THE QUADRO 2021 MANUAL

PART 4

DELAY MODELLING IN QUADRO

Contents

Chapter

1. ELEMENTS OF DELAY

1.1 The user costs associated with roadworks are made up of a number of components. Delays will occur at all levels of flow due to reduced running speeds through the site, and on single carriageways with shuttle-working the method of traffic control imposes additional delay. At higher levels of flow the restrictions imposed by the site may mean that there is insufficient capacity available for the normal traffic demand, in which case queues will form. Traffic may then divert onto alternative routes to avoid queuing, although the resulting journey times will still be longer than that experienced on the main route in the absence of works. Traffic already using these alternative routes may well have its own journey time increased. All these delays are calculated by the General Delay Sub-Model (see Chapter 2), which uses a deterministic treatment of queuing at the works site in order to control the volume of traffic diverting.

1.2 Because space is normally restricted at works sites, an incident such as a breakdown or accident can have a highly significant effect, with queues building up rapidly, and often persisting long after the blockage has been removed. The effect of an incident is dependent on many factors, such as the time of day when it occurs, the width of carriageway blocked, the duration of the blockage, and the availability of alternative routes. The delay costs of average incidents, using different blockage durations for accidents and for breakdowns, are calculated by the Incident Delay Sub-Model, see Chapter 3.

2. THE GENERAL DELAY SUB-MODEL

2.1 This is the basic modelling component of QUADRO and in the course of a single maintenance job run this sub-model is used eight times, once in each direction of travel, for each of four day types (see Part 5 paragraph 3.4). Within the sub-model, each hour of the day is modelled in turn, with the traffic conditions at the end of one hour (specifically, the queue length) being carried forward to the next hour.

2.2 The underlying assumption of the sub-model is that regular drivers become familiar with the presence of the works and the scale of delays involved, and will select their route so as to minimise their journey time. Although non-regular drivers may lack the experience to make this choice, they may have some knowledge of the works through various publicity channels. Also, at the present time, many drivers may have live traffic information via satnav devices. Therefore, QUADRO assumes that there will be sufficient drivers trying to minimise their journey times for the following expression (which although not empirically calibrated, is consistent with the limited observations so far made) to be valid to describe the limiting condition at which traffic on the main route will seek an alternative route,

Journey time via main route (including any queuing delay) is (on average)
= Journey time via diversion route.

2.3 QUADRO also assumes that the single diversion route specified for the program can represent all types of diversion behaviour. In practice some drivers will have origins or destinations such that, with the works present, they re-assign part of their trip away from the specified main route, and use only part of the diversion route. Or they may re-assign to a completely different corridor, or retime or suppress their trip. In QUADRO such patterns of behaviour are not modelled specifically, and the simple 'by-pass' diversion behaviour is used as a proxy. If traffic is not expected to divert at a particular site, but instead to queue on the main route, this implies unattractive alternative routes, which will be reflected in the specification of the diversion. QUADRO users have found that the specification of the diversion route can be particularly difficult especially where long distance (strategic) diversion is likely to occur. The specification of routes in urban and suburban areas can also be problematic. A 'maximum queuing delay' solution to this problem may be useful, see Part 5 paragraph 2.8.

Equilibrium Queue

2.4 The principle of equal journey time leads directly to the concept of an equilibrium queue that is used by the program to establish the queue length on the main route during period(s) when the site is overloaded. The equilibrium queue is defined as "that queue on the main route which for a given demand of flow on the diversion route and main route will make the journey time on the main route equal to the journey time on the diversion route". The equilibrium queue is variable, depending on the characteristics of the diversion route and the level(s) of demand flow on the mainline and diversion routes.

2.5 The program calculates the equilibrium queue by comparing the journey time on the diversion route with that on the main route. The journey time on the main route includes the time spent queuing on the approach as well as the time to pass through the works site and reach the end of the section downstream of the site.

Queues

2.6 Queue length is treated deterministically in QUADRO and is a function of demand flow through the works site and the site capacity. For example, when demand exceeds capacity a queue will grow, when demand equals capacity a queue will remain constant and when capacity exceeds demand there will be either no queuing or a queue will disperse. The development of a queue within a time period of constant demand and capacity is shown in Fig. 2/1. Note that the development of a queue is a function of how many vehicles divert.

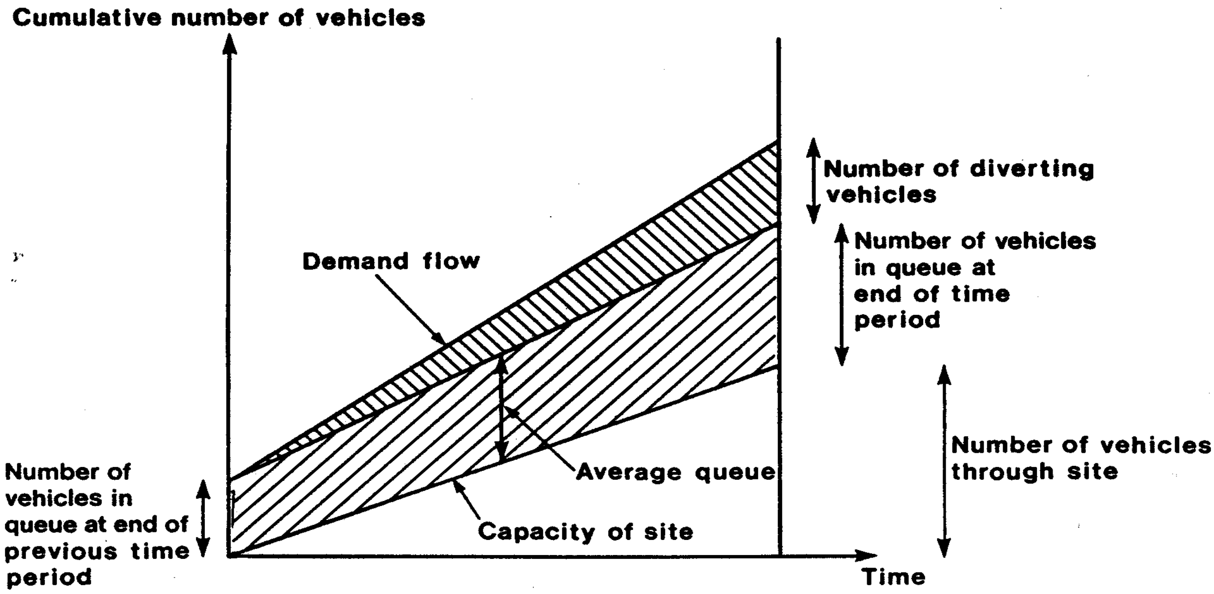

Figure 2/1: Development of a Queue

2.7 It is unlikely in reality that a situation would be tolerated where queues are present at the flows expected around midnight. However, if this occurs in the model, the queue at the end of hour 24 is carried over into hour one of the **same day**. (This means that a queue at midnight on Friday will be carried forward to hour one of Friday, rather than hour one on Saturday - a technical limitation arising because each day type is modelled independently).

Vehicles Diverting

2.8 The program assumes diversion takes place according to Fig. 2/2 below. Curve A describes the possible variations in the average queue length as a function of the number of diverting vehicles varying between 'nothing diverts' and 'everything diverts'. Curve A is defined by deterministic queuing theory applied as illustrated in Fig. 2/1. Curve E on the other hand describes the equilibrium queue length as a function of the number of vehicles diverting, and the intersection of the two curves determines the amount of traffic diverting and in turn the queue length.

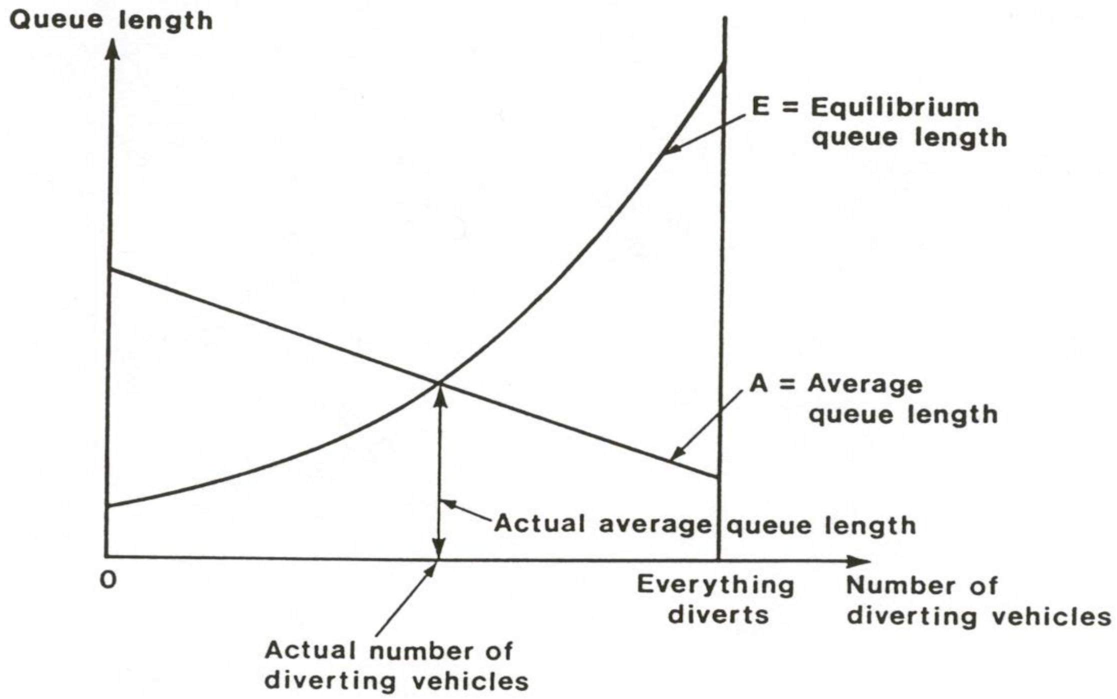

Figure 2/2: Method of Determining Queue Length and Number of Vehicles Diverting

2.9 There may, however, be situations where the two curves do not intersect:

i) when flow is below capacity there is no queuing and all traffic is assumed to stay on the main road;

ii) when curve A is entirely below curve E, all traffic will stay on the main road, since the queue never reaches the equilibrium queue length within the given time period;

iii) when curve A is entirely above curve E, all traffic will divert until eventually the queue is dispersed after which all traffic stays on the main road.

Time Basis

2.10 The time basis for average queue length, speeds etc is 1 hour. The program calculates queue length and number of vehicles diverting in half hourly intervals in order to smooth flows between hours. At the end of each hourly interval the weighted averages of number of vehicles, capacity and speeds are produced and costed. Because of this smoothing process, the output number of vehicles in each hourly period (in Phase 6, see Part 6 paragraph 4.6), may not always exactly match the input hourly values.

Long Queues

2.11 If queuing extends beyond the start of the diversion route the program automatically makes allowances when calculating the equilibrium queue on the basis of the following assumptions. If the main route is a dual carriageway it is assumed that traffic queues in the one or two right-hand lanes, leaving the left lane open for traffic wishing to reach the diversion route. However, if the main route is a single carriageway, traffic wishing to divert is assumed to have to wait in the queue until the start of the diversion is reached. This assumption may not always be realistic and the use of the diversion route will be underestimated.

2.12 As a general rule, the user should bear in mind the role of the diversion route in QUADRO as representing all possible alternative uses of the network, even when it is specified in terms of a realistic unique route. If queues frequently extend well beyond the diversion turn-off, the diversion route may need to be respecified, taking into account the possibilities of diverting from the main route further upstream.

3. THE INCIDENT DELAY SUB-MODEL

3.1 If an incident such as a breakdown or accident occurs within the site length, the already restricted capacity will be further reduced. This may result in queuing where there was none before, or queues already present starting to get longer. These queues will not be expected in the same way as those occurring regularly because of the works, so drivers will not be able to learn a rational response and divert to equalise journey times. However, if queues are long enough extra diversion is likely to occur. (The sub-model does not run for single carriageway sites with shuttle working. At such sites, which cannot be more than 500m long, it is assumed that any obstruction caused by an incident will be speedily removed).

3.2 The sub-model estimates the delays and resulting costs caused by incidents that occur within the site itself. Incidents elsewhere on the network are considered less likely to have a major effect on the main route traffic, and are not accounted for. For simplicity in calculating queue lengths, the sub-model assumes all incidents occur at the centre of the site.

Type of Incident

3.3 The sub-model is run twice for each run of the General Delay Sub-Model, once for breakdowns and once for accidents because the two may have different characteristics, for example in terms of their duration (the time from the occurrence of the incident to the time when the obstruction is removed). The incident duration will be dependent on the level of provision made for surveillance of the site and the speed of access for emergency vehicles (breakdown recovery, ambulance, etc). The sub-model also simplifies matters by using a fixed (user-specified) average incident duration, rather than a distribution of values, see Part 5 paragraph 1.10.

Breakdowns

3.4 The sub-model assumes that breakdowns occur at the rate of,

10 per 10^6 veh-km (light vehicles)
5 per 10^6 veh-km (heavy vehicles).

These rates are significantly lower than those used in previous versions of QUADRO. Recent research (Ref 4.1) has shown that the rate at which breakdowns occur is much less than previously observed. Although these rates were derived from observations at motorway worksites, it is considered reasonable to apply these rates to conditions both on motorways and on all-purpose roads. The research also indicated that on average breakdowns block 80% of the lane where the breakdown takes place and that each adjacent lane has its effective 'capacity' reduced by approximately 15%. These values have been used in QUADRO, and can be expressed as follows:

- if N lanes are open past the worksite each with a normal capacity C, then the site capacity during a breakdown would be reduced to,

$$C [0.2 + 0.85 (N-1)].$$

- for example, on a dual 3 motorway with two lanes open in each direction (each with a capacity of 2000 pcu/hr), the <u>directional capacity</u> during a breakdown would be reduced,

from, 2 x 2000 = 4000 pcu/hr,
to, 2000 [0.2 + 0.85 (2-1)] = 2100 pcu/hr.

Accidents

3.5 For accident delays during the works, the sub-model uses the 'site-length' accident rate for the appropriate works type (Part 2 paragraph 3.6), factored to include damage only accidents. 'Site-presence' accidents, most of which occur in the approaches to the site, are ignored although many of them may cause delays. The factor is selected according to the link accident type, (see Part 2 Table 3/2) and is 17.7 damage only accidents per personal injury accident in urban areas, 7.8 in rural areas and 7.6 on motorways. These figures are based on national statistics regardless of whether works are present, but QUADRO applies them to the works sections. It is possible that accidents block more of the available road width than do breakdowns, but in QUADRO accidents are assumed to occupy the same width as breakdowns and cause the same percentage capacity reductions given in paragraph 3.4 above.

Modelling Method

3.6 Incidents occur randomly, within a given volume of traffic, and the effect of an individual incident is critically dependent on the time of day at which it occurs. Because the number of incidents per day is small, if the sub-model generated random incidents it would need to model many days of operation before a useful estimate of the average delay could be obtained. Instead a single day is modelled but with an incident generated as a simplifying assumption, uniformly every 1000 veh-km of travel through the site, which is much more frequent than the actual rate - see paragraph 3.4 above. This means that, for example, in a busy 5km site carrying peak flows of 3000 veh/h, 15 incidents will be generated during the peak hour alone. Within the program, delays due to this large number of generated incidents are averaged, and then factored by the average expected actual number of incidents per day, to get an average daily delay (and hence cost) due to incidents of the specified type. The effects of each incident modelled are treated discretely, with any cumulative effects due to overlapping incidents being ignored. No allowance is made for real overlapping of effects, which will occur randomly from time to time. As an indication of the range of delays an incident can cause, at different times of day, the maximum and minimum delays calculated for individual incidents are output.

Diversion

3.7 Since an incident is by definition unexpected at any particular time, diversion is unlikely to take place unless drivers are aware of the extra delay at a point where there is an option to divert. The rule in the sub-model is that when a blockage occurs, additional queuing will occur first in the site itself, then beyond the end of any queue that was already present because of site overloading. (Information about existing queues is passed to the sub-model - in a simplified form - from the General Delay Sub-Model). When the queue reaches the junction at the start of the diversion route, extra diversion will start to occur. ('Extra' meaning in addition to any diversion calculated by the General Delay Sub-Model). If the queue reaches back to the next upstream junction, all excess traffic will divert and the queue will grow no further. At intermediate queue lengths, the extra diversion is proportional to the length of the queue relative to the distance between the two junctions. After the obstruction has been cleared extra diversion will continue until the queue no longer extends beyond the junction at the start of the diversion route. The rest of the queue will clear by discharge through the site in due course.

3.8 The Incident Delay Sub-Model is an optional component of the program, and it may be convenient to ignore it during trial runs. However, in any full run of QUADRO it should always be specified.