APPENDIX B. CONGESTION COSTS

Readers' Guide: Appendix B

This appendix shows how the marginal costs of the congestion imposed by HGVs can be calculated. However, since congestion varies across the network, and by the time of the day or week, we indicate why we do not believe it is appropriate to include congestion costs in this type of aggregate model.

B.1. Marginal Congestion Impacts of HGVs

When an extra HGV joins a traffic flow at other than free flow conditions it imposes some delay on all other vehicles, including other HGVs, in the flow. It follows that, in congested conditions, HGVs impose external costs, in the form of slower journey time, on all other vehicles in the flow. In a similar way, any other vehicle joining a congested flow imposes a congestion cost. Of course HGVs also suffer from congestion, and this is internalised as an increase in operating costs.

The relevant cost of congestion is the marginal cost, that is the extra cost imposed by an additional vehicle in the flow. This is equal to the sums of the delays imposed on all other vehicles in the flow. In congested condition the efficient pricing solution is to impose a congestion charge on all vehicles in the flow, although those vehicles which impose more congestion than others would be liable to pay a higher charge.[21] We can illustrate the measurement of congestion costs using one particular approach. This is the approach adopted by NERA to estimate congestion costs in Great Britain, and subsequently extended to analyse the marginal congestion costs imposed by HGVs across Europe (Dodgson and Lane, 1997; Link, Dodgson, Maibach and Henry, 1999). The DETR have themselves developed a model to estimate congestion costs in Great Britain, but no specific estimates of marginal congestion costs were available to incorporate into the present model.

B.2. An Approach to Estimating Marginal Congestion Costs[22]

The approach to be considered uses two types of relationship:

1. Speed-flow curves, which show a mathematical relationship between traffic flows on a road (usually in terms of vehicles per lane per hour), and the resulting traffic speeds on that road; and

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[21] See Section 4.8 of this report for a discussion of the impact of HGVs on congestion, and hence on PCU values.

[22] This section draws heavily on Link, Dodgson et al (1999), pages 62-65.

2. Operating cost formulae, which show a relationship – for a particular type of vehicle – between cost per km and speed. Since there is an exact inverse relationship between the speed and the time taken to travel one kilometer, time values can be incorporated into these formulae.

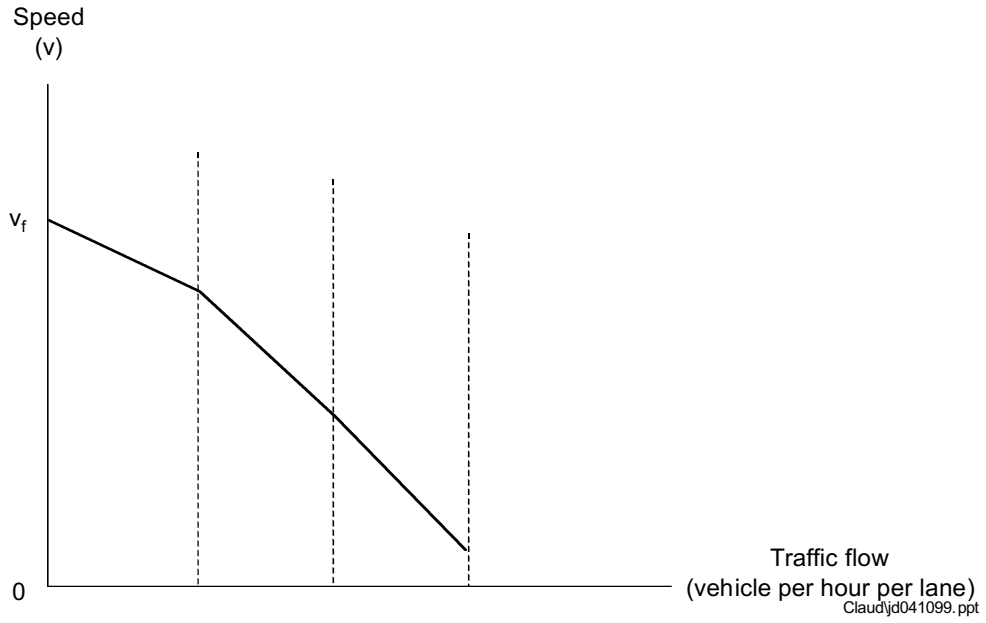
Combining these formulae gives a mathematical relationship between the volume of traffic flow on any section of road, and the cost of travel along that section of route. This means that is possible to calculate the marginal cost of congestion for any traffic flow level.

Figure B.1 shows piecewise linear speed-flow curves. The shape and position of this curve will depend on the type of road. The vertical intercept, v_f, can be defined as the "free-flow" speed, the speed which is obtained when there is only one vehicle per hour.[23] Each downward-sloping section of the speed-flow curves has an equation of the form:

$$V = A - B \cdot F \qquad (1)$$

Where v is the actual speed, F is the traffic flow in vehicles per lane per hour, and A and B are constants determined by the characteristics of the road, and by the particular segment of the "curve" which covers a range of traffic flows.

Figure B.1
Speed Flow Curve



[23] Some speed-flow curves have an initial horizontal segment, indicating that speeds initially do not fall as more vehicles join the traffic flow.

DETR use operating cost formulae of the form

$$g = a + b/v + c \cdot v^2 \quad (2)$$

Where g is operating cost per kilometer for a particular type of vehicle, including time cost. The term g therefore represents "generalised" cost, i.e. money plus time cost per km. As before, v is speed in km per hour, and the terms a, b and c are parameters which vary between different types of vehicle. The term b incorporates a part which equals the value of occupants' time per hour for that particular type of vehicle.

To calculate the marginal cost of congestion, we need to combine the two mathematical functions from formulae (1) and (2) to derive a relationship between traffic flow and generalised cost per vehicle. We can then differentiate generalised cost with respect to traffic flow, and evaluate the value of this differential at the actual traffic flow. This shows the way in which an extra unit added to the traffic flow changes the generalised cost of travel for another vehicle in the traffic flow. We then need to sum all these changes over all other vehicles in the traffic flow. This gives us the marginal cost of congestion.

Suppose first of all that all vehicles in the traffic flow are of the same type, for example cars. Then, from formulae (1) and (2) the relationship between generalised costs and traffic flow is:

$$g = a + [b / (A - B \cdot F] + c\,[a - B . F]^2 \quad (3)$$

And the marginal cost of congestion is:

$$\partial g / \partial F \cdot = [b \cdot B(A - B \cdot F)^{-2} - 2 \cdot c \cdot B(A - B \cdot F)] \cdot F \quad (4)$$

In words, the marginal cost of congestion can be calculated from data on the actual traffic flow (F), and the slope parameter (B) of the speed-flow relation,[24] and the variable parameters (b and c) of the generalised cost formula.

Now suppose that the traffic flow consists of five types of vehicles:

1. cars;
2. light goods vehicles;
3. rigid heavy goods vehicles;
4. articulated goods vehicles; and

[24] Where the speed-flow curve has a number of linear segments, the value of B will depend on the range within which the traffic flow value F lies.

5. buses.

Now we have first to allow for the fact that these different vehicles make different contributions to congestion, eg an extra articulated goods vehicle slows down the average traffic speed more than does an extra car. This is usually allowed for by weighting vehicle numbers by passenger car units (PCUS) where a car has a value of one, and other types of vehicle have values which reflect their relative contribution to congestion.

We now need to reinterpret the hourly traffic flow in terms of PCU-weighted vehicles, i.e.

$$F = F_1 + PCU_2 \cdot F_2 + PCU_3 \cdot F_3 + PCU_4 \cdot F4 + PCU_5 \cdot F_5 \quad (5)$$

An extra car will then impose additional congestion costs on all other vehicles in the flow equal to:

$$(\partial g_1 / \partial F) \cdot F_1 + (\partial g_2 / \partial F) \cdot F_2 + (\partial g_3 / \partial F) \cdot F_3 + (\partial g_4 / \partial F) \cdot F_4 + (\partial g_5 / \partial F) \cdot F_5 \quad (6)$$

An extra articulated heavy goods vehicle (vehicle type 4) will impose extra congestion costs on the rest of the traffic flow equal to:

$$PCU_4 \left[(\partial g_1 / \partial F) \cdot F_1 + (\partial g_2 / \partial F) \cdot F_2 + (\partial g_3 / \partial F) \cdot F_3 + (\partial g_4 / \partial F) \cdot F_4 + (\partial g_5 / \partial F) \cdot F_5 \right] \quad (7)$$

where PCU_4 is the number of cars equivalent to one extra articulated heavy goods vehicle.

Again terms $\partial g / \partial$ F for each vehicle class can be measured from the speed-flow and generalised cost parameters, as was shown above in equation (4).

B.3. Interpretation of Congestion Costs in the Model

NERA are concerned that incorporation of marginal congestion costs in the model would give misleading signals about the way to deal with congestion. Congestion varies by area of the country, by type of road and by time of the day and week. Consequently marginal congestion costs vary very considerably, whereas the structure of the model would involve averaging of congestion costs per km to give a figure which did not reflect the external costs imposed at the times they are most serious. Consequently, incorporating congestion costs into an annual licence fee would be a particularly ineffective way of dealing with the problem of congestion. It would also be invidious if only one group of road users were to bear this "congestion levy".