity values determine the shape of **speed-flow curves** by establishing the **ultimate capacity** value.

- **Free speed**

  The speed of each vehicle at zero (or very low) flow. It is unaffected by other traffic but is affected by the physical characteristics of the road and other non-traffic factors (see Part E). The average free speed is calculated for each vehicle type.

- **Speed at capacity**

  As traffic flows increase, average speeds for all vehicles converge towards the speeds of the slowest vehicles in the stream, as passing becomes more and more restricted. As flow approaches the ultimate capacity, average speeds may fall even lower than slow vehicle free speeds, and any small disturbances in the traffic stream causes a stop-and-go situation. An estimate of average **speed at ultimate capacity**, also known as **jam speed**, is needed to describe the **speed-flow-capacity** relationship.

6.1.1 Speed-flow model

The speed-flow model adopted for motorised transport (MT) is the **three-zone** model proposed by *Hoban et al. (1994)*. This model is illustrated in Figure B1.1.

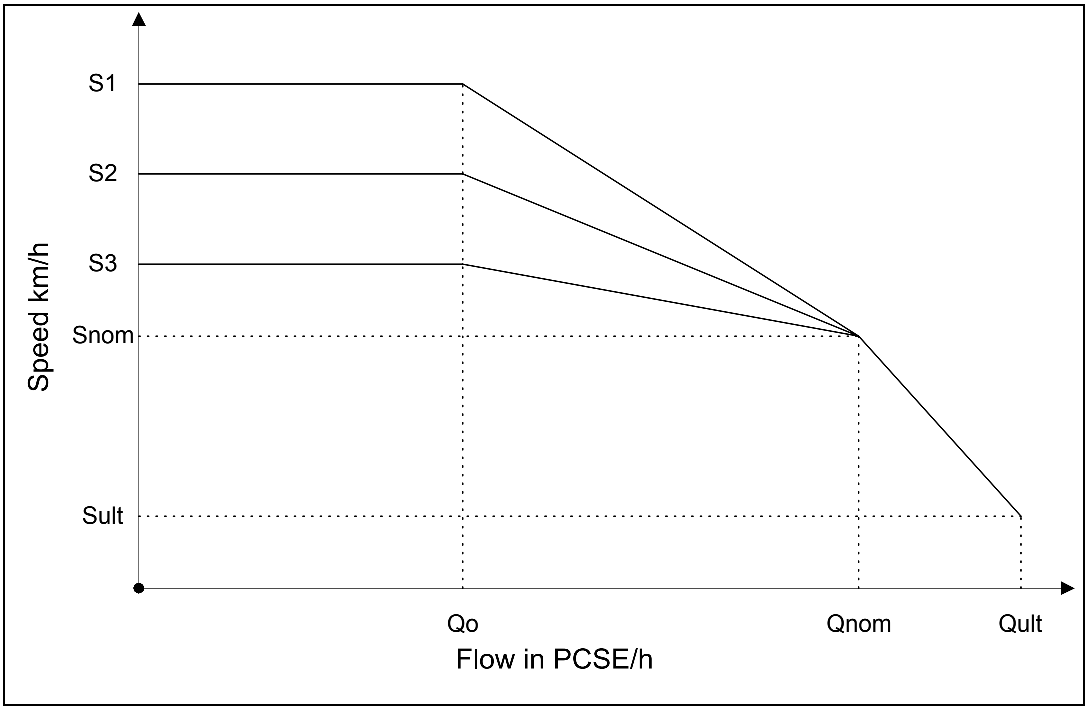

Figure B1.1 Speed-flow model

The following notation applies to Figure B1.1:

Qo	the flow level below which traffic interactions are negligible in PCSE/h
Qnom	nominal capacity of the road (PCSE/h)
Qult	the ultimate capacity of the road for stable flow (PCSE/h)
Snom	speed at the nominal capacity (km/h)
Sult	speed at the ultimate capacity, also referred to as jam speed (km/h)
S1 to S3	free flow speeds of different vehicle types (km/h)
PCSE	passenger car space equivalents (see below)

6.1.2 Passenger car space equivalents

To model the effects of **traffic congestion**, the mixed traffic flows are converted into equivalent standard vehicles. The conversion is based on the concept of Passenger Car Space Equivalents (PCSE) *Hoban et al. (1994)*. This accounts only for the relative space taken up by the vehicle on the road, and reflects the fact that the speed-flow model takes account explicitly of speed differences of the various vehicles in the traffic stream. PCSE factors vary by road type, and narrow roads have higher PCSE values than wide roads. Table B1.1 gives the values of PCSE by vehicle class and road type.

Table B1.1 PCSE Values

Vehicle	Average Length (m)	Space Headway (m)	Total Space (m)	Basic PCSE	Recommended Values		
					2-Lane 4-Lane	Narrow 2-Lane	1-Lane
Car	4.0	32.0	36.0	1.0	1.0	1.0	1.0
Utilities (Pickup)	4.5	36.0	40.5	1.0	1.0	1.0	1.0
Heavy Bus	14.0	44.0	58.0	1.6	1.8	2.0	2.2
Light Truck	5.0	40.0	45.0	1.3	1.3	1.4	1.5
Medium Truck	7.0	44.0	51.0	1.4	1.5	1.6	1.8
Heavy Truck	9.0	48.0	57.0	1.6	1.8	2.0	2.4
Trailer	11.0	50.0	65.0	1.8	2.2	2.6	3.0

Source: *Hoban et al. (1994)*

Notes: The basic PCSE values have been used as defaults for the HDM-4 standard vehicle types (see Part E)

6.2 Data to be specified

The key parameters for use in the speed-flow model vary depending upon the road type and width. Table B1.2 lists the recommended values for these parameters. The values for Qo and Qnom are expressed relative to Qult.

Note that in HDM-4 the ultimate capacity for the road section Qult is obtained from the product of the ultimate capacity per lane (QLult) and the number of lanes for the road section (NLANES).

The ratio of Qo to Qult is designated by XQ1, and is expressed as follows:

$$XQ1 = \frac{Qo}{Qult} \qquad ...(6.1)$$

The ratio of Qnom to Qult is designated by XQ2, and is expressed as follows:

$$XQ2 = \frac{Qnom}{Qult} \qquad ...(6.2)$$

Table B1.2 Examples of capacity and speed-flow model parameters for different road types

Road type	Width (m)	XQ1	XQ2	QLult (PCSE/lane/hr)	Sult (km/hr)	σmaxr (m/s^2)
Single lane road	< 4	0.0	0.70	600	10	0.75
Intermediate road	4 to 5.5	0.0	0.70	1200	20	0.70
Two lane road	5.5 to 9	0.1	0.90	1400	25	0.65
Wide two lane road	9 to 12	0.2	0.90	1600	30	0.60
Four lane road	>12	0.4	0.95	2000	40	0.60

Source: *Hoban et al. (1994)*

Since these data apply to individual road sections, it is important to ensure that the data relates to a single and not a dual carriageway. This ensures consistency with the definition of a road section as used in HDM-4.

The data in Table B1.1 describing the capacity of road sections are specified for each road type:

- **Ultimate capacity per lane** (QLult) (PCSE/lane/hr). The ultimate capacity for the road section Qult = QLult*NLANES
- **Free flow capacity as a proportion of the ultimate capacity** (XQ1)
- **Nominal capacity as a proportion of the ultimate capacity** (XQ2)
- **Speed at ultimate capacity** (Sult) (km/hr)

Free speed value for each vehicle type is determined internally using the model described in Part E.

The speed at nominal capacity is estimated to be 85% of the free speed of the slowest vehicle in the traffic stream.

The maximum acceleration noise (σmaxr) represents the maximum standard deviation of acceleration for each road type. This is required for modelling the effect of speed change cycles (that is, speed variations along the road) on vehicle operating costs. In addition to driver behaviour, speed fluctuations are sensitive to road geometry, road condition, the presence of NMT, roadside friction, intersections, etc. (See Part E).

7 Hourly flow-frequency distribution data

7.1 Basic concepts

There is a need to take account of the differing levels of traffic congestion at different hours of the day, and on different days of the week and year. Therefore the number of hours of the year for which different ranges of hourly flows are applicable needs to be considered. By defining the distribution of hourly flows over the 8760 (365 days x 24 hours per day) hours of the year, the AADT data can be converted to hourly flows. Congestion analysis can then be undertaken for a number of hourly traffic flow levels, and the results combined to represent the full year. Because congestion delays and costs are greatest during the highest-flow hours, particular attention should be paid to these hours. These highest-flow hours should be divided into periods of shorter duration. Figure B1.2 shows a typical example of a flow-frequency distribution in which the number of hours in a year are divided into five traffic flow levels or periods.

7.2 Data to be specified

Hourly flow-frequency distribution data is specified for each road use category. This reflects the fact that the predominant use (see Section 2.1) of different roads requires different shapes of flow-frequency distribution curves. The curves are defined in terms of the number of hours per year that the traffic volume is at a certain percentage of the AADT. Each specified flow-frequency distribution is referred to as **traffic flow pattern**, and can be assigned to a number of road sections with similar use pattern.

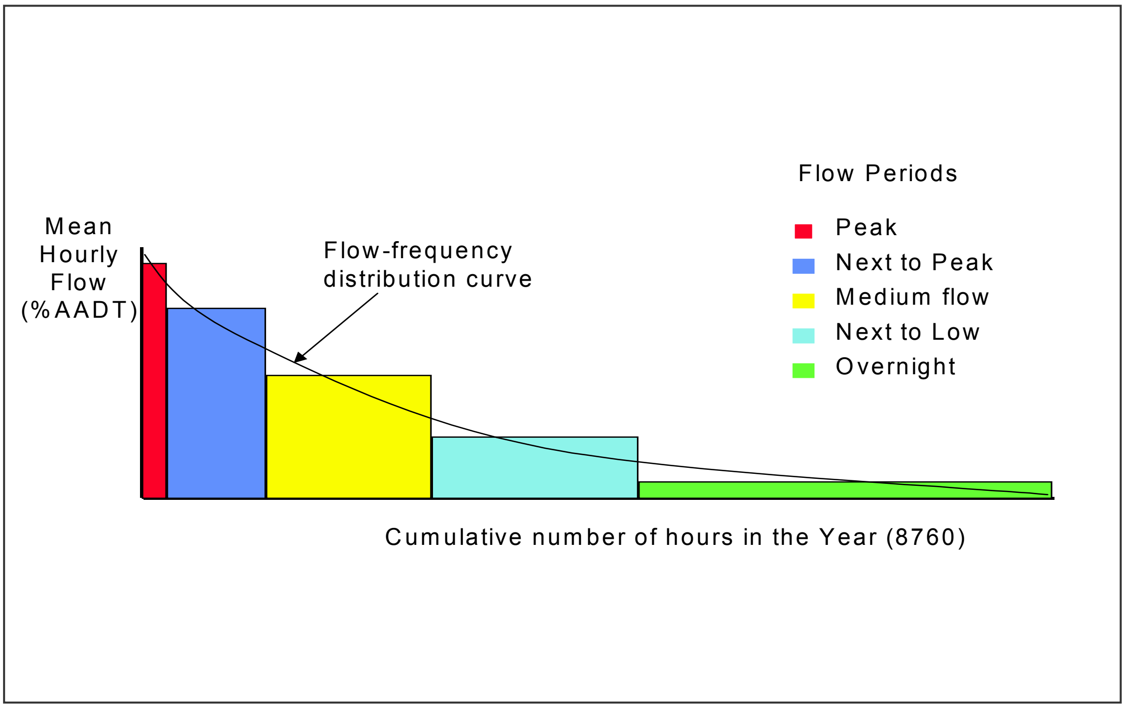

Figure B1.2 Hourly flow-frequency distribution

Traffic flow patterns are specified as follows:

- **Name**

- **Number of flow-frequency periods**

  The number of flow periods into which the total number of hours in a year (8760) are divided. Only one flow period needs to be specified for aggregate or network level analyses. A uniform traffic composition and value of travel time across all flow-frequency periods is assumed.

- **The number of hours in each flow-frequency period, p ($HRYR_p$) and**

either

- **Hourly traffic flow in each period as a proportion of AADT (HV_p)**

or

- **The percentage of AADT in each flow-frequency period, p ($PCNADT_p$)**

When specifying a flow-frequency distribution, the following conditions must be satisfied:

- The sum of the number of hours in each flow-frequency period ($HRYR_p$) should be 8760
- The sum of $PCNADT_p$ over all the flow periods should be 100
- The sum of the products of HV_p and $HRYR_p$ (over all the traffic flow periods) divided by 365 should be equal to 1.00 ± 0.05

Table B1.3 shows typical values of hourly flow-frequency distribution data for three road use categories: seasonal, commuter and inter-urban.

Table B1.3 Examples of hourly traffic flow distribution data

Flow Period (p)	HRYR	HV		
	(hours)	Seasonal	Commuter	Inter-urban
1	87.6	0.18	0.13	0.09
2	350.4	0.14	0.12	0.08
3	613.2	0.10	0.10	0.07
4	2978.4	0.05	0.07	0.05
5	4730.4	0.02	0.01	0.03

Source: *Hoban et al. (1994)*

Table B1.4 shows typical values of hourly flow-frequency distribution data for the three road-use categories with hourly flows expressed as a percentage of AADT.

Table B1.4 Examples of hourly traffic flow distribution data

Flow Period (p)	HRYR	PCNADT (%)		
	(hours)	Seasonal	Commuter	Inter-urban
1	87.6	4.25	3.05	2.17
2	350.4	13.24	11.33	7.59
3	613.2	16.60	16.55	11.64
4	2978.4	40.32	56.26	40.24
5	4730.4	25.59	12.81	38.36

The parameter PCNADT is converted to hourly traffic flow as a proportion of AADT using the following expression:

$$HV_p = \frac{365 * PCNADT_p}{100 * HRYR_p} \quad ...(7.1)$$

where:

HV_p	hourly traffic flow in period *p*, as a proportion of AADT
$PCNADT_p$	percentage of AADT in period *p*
$HRYR_p$	number of hours per year in period *p*

The data that describes the hourly traffic flows and the volume-capacity ratios are required for modelling congestion effects on vehicle speeds and vehicle operating costs. Therefore the key parameters are as follows:

- **Q_p**

  The traffic flow, in PCSE per hour, during traffic flow period *p*.

- **VCR_p**

  The volume-capacity ratio for traffic flow period *p*.

The traffic flow during each flow period is calculated as follows:

$$Q_p = \sum_{k=1}^{K} HV_p * PCSE_k * AADT_k \quad ...(7.2)$$

where:

Q_p	hourly traffic flow in period *p* (PCSE per hour)
$AADT_k$	annual average daily traffic of vehicle type *k*
$PCSE_k$	passenger car space equivalent of vehicle type *k*

The volume-capacity ratio during each traffic flow period is expressed as follows:

$$VCR_p = \frac{Q_p}{Qult} \quad ...(7.3)$$

where:

VCR_p	Volume-to-capacity ratio for traffic flow in period *p* (dimensionless)

All the other parameters are as defined previously.

7.3 Limits on traffic flows

The annual growth of traffic over the analysis period can lead to high values of AADT and hourly traffic flows, and a change in the hourly flow-frequency distribution. For realistic analyses, the traffic flows in terms of AADT and hourly traffic flows in each flow period should be limited to the capacity of the road. The following flow-capacity limits are therefore included:

For each year of the analysis period, the annual average daily traffic on a road section is limited as follows:

$$AADT_y \leq AADT_{ylim}$$

and:

$$AADT_{ylim} = \frac{24 * Qult}{\sum_{k=1}^{K} (PCSE_k * MIX_k)} \qquad ...(7.4)$$

where:

$AADT_y$	the total AADT in year *y* (veh/day)
$AADT_{ylim}$	the limiting road capacity in year *y* (veh/day)
Qult	the ultimate road capacity in (PCSE/hr)
MIX_k	the proportion of vehicle type *k* in the traffic on the road in year *y*
$PCSE_k$	the passenger car space equivalent of vehicle type *k*

Since the proportion of each vehicle type in the traffic stream (MIX_k) may vary each year, and the ultimate road capacity Qult may also change due to a works intervention, the value of $AADT_{ylim}$ is calculated for each year of the analysis period. A check on the AADT limit is carried out within the traffic module for every analysis year. Necessary adjustments to the values of the traffic data are then made before passing on the data for use in the subsequent modules. If the projected $AADT_y$ is higher than the AADT limit for the road, $AADT_y$ will be set equal to $AADT_{ylim}$, and the analysis in year *y* will be performed using $AADT_{ylim}$. In these circumstances, a printed warning is included in the HDM-4 outputs.

In reality, changes in the hourly flow-frequency distribution take place on a continuous basis as traffic volume on a road increases with time. As a result, adjustments to the values of the flow-frequency distribution parameters HV_p and $HRYR_p$ are required. However, for the purposes of analyses, the hourly flow-frequency distribution is only changed under one of the following conditions:

1 When a **spill-over** from one high flow period to the next period occurs; that is, when the hourly traffic flows computed for a high flow period exceeds the ultimate capacity of the road, the excess flows will spill-over into the next highest flow period, so that some peak spreading occurs. In this circumstance, new values of HV_p are calculated, but $HRYR_p$ values remain unchanged in order to simplify the analysis.

2 An intervention occurs that changes road users' pattern of journey time (for example, an increase in road capacity that reduces traffic congestion).

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