APPENDIX 5
HIGHWAY CAPACITY

The basis for identifying sections of the road network that require to be developed relies on a comparison of existing and forecast traffic flows with the existing capacity of the respective sections of the highway network. The timing of any future development is important too for justifying that future investment. Experience of the Region suggests that some recent and current highway improvement schemes, particularly some involving the construction of Motorway type facilities, have been undertaken well in advance of the time when traffic levels would have normally justified such investments.

Establishing unique values of capacity for the respective sections of the network is not appropriate, given the range of terrain and traffic characteristics to be found across the region and the fact that the majority of the network consists of 2 lane highways in varying conditions of maintenance, all of which make a profound impact on the level of service of the highway. A capacity range has therefore been selected for a number of different cross sections of highway, which are considered representative of the network infrastructure. This range has been determined from a number of computations, which have taken account of recommended levels of service\(^1\) and a variety of traffic conditions, which may be experienced.

**Level of Service**

The level of service (LOS) for the network, takes account of possible congestion and delays as well as average running speed along the specific sections of the highway network. The recommended practice for Trans-European Motorways suggests that a minimum level of service C should be guaranteed, when making computations based on the Highway Capacity Manual (HCM). For planning activities, such as for TIRS, this may be taken as the guideline for computations, even for non-motorway sections.

The traffic flow that relates to this stated LOS corresponds to the 50\(^{th}\) peak hour expressed in passenger car units (pcu); this may equate to 14% of the Annual Average Daily Traffic (AADT) for multi lane highways and 12% for 2 lane highways. Under ideal conditions these may reflect a “base” flow of 2800 pcu per hour (total two way) for 2 lane highways and 2000 pcu per lane per hour for multi lane highways, representing the maximum possible flows that may be experienced for such carriageway sections.

**Selected Carriageway Cross Sections**

Seven cross sections of carriageway have been selected for analysis, which are deemed to represent the types of highway to be found on the network throughout the region. Analysis of these sections has then been conducted for two types of terrain: flat / rolling - hilly and very hilly / mountainous.

The selected representative sections are:

- Sub-standard 2 lane: 5-6m pavement on a 8-9m platform
- Standard 2 lane: 7m pavement on 11m platform reflecting EU norms
- Standard 2 lane + (crawler lane): As standard above plus 3\(^{rd}\) lane of 3.5m
- Half Motorway profile (2x 3.75m lane carriageway with shoulders)

\(^1\)Trans-European Motorway Standards and Recommended Practice, UN-ECE, Trans-European North-South Motorway; Revised Draft March 2000
- Expressway: 4 lane divided carriageway
- 2x2 lane Motorway
- 2x3 lane Motorway

Computation Method

Capacity is highly sensitive to speed, traffic mix and peak hour characteristics and is normally computed for design for hourly or quarter hour periods. For planning purposes however such as for TIRS it is normally accepted practice to consider daily flows. Calculations of capacity, in terms of AADT have therefore been made for the previously described sections.

Reference has been made to the HCM and formulae selected derived from recommendations in that manual. The selected formulae, which are set out below, are designed to give appropriate indications of capacity in AADT terms, incorporating parameters which reflect traffic mix, road infrastructure and peak hour characteristics.

- Two Lane Highways

\[
\text{AADT} = [2800 \times (v/c) \times F_d \times F_w \times F_g \times F_{hv}] \times \text{PHF/K}
\]

where:
- \(v/c\) = flow capacity ratio for selected level of service (Table 8-7 in HCM)
- \(F_d\) = peak hour flow directional distribution factor (Table 8-8 in HCM)
- \(F_w\) = lane and useable shoulder width factor (Table 8-5 in HCM)
- \(F_g\) = factor for effect of grade on cars = \(1/[1 + (P_p \times 0.02\{E-E_o\})]\) where:
  - \(P_p\) = proportion of cars in upgrade traffic stream
  - \(E\) = base car equivalent for % and length of grade and speed (Table 8-9 in HCM)
  - \(E_o\) = base car equivalent for 0% grade and given speed (Table 8-9 in HCM)
- \(F_{hv}\) = factor for effect of grade on trucks = \(1/[1+P_{hv}(1+[0.25+P_{t/hv}][E-1])-1)]\)
  - \(P_{hv}\) = proportion of total heavy vehicles in upgrade stream (trucks, buses etc.)
  - \(P_{t/hv}\) = proportion of heavy trucks among heavy vehicles in stream
  - \(E\) = as defined above
- \(\text{PHF}\) = peak hour factor for Level of Service (Table 8-3 in HCM)
- \(K\) = proportion of AADT expected to occur in the design hour

- Two Lane Highway with Crawler Lane

Formulae identical above except to simulate the crawler lane, the effect of heavy vehicles on the upgrade as been virtually discounted with the factor \(P_{hv}\) being selected as 1% and \(P_{t/hv}\) selected as 95% and with 40% “no passing” opportunities selected for the traffic stream.

- Multi Lane Highways

\[
\text{AADT} = ([100 \times P] \times [5000 \times N])/(100+T\{j-l\}) \times K \times D)
\]

where:
- \(P\) = lane capacity base in pcu per hour for selected level of service (ranges between 2000 for expressways to 800 pcu for major highways with frequent “at grade” access)
- \(N\) = total number of traffic lanes
- \(T\) = % of heavy trucks in traffic during peak hour
- \(j\) = pcu equivalent for trucks ( = 2 for level terrain; 4 for rolling terrain and 7 for mountainous)
- \(l\) = lane factor ( = 1 for 3.75m lane width; 0.97 for 3.5m lane width)
- \(K\) = % of AADT expected to occur in the design hour
- \(D\) = % of one way traffic during peak hour in peak direction.
Terrain, Infrastructure and Traffic Characteristics Examined

In order to arrive at the capacity ranges for each of the selected carriageway cross sections, a number of assumptions have been made which are believed to be representative of the identified highway network across the region. These are summarised below:

**Terrain:**
Gradient has been rationalised to the following limiting grades:
- flat / rolling – hilly: 3%
- very hilly / mountainous: 5-7%
Lengths of grade range from 400m to 1.6km

**Infrastructure:**
Useable shoulders have varied from 0m for sub-standard highways to 1.6m for motorways. Intermediate values have been selected for selected standard 2 lane highways.
The % of highway over which passing is restricted ranges from 30-40% for sub-standard sections to 10-20% for standard sections except for “half motorway” profiles when no overtaking restrictions have been applied.
Lane widths vary from 2.75m for non-standard sections to 3.75m for motorways. Expressways and standard highway sections have included analysis of 3.5m widths.

**Traffic:**
Average upgrade speeds considered vary between 56kph (for mountainous non-standard sections) to 80kph (examined for most sections).
The proportion of passenger cars in the traffic has been taken as 85% (15% heavy vehicles). The proportion of heavy trucks within the total heavy vehicle flow has been taken as 70%.
pcu equivalent for trucks has varied from 2 (level terrain) to 7 (mountainous terrain).
A range of value for K, the proportion of AADT in the peak hour flow, has been assessed from 0.10 to 0.15, depending on highway type and urban / rural conditions.
The directional split of traffic on the upgrade stream has been taken as 50:50 generally although some cases have been examined for 60:40.

**Computed Capacities**
The range of capacities resulting from the above mentioned computations have been summarised in the Table below for each type of carriageway cross section considered.

### Table A5 – 1: Highway Capacity (vehicles per day)

<table>
<thead>
<tr>
<th>Carriageway Type</th>
<th>Flat / Hilly Terrain</th>
<th>Very Hilly / Mountainous Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-standard 2 lane</td>
<td>4000 - 7000</td>
<td>1200 - 4000</td>
</tr>
<tr>
<td>Standard 2 lane</td>
<td>8000 - 12000</td>
<td>4500 - 5500</td>
</tr>
<tr>
<td>Standard 2 lane + (crawler lane)</td>
<td>-</td>
<td>6000 - 7500</td>
</tr>
<tr>
<td>Half Motorway profile</td>
<td>9500 - 14000</td>
<td>6000 - 9000</td>
</tr>
<tr>
<td>Expressway</td>
<td>17500 - 30000</td>
<td>11000 - 20000</td>
</tr>
<tr>
<td>2x2 lane Motorway: Rural Urban</td>
<td>20000 – 35000</td>
<td>13000 - 27500</td>
</tr>
<tr>
<td>2x2 lane Motorway: Rural Urban</td>
<td>30000 - 55000</td>
<td></td>
</tr>
<tr>
<td>2x3 lane Motorway: Rural Urban</td>
<td>31000 - 52000</td>
<td>27500 - 41000</td>
</tr>
<tr>
<td>2x3 lane Motorway: Rural Urban</td>
<td>65000 - 85000</td>
<td></td>
</tr>
</tbody>
</table>
Capacity Constraint

In order to make an initial assessment of the likely immediate need for implementing capacity improvements on the network, current traffic flows have been compared with the mid value figures for capacity given in Table A5 – 1 above, throughout the respective sections of the network. Map 08, which follows, shows the ratio of current flow (year 2000) to capacity.

For the three bands where the ratio is calculated to be less than or equal to unity, the existing capacity may be considered adequate for the foreseeable future, without serious loss in the LOS of the highway network.

For sections of the network, which have been coded red, existing traffic flows may be close to the selected “design” capacity\(^2\), but nevertheless are considered to remain within an acceptable tolerance of that capacity without serious loss in the level of service. Certainly it may be argued that for a flow – capacity ratio of between 1 and 2, the chosen level of service may be reasonably maintained, although it may reflect an hourly flow, which may be between the 50\(^{th}\) and 100\(^{th}\) highest hour of the year. The number of hours that such flows may occur during the year could equal or exceed 100 times, depending on the individual characteristics of particular sections of the network including in particular peak travel patterns.

Sections of the network on which current traffic flow – capacity ratios in excess of 2 have been calculated, are shown in black. These elements may already be experiencing varying degrees of constraint particularly during peak hour flows, with consequential breakdown of traffic movements leading to unacceptable delays. The present capacity, for free flow conditions at the chosen level of service, may only be equivalent to a flow represented by more than the 100\(^{th}\) highest hour and typically the 200\(^{th}\) highest hour or more, with an incidence of such flows occurring in excess of 400 hours during the year. This degree of deviation from the targeted design capacity and associated level of service, previously discussed, is considered unacceptable and may therefore be an indicator for undertaking detailed studies with the objective of increasing the capacity of such sections of the network in the near future.

\(^2\) 50\(^{th}\) peak hour equating to 14\% of AADT for multi lane highways and 12\% for 2 lane highways for a minimum guaranteed LOS of C.