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THE USE OF TRANSYT AT SIGNALISED ROUNDABOUTS

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THE USE OF TRANSYT AT SIGNALISED ROUNDABOUTS

ABSTRACT

As traffic flows continue to rise, delays at many major roundabouts are increasing. One method adopted in an effort to reduce delay and increase capacity is to signalise one or more of the entry arms. Where roundabouts require signals on most or all entries, the TRANSYT method of signal settings can be used to predict the effect of fitting signals and to find optimum signal timings.

The report discusses the factors to be considered in modelling a signalised roundabout using TRANSYT. These factors include the link structure, treatment of flared approaches, estimation of saturation flows, and the use of link weighting and queue penalties to avoid blocking back and 'locking up' of the roundabout. Two examples are used to illustrate the techniques described.

1 INTRODUCTION

Traffic flows, particularly on motorways, have continued to rise steadily over recent years, and this has led to long delays occurring at some junctions. Many of these junctions are large roundabouts, and at peak times long queues can form on the slip roads and could back-up onto the motorway. One method of reducing these dangerous queues is to signalise the motorway exit slip road, either part or full time.

There are other situations, for example at gyratories in towns, where signalising can increase capacity and hence reduce queues. Signalisation can often be used to allow for flow increases due to new developments etc. In these situations some of the sections of road round a gyratory can be very short, leading to problems if a queue should block back to a previous junction.

Signalling roundabouts to prevent queues blocking the junction was first studied in 1959 (Webster 1960), and the technique has been selectively applied over a range of circumstances. Several authors have shown that the performance of three arm roundabouts could be improved by traffic signals (Davies et al 1980, Flanagan et al 1983) and, more recently, this work has been extended to larger junctions. Other authors have studied junctions in London (Huddart 1983, Wright et al 1984) and Sheffield (Bull et al, 1983) with success. The Sheffield study used TRANSYT to provide initial signal timings for a six arm junction.

Many roundabouts have had part-time signals on one or two entry arms, and in these situations co-ordinating signal timings for traffic progression around the roundabout has not been a consideration. More recently there have been situations where most or all entry arms to a roundabout need to be signalled, usually for 24 hours a day. In these circumstances there are nearly always benefits to be gained by optimising the co-ordination of the signals round the roundabout. The TRANSYT program (Vincent et al, 1980) is the most commonly used method for optimising signal timings in signal networks where benefits can be obtained by co-ordination between adjacent junctions. The method is suitable for roundabouts where most or all of the arms are signalled. By using various facilities available in TRANSYT such as link weighting, the shared link facility, and queue penalties, the program can be used to model traffic behaviour on the roundabout, control queue lengths, and find signal timings such that queues do not form to block upstream junctions.

2 THE TRANSYT PROGRAM

The TRANSYT computer program is a method for finding and studying the 'best' fixed-time signal timings with which to co-ordinate adjacent signal junctions, so that, wherever possible, platoons of traffic can receive a green signal. The program runs off-line and uses information about the junctions (nodes), and flows and turning movements on the sections of road joining the nodes (links). The program was developed at TRRL during the late 1960s and has become the most widely used method of producing fixed-time signal plans for networks of centrally controlled signals.

TRANSYT uses an off-line model of traffic behaviour on links and signalled nodes to estimate the value of a Performance Index (PI) consisting of a weighted sum of the total vehicle delay and stops in a network. This measure of performance is used by an optimisation routine that systematically alters the signal timings until a set are found that give minimum PI in the network.

The program is described fully in TRRL Laboratory Report LR888 User guide to TRANSYT version 8 (Vincent et al, 1980) and the TRRL Application Guide AG 8, TRANSYT/9 Users Manual (Crabtree 1988). The program will run on mainframe, mini and microcomputers, and is available from TRRL.

Several features of the program are of special significance when using TRANSYT to model a signalised roundabout. These are: link weighting, the shared link facility, and queue penalties. Descriptions of these features are given in LR888 and discussed below. Another feature which may be significant is the give-way model which can be used if there are any unsignalised entries to the roundabout.

One disadvantage of the TRANSYT model is that arriving vehicles are assumed to have an uninterrupted passage to the stop-line, regardless of any queue on the link. TRANSYT effectively queues vehicles in a vertical heap on the stop-line, and this simplification of the model has implications in situations where links are short and flows are high—as can occur at signalised roundabouts. This effect is discussed in more detail in sub-section 3.6.3.

3 MODELLING A ROUNDABOUT

The principles involved in modelling a roundabout are discussed below and illustrated by using a simple, hypothetical, four-arm roundabout shown in Figure 1. Further examples based on real-life sites are described in sections 5 and 6.

Note that the units used throughout the report are passenger car units (pcu). Other units may be substituted (vehicles for example) with the qualification that flow and saturation flow should be in the same units for a given link.

3.1 CYCLE TIME

In networks which contain some short links (such as roundabouts), severe problems can arise if

traffic queues fill these links and block upstream nodes. If this blocking continues for any significant time, the capacity of the network will fall dramatically and traffic queues can block back and 'lock up' around a roundabout. One of the most important methods of keeping queues short is to keep the length of the red time short. This can be achieved by having a short cycle time, giving as much green time as possible to the short link, consistent with having no link running at more than 90 to 95 per cent saturation (if possible).

TRANSYT has a cycle time optimiser (CYOP) that predicts the saturation of each node over a range of cycle times. This can be used to select the lowest possible cycle time such that no link has a degree of saturation worse than 90 per cent.

3.2 LINK STRUCTURE

A link in TRANSYT is used to represent more than one lane when the traffic in the lanes behaves in a similar way and forms equal length queues. In many cases, however, traffic will not form equal queues because a particular lane may be used for a specific movement only. For example, on a two lane approach, virtually all vehicles wishing to turn left at or before the next signal may use the nearside lane on the approach. This may occur even though the nearside lane has longer queues than the offside lane. By using the nearside lane, vehicles avoid having to 'push in' from the offside lane. In this situation two separate links will have to be used and the proportion of traffic in each must be measured or estimated separately.

Unequal use of lanes often occurs when arrow markings in the lanes direct vehicles making a left turn into the nearside lane, and other traffic into the offside lane, as shown in Figure 1—node 2. In

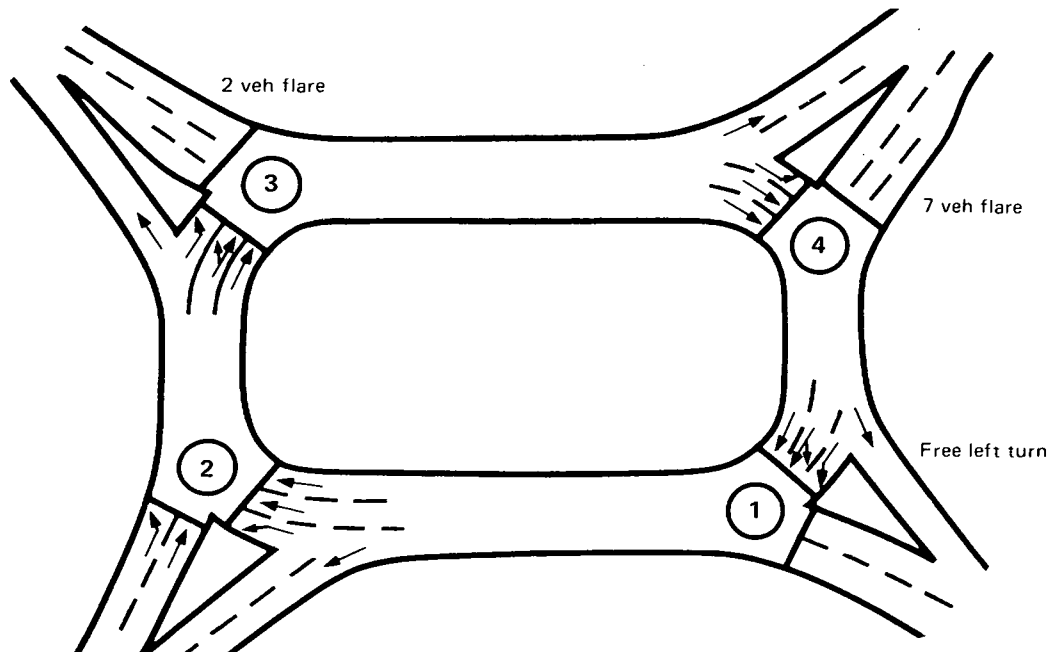


Fig.1 Site diagram for a four-arm roundabout

At nodes 1 and 3 the centre circulating lanes have been marked for both straight ahead and left turn traffic. This should be acceptable because the left turning traffic exits down a two lane road. As the centre lane is therefore likely to contain both left turn and straight ahead traffic, it is probable that the queues on all lanes will form at the same rate. Queues at the circulating link stop-line should therefore form equally for all lanes and one link can be used.

This assumption is only valid, however, when the arriving flow is reasonably balanced between turning and straight ahead. If, for example, during any part of the cycle more than 67 per cent of the flow arriving at the stop-line wished to turn left, then the queue in the left and centre lanes would be longer than that in the outside (straight ahead only) lane. Equally if in another part of the cycle less than 30 per cent of the arriving traffic was turning left, then the queue in the left lane would be smaller than the queue in the centre and outside lanes. In this situation it would be necessary to use one link for each lane.

The link diagram in Figure 2 shows one main circulating link for node 1 (link 11), and two main circulating links for node 2 (links 21 and 25)

where left turn traffic uses the nearside lane exclusively. The link structure for node 3 is similar to node 1, and the link structure for node 4 is similar to node 2. For nodes 2 and 4, where there are two main links for the circulating traffic, one main link is used to model traffic continuing round the roundabout and through to the next downstream junction (eg link 21), and a second main link models traffic that turns left, leaving the roundabout prior to the downstream junction (eg link 25). Vehicles on these second links have a 'free left turn' before they reach the subsequent node (eg node 3 for link 25), and are not considered again by TRANSYT.

It is also necessary to represent traffic by more than one link where one lane on an entry arm is exclusively used for traffic making a specific movement. For example the two lane entry at node 2 is split into two links, the nearside lane is modelled using link 29 for traffic making a immediate left turn before node 3, and the offside lane is modelled by link 20 for other traffic.

Driver behaviour can be influenced by lane markings, and how the lanes are marked can make a significant difference to the capacity of a junction in many circumstances. Generally it is better to encourage equal use of all lanes by using, for example, combined straight ahead and left turn (or right turn) arrows wherever possible. This tends to maximise capacity by ensuring that lanes do not empty during the green while neighbouring lanes still have queues.

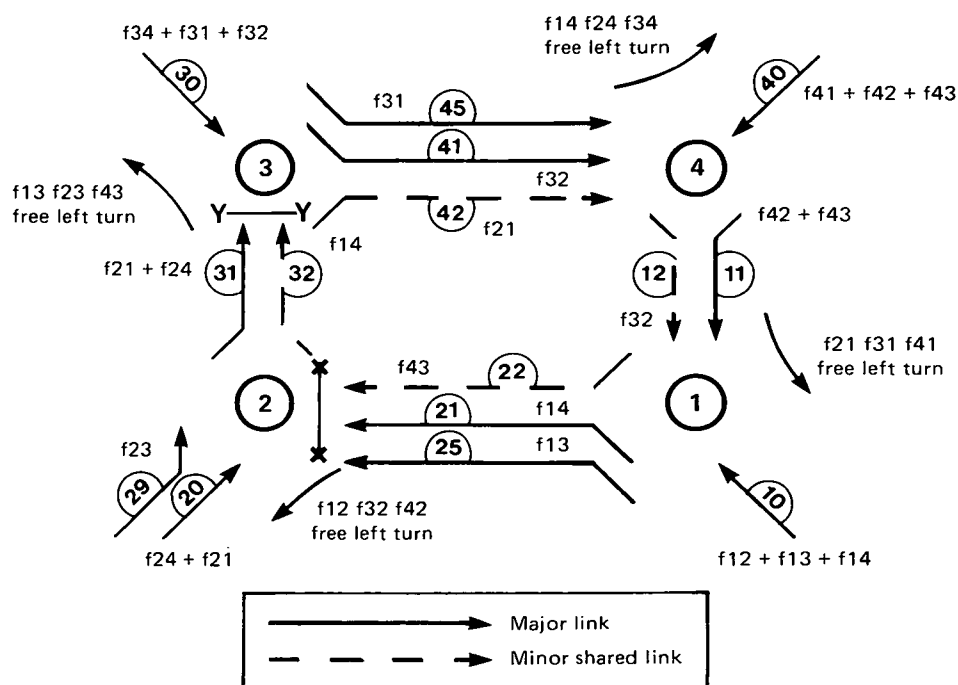


Fig.2 Link diagram for a four-arm roundabout

The use of markings, however, cannot be guaranteed to ensure full use of all circulating lanes, especially if flow on one of the entries is destined predominately for a particular destination. Each case must be considered on its merits. Care must also be taken that markings appropriate for one period of the day with a certain origin-destination pattern are also appropriate for the rest of the day. If no doubt, it may be better to omit the directional arrows.

3.3 FLARED APPROACHES

These are common on roundabout entries where extra short lanes are often added prior to the stop-line to increase entry flow into the roundabout. Unfortunately TRANSYT can only model uniform saturation flow, so the model will not be accurate for flared links. In these situations the saturation flow in reality will start at a high level (say three-lane flow) and then drop as the flare is emptied (to two-lane flow).

3.3.1 Increasing Average Saturation Flow

A knowledge of the green time at the node will allow a substitute 'average' saturation flow to be calculated for use in TRANSYT. It must be remembered, however, that this will be modelled as a slightly higher uniform flow throughout the green, whereas in reality there would be more traffic at the start of the green and less at the end. Should the timings be re-optimised and result in a different green time, the 'average' saturation flow would also need to be re-calculated.

3.3.2 Calculating the average saturation flow

Before calculating the average saturation flow, two parameters of the flare need to be known: firstly, the number of pcu that can be accommodated in the flare over-and-above the number of pcu that would be present if there were no flare; and secondly, the saturation flow of the extra lane(s) in the flare. From this information, the following formula should be used to calculate the time taken for the flare to completely empty (the flare clearance time):

$$g_c = \frac{3600 \times N}{S_f} \quad \dots \text{equation 1}$$

where: g_c the flare clearance time in seconds;
 N the extra number of pcu that can be accommodated in the flare in pcu (see note below);
 S_f the extra saturation flow of the flare in pcu/hour (see note below).

Note: where the flare has more than one extra lane, and these lanes are not of equal length, then N should be the number of pcu in the *longest* of

the extra lanes and S_f should be the saturation flow of that lane.

Then, providing the flare clearance time is less than the effective green time, the following formula can be used to calculate the average saturation flow of the link:

$$S_a = S_1 + \frac{3600 \times N}{g_e} \quad \text{where } g_c < g_e \quad \dots \text{equation 2}$$

where: S_a average saturation flow of the link for time g_e in pcu/hour;
 N as in equation 1 above;
 g_e the effective green time in seconds;
 g_c the flare clearance time in seconds;
 S_1 the saturation flow without the flare in pcu/hour.

Equation 2 can be applied without modification to situations where the extra lanes in a flare are of unequal length, and $g_c < g_e$.

If $g_c \geq g_e$ then $S_a = S_1 + S_f$ (where S_f is as in equation (1) above) *except* in the situation where the flare has extra lanes which are of unequal length. In this case, S_1 becomes the sum of the saturation flows for all long-lanes, plus the saturation flow for all short lanes that do not empty during the effective green. This value of S_1 is then used in equation 2 and N becomes the extra pcus accommodated by short lanes that do completely empty during the effective green.

As an example calculation, take link 40 in Figures 1 and 2. The extra capacity of the flare is 7 pcu and the flare lane saturation flow is 1750 pcu/hour. This gives a flare clearance time of:—

$$g_c = (7 \times 3600)/1750 \\ = 14.5 \text{ seconds.}$$

Then, for a initial guess use say 20 seconds for the effective green time. The average saturation flow for the link is then:—

$$S_a = 3500 + (3600 \times 7)/20 \\ = 4760 \text{ pcu/hour.}$$

The value arrived at should then be entered into the data; TRANSYT run; and the new effective green-time used to recalculate the average saturation flow. The process is repeated until the green-time arrived at in the TRANSYT run is the same as that used to calculate the saturation flow (preferably to the nearest step, particularly for critical links).

3.3.3 Reducing the Start Lag

Another possibility is to reduce the start lag and so input an amount of extra flow at the saturation flow rate of the long lane(s) (without the flare), before the main flow on the link starts. This has

rather limited possibilities, but can be useful when flares are small, say 1 or 2 pcu (equivalent to about 2 or 4 seconds per lane reduction in start lag).

The formula for decreasing the start lag is:—

$$T = \frac{N \times 3600}{S_f}$$

. . . equation 3

where: T is the reduction in start lag (seconds);
and
N and S_f are as in equations 1 and 2 above.

This method is illustrated in Figures 1 and 2 for the 2 pcu flare on the two lane approach represented by link 30, where the saturation flow of the flare is 1750 pcu/hour, and the start lag is reduced from 5 seconds to 3 seconds.

This again does not model the real situation and will cause vehicles to arrive downstream earlier in the model than real life. This can be overcome to some extent by reducing the cruise time slightly. Both the above methods will, however, model the overall capacity of the node correctly.

3.4 SATURATION FLOWS

At normal signalised junctions such as cross roads, saturation flows can be estimated using formulae in TRRL report RR67 (Kimber et al, 1986). Unfortunately, these formulae do not take account of flared approaches, stop-lines with more than 3 lanes, oblique stop-lines or curved approaches. This can lead to problems when calculating or estimating saturation flows at roundabouts. Consequently the RR67 formulae cannot always be taken as appropriate.

3.4.1 Entry arms

Entry roads to roundabouts can have a number of stop-line features not common on other types of signalised junctions. The way to model flared approaches in TRANSYT is described in the previous section. Other features that can affect saturation flow are: oblique stop-lines; sharp bends; and gradients. Such features tend to reduce the saturation flow and due account should be taken of them if saturation flows are not to be over-estimated. Where possible, it is advisable to measure saturation flows.

3.4.2 Circulating arms

Deciding on the saturation flow to use for circulating links in TRANSYT can be more of a problem than for entries. As yet there is little evidence about saturation flows for circulating sections of carriageway. The factors that can affect saturation flow are as follows:—

- (a) lane changing or 'weaving' (which can occur when traffic moves from offside to nearside prior to exiting and tends to introduce gaps into the traffic stream);
- (b) oblique stop-lines;
- (c) road curvature;
- (d) short links with several lanes.

Item (d) above may require a great deal of thought if accurate modelling is to be achieved. On most signalised roundabouts there are at least some short circulating sections of carriageway with several lanes. Often, not all these lanes are fully utilised.

Ideally, a single TRANSYT link should be used to represent more than one lane only if the queue lengths are similar in each lane throughout the cycle. Where lane usage (and, therefore, queueing behaviour) is known or can be predicted (through the use of destination markings for example) one link should be used to represent one lane. In these circumstances the formulae in RR67 (Kimber et al, 1986) may be applicable (once due account has been taken of the factors (a) to (d) above). Where knowledge of lane usage for a section of road is inadequate, it may only be feasible to use one TRANSYT link to represent more than one lane on-street. However, where it is necessary to represent more than one lane on one link, the effects of uneven queueing may be compensated for by reducing the saturation flow in TRANSYT. The amount by which to reduce the saturation flow will depend on the extent to which queueing is uneven, but it is likely to be in the order of a few hundred pcu/hour per lane. If there is doubt about the extent of the unevenness of queueing, it will be necessary to err on the low side, otherwise the capacity of the roundabout may be over-estimated. The initial estimate can be refined following observation of the junction with a set of TRANSYT timings.

3.4.3 Measuring saturation flows

It can be difficult to measure saturation flow at signalised roundabouts since, if co-ordination is effective, queues are often short and saturation flow can fall during a long green. The correct way to measure saturation flows is to measure the lane or lanes represented by one TRANSYT link (and in this context the major and minor links forming a shared link are one link). Where a link represents more than one lane, the saturation flow should be measured until the traffic has ceased to flow at full saturation in ALL the lanes. The resulting saturation flow value will then compensate for uneven queueing as explained in section 3.4.2.

Measurements have been attempted (in the way described in the previous paragraph) on the M4 at

junction 11 (where part-time signalling was operating) and at the Handy Cross roundabout at the intersection of the M40 and the A404 at High Wycombe. For the motorway off-ramps (which were uphill from the motorway at both sites) values of 3400 to 3500 pcu/hour were measured for the two-lane entries. For circulating carriageways, saturation flows for three-lane links were measured at about 4900 pcu/hour, and saturation flows for two-lane links were measured at about 3200 to 3400 pcu/hour.

Even where saturation flow was maintained on all lanes throughout the green, it tended to become reduced as time went by, particularly on the uphill motorway off-ramps. This supports the use of short cycle times where possible (see section 3.1).

3.5 SHARED LINKS

The use of shared links can improve the modelling of the junction significantly, especially if origin/destination flows are available. More accuracy is obtained as more information is added to the TRANSYT model.

TRANSYT models traffic flows in a series of time intervals or 'steps', and the number of steps per cycle is chosen by the user in card type 1—General Parameters. Steps are generally chosen to be an integer number of seconds (usually 1 or 2 seconds). When modelling a discharging queue, TRANSYT calculates the proportion of flow that continues into each downstream link from its knowledge of the total flow on the discharging link and the total flow required to enter the downstream link. For example, if 75 per cent of the upstream link flow continues into the downstream link (with 25 per cent turning off) then for every step in the cycle, three quarters of the discharging flow is taken as the entry flow into the downstream link. This is repeated for every step in the cycle. The remaining flow is assumed to have turned out of the network and is not considered further. Thus every fourth vehicle will be assumed to turn off prior to the next node.

In many cases this simplified model is not accurate, as in reality there will be predominate movements across the roundabout. While on average one vehicle in four will exit, it is probable that these turning vehicles will not be evenly distributed during the cycle. It is not uncommon that for most of the cycle there is little traffic turning out at a given node, but then, for a short time, a platoon arrives of which the majority exit.

Figures 1, 2 and 3 illustrate this for a simple four-arm roundabout. Consider the flows arriving at the stop-line X—X at node 2. Some vehicles will have come from the entry at node 4, heading for node 3 (f_{43}), and will exit before the stop-line Y—

—Y at node 3. The remaining vehicles arriving at X—X will have entered at node 1 (f_{13} and f_{14}) and a proportion of this (f_{13}) will also exit before stop-line Y—Y at node 3. The vehicles from nodes 4 and 1 enter the circulating carriageway between nodes 1 and 2 at different times in the cycle and so will form two distinct platoons at the stop-line X—X. The platoons are illustrated in Figure 3 (a). Of the two platoons only the proportion which entered at node 1 and continuing to node 4 (f_{14}) will continue to stop-line Y—Y. This traffic alone should flow into the downstream link 32.

Fortunately it is possible to model two entry flows separately using the shared link facility in TRANSYT. If vehicles that are turning out of the roundabout before the next node (f_{43}) are modelled as a minor shared link, then the fixed proportional reduction for circulating traffic can be applied to the newly entered traffic only (f_{13} and f_{14}). This will give significantly improved modelling compared to taking a (smaller) fixed proportion of the total traffic on a single link between nodes 1 and 2.

This is further illustrated in Figure 3. The two platoons arriving at stop-line X—X are shown in graph (a), and their departure in graph (b). Graph (c) shows the flow along links 31 (circulating flow) and 32 (entry flow), and it can be seen that flows f_{13} and f_{43} have turned out of the roundabout. Graph (d) shows what would happen if only one link was used to model all the flow between nodes 1 and 2 ($f_{13} + f_{14} + f_{43}$)—TRANSYT simply reduces the flow leaving stop-line X—X by the proportion which is turning out of the roundabout. Hence arrivals downstream would be earlier in the cycle than in real life. This can have a significant detrimental effect on the co-ordination of the final signal timings, and wherever possible the shared link model described above should be used. The shared link model does require complete origin/destination flow data.

Use of the shared link facility is required to separate circulating traffic such that, on each section of circulating carriageway, either:

- (a) traffic from each entry is represented by a different link; or
- (b) traffic to each exit is represented by a different link.

The option (a) is described above—the equally acceptable alternative (b) is illustrated in example 2, section 6.2.

For roundabouts with five or more entries (or four entry roundabouts with significant U-turning traffic) inaccuracies of the nature described in paragraphs 1 and 2 of this section are introduced. For correct modelling of such roundabouts, extra

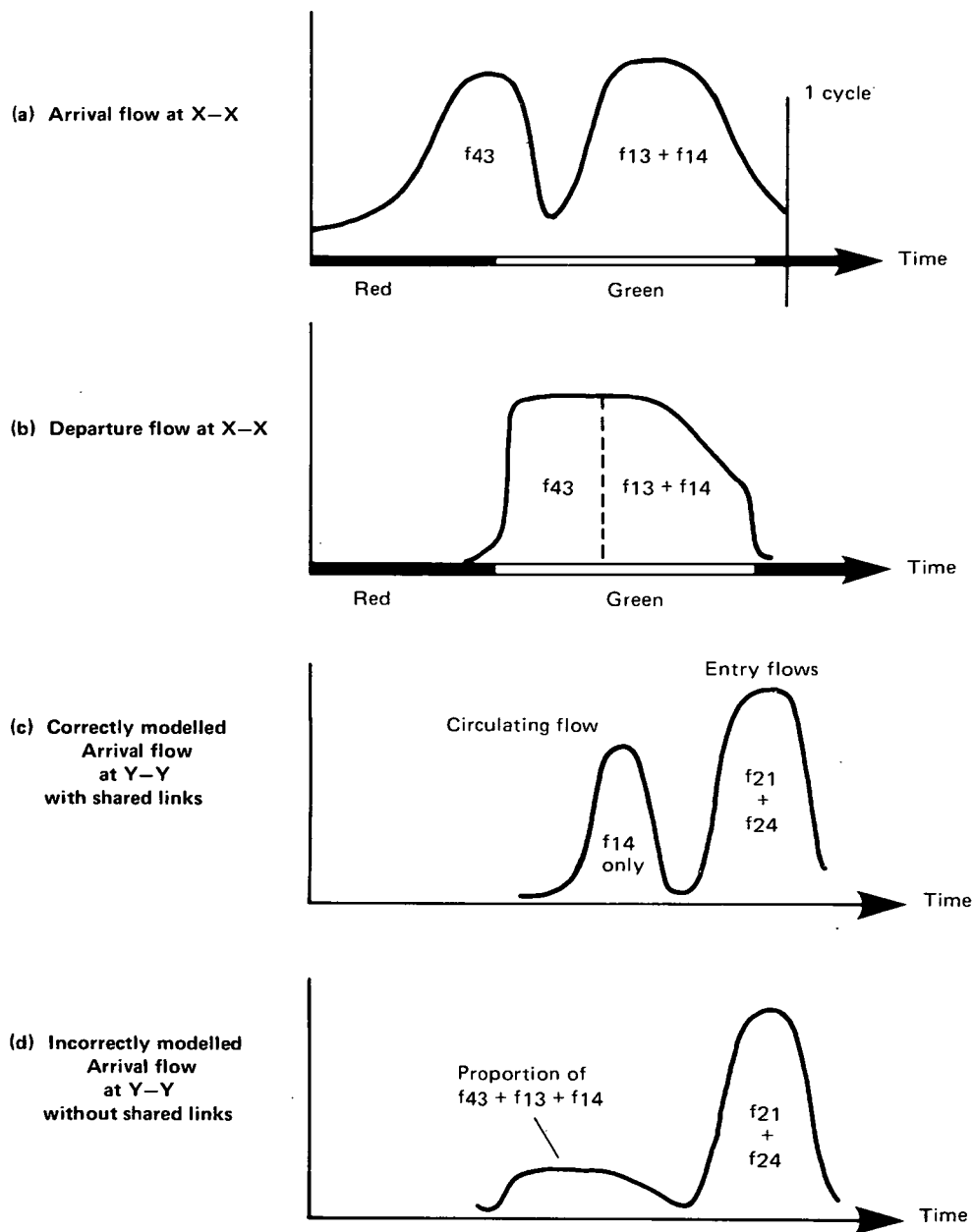


Fig.3 The use of shared links to model flows

shared links would be required such that either (a) or (b) above is taken into account.

3.6 BLOCKING BACK

It is important that queues on circulating links do not extend back and block the upstream junction. If this should occur the capacity of the system can fall and queues build up very quickly. While a set of signal timings can be found that prevent this occurring under 'normal' or average conditions, it is necessary to consider the effect a sudden large increase in arrival flow would have on the system.

The use of a short cycle time is important, as described in section 3.1. The use of the limit-queue facility, and the effect of increased demand are discussed below.

3.6.1 Limit queues

One method of discouraging the formation of queues on circulating links is to use the 'limit queue' facility on card type 38. The user must specify a maximum queue in pcu, and a penalty factor to be applied as soon as the limit queue is exceeded. The penalty is added as soon as the back-of-queue modelled by TRANSYT exceeds the

maximum number of pcu defined in card type 38. The number of pcu specified in the limit queue will normally be based on an estimate of the allowable queue length for each link, assuming 5.75 metres/pcu per lane (or about 6 metres/vehicle). This allowable queue length at a roundabout will usually be less than the total link length, because the criteria for link blocking is often when vehicles are unable to make the 'free left turn' out of the link. For roundabouts this left turn can be midway down the circulating link, so the maximum allowable queue length must be less than the link length to take this into consideration.

The maximum back-of-queue (known as the Mean-Max-Queue or MMQ) in TRANSYT is calculated for an 'average cycle' during the period under consideration. Because this maximum back-of-queue is for an average cycle, it is expected that in 50 per cent of cycles the maximum queue in real life will exceed the value calculated by the TRANSYT model. It is necessary, therefore, to make an allowance for this by reducing the number of pcu specified for the limit queue by a factor. A factor of 60 to 75 per cent of the estimated maximum allowable queue length has been found suitable, but a lesser value may sometimes be needed, depending on the situation. Where there is likely to be a large variation in numbers of vehicles arriving in each cycle, a smaller percentage factor should be chosen (nearer 60%); but if there is unlikely to be much variation in arrivals per cycle, a larger percentage can be used. It is possible that on circulating links there is less opportunity for arrivals to vary much between cycles compared with entry links; but each situation should be considered carefully.

When choosing penalty values it should be remembered that the penalty is added to the TRANSYT Performance Index only during those parts of the cycle when the limit queue is exceeded. This is likely to be a small proportion of the cycle, but even this short time can be critical when the link becomes full enough to affect the entry rate from upstream links. Penalty factors should therefore be quite large, and values in the range 3000 to 6000 pence/pcu-hour are often appropriate.

There may be occasions when, despite a high penalty, the limit queue on circulating links is still exceeded. This can occur because in order to reduce queues on a given link, TRANSYT must increase the green time for the stage in which the circulating link receives green. This can only be at the expense of entry link(s) that run in the other stage, and some of these entry links may then be forced into over-saturation. This over-saturation causes the Performance Index to increase considerably, and the optimiser will attempt to reduce the over-saturation to lower the Performance Index. This in turn will cause the limit

queue to be exceeded, and even a very high excess queue penalty may not keep the queue below the limit in situations where entry links running in the other stage have high degrees of over-saturation.

In such cases, a low delay weighting for over-saturated entry links which can usually accommodate a long queue may help to force the critical circulating queue below the desired limit, but the consequences of having an over-saturated link should be carefully considered.

3.6.2 Excess Demand

A situation can occur when a large increase in demand, (such as departures from a football match or similar event) may cause queues to form on the circulating links that block upstream junctions and cause the roundabout to 'lock up'. Obviously if the demand is suddenly increased, queues are going to form somewhere, but it is important to ensure they form on the approach arms and not on the circulating links.

This can be achieved by making sure all entry arms are running at a high degree of saturation (typically 85 to 95 per cent). This will ensure that, even if demands double, flows on circulating links can only increase by about 10% on average, which should not cause problems due to blocking back and 'locking up' the roundabout.

In some situations, for example motorway entry slip roads, this may not be appropriate, as queues forming here are just as undesirable as queues on circulating links. In these situations a lower degree of saturation on the entry link will be necessary, but the consequences on the circulating traffic should be carefully considered during periods of higher than average flow.

When modelling a normal urban network, TRANSYT will calculate the delay and number of stops on each link in the network. It then multiplies these by the value of delay and the cost of stops for each link to produce an overall Performance Index for the optimiser to minimise. Unless specific action is taken to 'weight' particular links, this process treats all links as being equally important and, for individual nodes, will distribute spare green time between links.

As discussed above, for roundabouts it is usually necessary to arrange entry links to have high degrees of saturation, giving any spare capacity to the circulating links. This can be achieved by removing the stop weighting for entry links by entering -9999 in columns 61–65 of card type 31; and by entering a low delay weighting of about 20 per cent so that only 1/5th of the normal delay cost (card 1 columns 71–75) is added to the PI. The low delay weighting on an

entry link is achieved by entering 20 in columns 76–80 of card type 31. This will ensure that entry links run at between 85 to 95 per cent saturation, leaving any spare capacity to the circulating links.

This low weighting factor may not be appropriate where the entry link is a motorway slip road, as it may be dangerous to form large queues which could block back onto the motorway. In this situation a larger weighting factor may be used (a value of 60% has been used in example 1, section 5) or perhaps no weighting factor at all. This means that at these nodes, queues are more likely to form on the circulating links, which could lead to blocking back, although the queues on the entry slip roads should not be excessive.

Once the signal timings have been found using the suggested weighting factors and queue penalties etc, an economic assessment of the delay of the network can be achieved by removing all weightings and queue penalties, and re-running TRANSYT with the final timings and no optimisation. This network should also be run with flows increased by about 20 per cent to check the network will continue to operate in higher than average flow conditions. Again, no optimisation will be needed. This is easily achieved by use of the network flow scale factor in columns 41–45 in card type 1. The TRANSYT output should be carefully checked to ensure queue lengths remain short on circulating and other critical links, so that blocking back to upstream nodes is unlikely to occur.

3.6.3 Blocked Links

When optimising the signal timings and, in particular, the node offsets, the TRANSYT program does not take into consideration whether any links are blocked or not. This means that situations can arise when TRANSYT produces signal timings that would discharge traffic from an upstream link straight into a queue on a short downstream link.

This happens because the TRANSYT model assumes that vehicles form a vertical queue at the stop-line, rather than a linear queue back along a link. The model can then release traffic into a blocked link believing that by the time the traffic reaches the stop-line, the (vertical) queue will have discharged. Thus the model does not correctly take account of the green starting wave and the physical length of the queue.

When timings are implemented it is possible that some links can therefore be poorly co-ordinated. In such situations signal timing offsets between adjacent signals may have to be adjusted manually. The use of low limit-queue values and high queue penalties will generally keep queues shorter and prevent this happening (see 6.4.2).

3.7 SAFETY

From observations at a trial site it was noticed that problems occurred when traffic entering the roundabout was almost immediately faced with a red signal on reaching the next stop-line on the circulating carriageway. Having waited at an entry, drivers seemed to expect an unrestricted passage through at least the next closely following stop-line downstream.

In certain cases where the downstream node did not have good coordination for the entry traffic, vehicles were often observed jumping red signals. It is possible that this problem was related to the fact that the signals were newly installed, and drivers were not used to stopping on the roundabout; and that with time this would not be a problem.

It was felt necessary, however, to try to arrange good coordination for the entry traffic at this site, where this did not compromise overall co-ordination in the network. This can be achieved by modelling the entry flow as a separate shared link when it enters the circulating link. The circulating traffic can be represented by:—

- a) a major shared link consisting of the entry arm traffic
- b) minor shared link(s) consisting of the traffic arriving from the upstream circulating link(s).

By setting a high stop weighting on the entry arm major link, the optimiser will be biased to try to arrange for this traffic to flow uninterrupted, and hence reduce the chance of any running through red signals. A value of 5 times normal stop weighting (so that every 100 pcu-stops contribute five times the value on card type 1 (columns 76–80) to the PI) has been used successfully, and this can be achieved by entering 500 in columns 61–65 in the card type 31 for the major shared link.

4 CHECKING COORDINATION

Once the final timings have been derived, it is usually worthwhile to obtain graphs for every link (major and minor where shared) using the card type 35. The graphical outputs from TRANSYT should be studied carefully as they show a great deal about the ways queues form, and the way the traffic will behave at the junction.

Individual platoons should be followed from entry link, round the roundabout, to final exit to see where red signals are encountered. Graphs are also useful to check links which require special coordination, for example where an entry arm should meet a green for safety reasons as explained in section 3.7. Examples of interpreting

graphs are included in section 5.2 of the roundabout example.

5 EXAMPLE 1—A MOTORWAY ROUNDABOUT

The example roundabout shown in Figure 4 has been chosen to be as typical of a motorway/trunk

road site as possible, and to demonstrate the features described above. Lane arrows have been shown but not destination markings; these would normally encourage the use of all lanes as far as possible. The link diagram is shown in Figure 5, which also gives link lengths, vehicle speeds and saturation flows. Saturation flows are based on 1750 pcu/hour for entry lanes and 1650 pcu/hour for circulating lanes. Vehicle speeds have all been set to 35 km/hour.

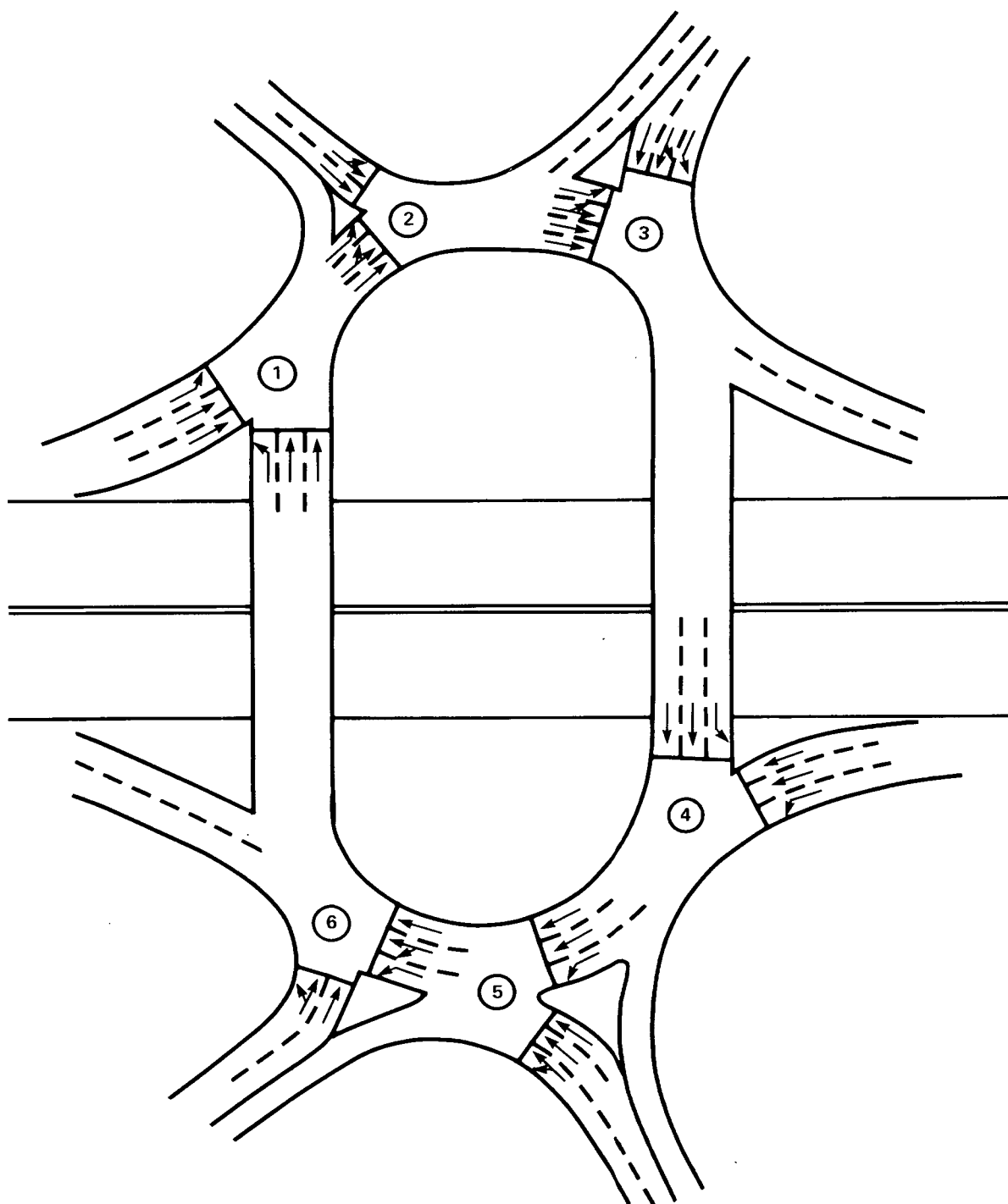


Fig.4 Example 1 roundabout site diagram

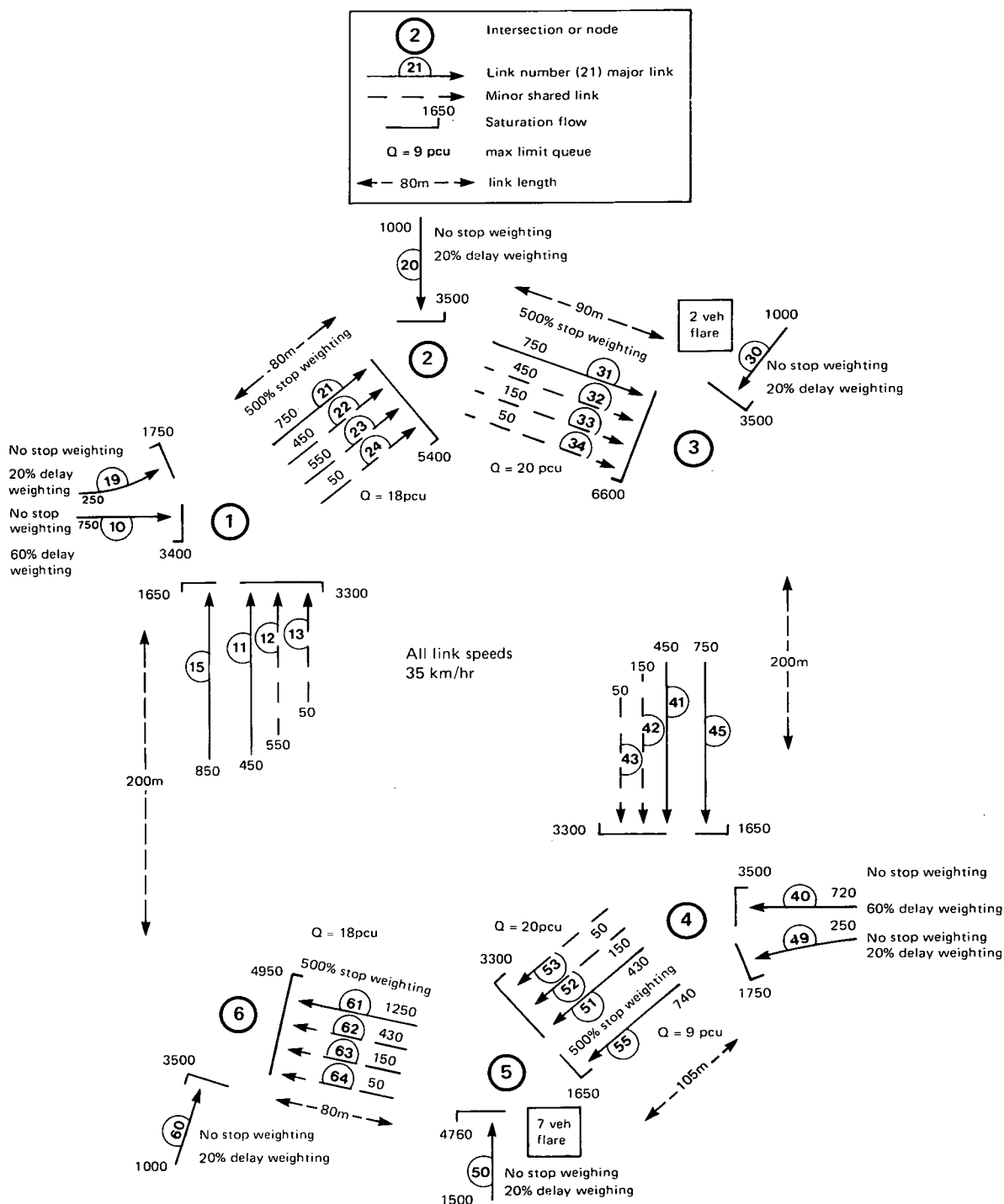


Fig.5 Example 1 roundabout link diagram

5.1 MODELLING THE JUNCTION

5.1.1 Link structure

As discussed in section 3.2, entries at nodes 2, 3, 5 and 6 have two or three lanes and the lane arrow markings would encourage the formation of equal length queues; so one link can be used (links 20, 30, 50 and 60). For the entries from the motorways (nodes 1 and 4), the nearside (left) lanes are marked for left turn only, therefore two links are required. The first link models the traffic entering the roundabout to continue at least one more node (links 10 and 40), and a second link to model traffic that exits immediately at the next downstream node (links 19 and 49). The circulating links are made up of a major shared link that models the traffic just entered, and two or three minor shared links modelling the circulating traffic.

Traffic that is about to exit sometimes has an exit with two lanes (after nodes 2, 3 and 6), and sometimes just one lane (after nodes 1, 4 and 5). Where a node has a single lane exit, the circulating stop-line has just the nearside lane marked for left turn, and where there are two exit lanes the circulating stop-line has the nearside lane marked for left turn only and the next lane marked for left turn and straight ahead.

The circulating traffic at nodes 1, 4 and 5 will generally form uneven queues, as the number of left turners in the nearside lane will not usually form the same length queue as the circulating traffic in the other lanes. Two links are therefore needed; one for left turners (links 15, 45 and 55) and one major with two shared links for the circulating traffic (links 11/12/13, 41/42/43 and 51/52/53).

The minor shared links model the circulating flow from other entries. For example, the major link 61 models flow entering at node 5, minor shared link 62 flow entering at node 4, minor link 63 entering at node 3, and minor link 64 flow entering at node 2.

5.1.2 Flows

The Origin/Destination flow matrix is given in Table 1. This shows the flow from each entry to each exit during the period under consideration. The links on which the flow travels are given in brackets in the order in which traffic travels down them.

As an example, consider the flow entering at node 1. Traffic exiting directly just before node 2 will use the left-turn-only lane (link 19). The traffic on link 19 exits at node 2 and is not considered again. All other traffic uses the other two lanes modelled by link 10. This consists of 300 pcu

exiting at node 3, 300 pcu going to node 4, 100 pcu to node 5, and 50 pcu to node 6 (750 in all).

The 750 pcu from link 10 now proceed into the major link 21. After node 2, the vehicles due to exit just before node 3 leave and are not considered again; the remaining 450 pcu from node 1 going to nodes 4, 5 and 6, enter minor shared link 32. After node 3, the 300 pcu from node 1 exiting before node 4 are not considered again; the 100 pcu due to exit just before node 5 join the pcu in the left turn lane at node 4 in link 45; the remaining 50 pcu due to exit just before node 6 enter minor shared link 43. On leaving node 4 the 50 pcu enter minor shared link 53 and finally exit the network before node 6 so are not considered further.

A similar method is used for the entry flows from other nodes.

5.1.3 Flared entries

The example has two flared entries; a small bay on the entry link at node 3 that holds two extra pcu (over-and-above the number present without the flare) on average, and a larger flare on the entry arm at node 5 that holds 7 extra pcu on average.

The smaller 2 pcu flare is represented by shortening the start lag for link 30 from 5 to 3 seconds. The start lag in TRANSYT corresponds to the normal inter-green time, or the time delay between a stage first being called and a green appearing on the street. This is commonly made up of 3 seconds amber for the stage about to lose right-of-way, plus 2 seconds of red/amber for the stage about to receive green; making 5 seconds in total. In order to model the extra 2 pcu, the lag at the start of green on link 30 should be reduced by 2 seconds (see equation 3, section 3.3.3), giving an extra effective 2 seconds of green time to link 30. Two seconds of green time at the saturation flow of link 30 (3500 veh/hour) corresponds to approximately 2 extra pcu.

The larger 7 pcu flare on link 50 is modelled by the more usual method of increasing the saturation flow of the link. Entry saturation flows for this link have, in the absence of a flare, been set to 1750 pcu/hour per lane, making a saturation flow of 3500. To calculate the increased saturation flow with the flare, knowledge of the effective green time is necessary. An initial estimate would normally be made and a value calculated and used in a first run of TRANSYT. This first run would give a green time for link 50 which is then used to recalculate the saturation flow, and the value changed if necessary.

TABLE 1

Origin-destination matrix for example roundabout

TO NODE

	1	2	3	4	5	6	TOTAL
1	–	250 (–)	300 (21)	300 (21) (32)	100 (21) (32) (45)	50 (21) (32) (43) (55)	1000
F 2	50 (31) (42) (53) (64)	–	250 (–)	300 (31)	300 (31) (45)	100 (31) (42) (55)	1000
R 3	100 (41) (52) (63)	50 (41) (52) (63) (15)	–	250 (–)	300 (45)	300 (41) (55)	1000
O 4	270 (51) (62)	100 (51) (62) (15)	50 (51) (62) (13) (24)	–	250 (–)	300 (55)	970
N 5	300 (61)	400 (61) (15)	500 (61) (12) (23)	50 (61) (12) (23) (34)	–	250 (–)	1500
D 6	250 (–)	300 (15)	300 (11) (22)	100 (11) (22) (33)	50 (11) (22) (33) (45)	–	1000
E							
Total	1000	1100	1400	1000	1000	1000	

Note: figures in brackets are the link numbers.

If the effective green time for link 50 were 20 seconds, the first consideration is whether this is longer than the time to discharge 7 pcu from the flare. At a saturation flow of 1750 veh/hour (the average saturation flow of entry lanes) it takes approximately 14.5 seconds to discharge 7 pcu (see equation 1, section 3.3.2), so an effective green time of 20 seconds is long enough to empty the flare.

If the flare were longer and not all the pcu in the flare could be discharged, then a full 3-lane saturation flow would be appropriate.

The saturation flow S_a (see equation 2, section 3.3.2) of link 50 with a 7 pcu flare becomes:-

$$\begin{aligned}
 S_a &= 3500 + (3600 \times 7/20) \\
 &= 3500 + 1260 \\
 &= 4760 \text{ pcu/hour}
 \end{aligned}$$

This gives a sizeable increase in the saturation flow, and shows that adding flares at the approaches is a very effective method of increasing capacity.

5.1.4 Weighting factors

In order to give all the spare capacity to the circulating traffic, all entry links have been given zero stop weighting and non-motorway entry links 20% delay weighting (links 20, 30, 50 and 60). This should ensure all these entry links will have a degree of saturation between 80 to 95 percent.

For traffic entering from the motorway slip roads on links 10 and 40 (ie non-left turning entries) the delay weighting has been reduced less than for non-motorway entries. The 60% weighting used is a compromise between causing blocking back on

the roundabout, and excessive queues forming on the motorway slip roads. The volume of the remaining left-turning traffic entering from the motorway (links 19 and 49) is small and does not add significantly to the slip-road queue. This traffic has been given a 20% delay weighting (to the benefit of circulating traffic).

A positive stop weighting of 500% has been given to five circulating links 21, 31, 51, 55 and 61. These links model the entry traffic from links 10, 20, 40 and 50, and this should encourage the optimiser to give good coordination to this entry traffic, and avoid entry vehicles running straight into a red. This is not deemed necessary for links 11 and 41 as these links are longer with better sight lines.

5.1.5 Limit queues and queue penalties

Queue penalties have been added for the five short links 21, 31, 51, 55 and 61. When shared links exist, the queue penalty is given to the major shared link and applies whenever the queue on the major AND minor links taken together exceeds the queue limit.

When deciding values for limit queues on roundabouts, the link should be studied, and the queue length beyond which the free-left-turn would be blocked should be estimated. This will normally be significantly less than the total stop-line link length.

For the 80 metre long link 21 a queue of 55 metres has been assumed to cause obstruction of traffic exiting immediately prior to node 2. If an average pcu-plus-gap length of 5.75 metres is used, then for the three lane link 21, 55 metres could store about 9 pcu per lane, or 27 pcu. As described in section 3.6.1, a factor of 60 to 75 percent of the available link storage is used, as the mean maximum queue calculated in TRANSYT is an average value and can often be exceeded. Applying a factor of 66% reduces the value from 9 pcu/lane to 6, or 18 pcu in total. This then becomes the limit-queue value entered in the card type 38. The TRANSYT optimiser will then start adding an excess queue penalty to the PI once more than 18 pcu are in the queue on links 21/22/23/24.

A similar value has been used for link 61/62/63/64; and for the slightly longer link 31, an excess queue length of 20 has been used. For the two link 51/52/53 a value of maximum queue length of 90 metres has been used to define the point where blocking back starts. This gives a maximum allowable queue of about 30 pcu, which is reduced to 20 for the limit queue by applying the factor of 66%. For link 55 a blocking distance of about 80 metres is appropriate, which leads to a maximum allowable queue of just over 13 pcu.

Applying a factor of 66% reduces this to a limit queue of 9 pcu.

5.1.6 Cycle time

The initial data set is given in Table A1 (Appendix A). CYOP was run on this data with the 'information only' option, and the 'cycle time information' output is given in Table A2 (Appendix A). The first section of Table A2 shows the maximum degree of saturation at the node when each node is considered in isolation (ie no consideration taken of coordination between nodes) over a range of cycle times. These show that with a 60 second cycle, the maximum degree of saturation is 90% at node 5. Shorter cycle times would not give sufficient capacity, and longer cycle times would allow spare capacity. For roundabouts the shortest possible cycle time should be used so a value of 60 seconds is appropriate.

The second section of Table A2 gives an estimate of the performance index (weighted sum of stops and delay) for each node over a range of cycle times. These show that a cycle time of 60 seconds gives a minimum estimated performance index (PI) of 419.1 with nodes 2 and 3 double cycled, and 435.4 with all nodes single cycled.

The CYOP Table shows some benefit in double cycling modes 2 and 3. Introducing double cycling in networks with short links can, however, often upset co-ordination on the street and is not always desirable. It is unlikely that double cycling node 2 would provide any major benefit as the estimated PI is 72 at 60 second cycle and 69 for a 30 second cycle. There may be benefit in reducing the cycle time at node 3 which has an estimated PI of 57 at 60 second cycle, and 44 at 30 seconds, and a second TRANSYT run with this node double cycled may prove worthwhile.

5.2 TRANSYT OUTPUT

5.2.1 Normal flows

Table A3 (Appendix A) gives the optimised TRANSYT output. There are several points to notice.

- (a) The estimate of 20 seconds effective green time for link 50 was correct and there is no need to re-calculate the saturation flow for link 50. Note that while the actual green time for link 50 is 19 seconds, TRANSYT adds one second as the difference between the start and end displacements on card type 1. The start displacement of 2 seconds allows for vehicles to accelerate to cruise speed, and the end displacement of 3 seconds allows for vehicles continuing to pass during the amber.

- (b) The degree of saturation on the non-motorway entry links (20 30 50 60) is between 86 to 95 percent, as required to prevent excessive entry flows and locking-up of the roundabout in periods of high demand.
- (c) For the motorway entries (links 10/19 and 40/49) the degrees of saturation are 88% for link 10 and 77% for link 40. The reserve capacity for link 10 is rather low, and the timings may have to be checked every few years to allow for traffic growth.
- (d) The degree of saturation on circulating links is generally below 80%, except for links 15 and 55. These links will need to be checked carefully to see how they behave when flows are increased. Node 5 appears to be the critical node in the network.
- (e) There is a small excess queue of 0.2 pcu for link 55. The graph for this link will have to be checked to see if blocking back is likely to occur at a critical point in the cycle.
- (f) Overall the optimised output shows that this signalised roundabout is just operating within capacity.

For an economic assessment of the performance of the roundabout the optimised signal timings should be used without optimisation or any weighting factors.

5.2.2 Excess demand flows

Table A4 (Appendix A) gives the TRANSYT output with the optimised signal timings from Table A3 and flows increased by 20%. This shows that all non-motorway entry links are over-saturated with queues building up.

Motorway entry link 10 is over-saturated and a mean queue of 65 pcu is predicted for the one hour period. This implies a queue at the end of the hour of approximately 130 pcu in two lanes; equivalent to a queue 370 metres in length. This is likely to be longer than the exit slip road. The other motorway entry slip road, link 40, is not over-saturated.

The circulating links, however, do not have large queues, and apart from link 55 are in no danger of blocking back to the upstream nodes. The queue on link 55 exceeds 20 pcu during part of the cycle and the effect of this should be studied further.

5.3 GRAPHICAL OUTPUTS

Figure A1 (Appendix A) shows the TRANSYT graphical outputs for links 40 41 42 43 45 and 55. These can be used to show when upstream vehicles arrive at link 55 stop-line, as indicated in the Figure. The signals controlling link 55 change

to red after the entry traffic from link 40 has passed through. The circulating traffic from links 42/43, followed later in the red by traffic from link 41, begin to form a queue at the stopline. The signals change to green after approximately half the circulating platoon of traffic from link 41 has arrived. The stopline queue has almost discharged by the time the entry traffic from link 40 has arrived.

The TRANSYT/9 queue graph for link 55 is given in Figure A2 (Appendix A) which shows pcus arriving and the queue discharging during the green. This graph shows the maximum uniform queue as 8 pcu which is less than the 11 pcu given for the mean-maximum queue in the TRANSYT output for link 55 in Table A3. This is because the graph only deals with the uniform queue, ie the queue that will form on average, and takes no account of random-plus-oversaturation fluctuations (2.5 pcu) that will lead to larger queues. Discharging vehicles meet the back-of-queue some 12 seconds into the green, at approximately time 28 seconds. From the link graph in Figure A1 this corresponds to the time when the circulating traffic has passed through, and just before the entry traffic starts to arrive.

As shown above, the queue is longest on link 55 between 24 and 30 seconds. The question is whether this will adversely effect the traffic turning out of the roundabout just before node 5; this is not modelled directly, but comes from links 45 and 49. The graph for link 45 shows that it discharges from time 43 seconds to time 18 seconds, when the queue on link 55 is 6 pcu long. As the limit queue for link 55 is 9 pcu, it is unlikely that the queue on the circulating link 55 will block the exit traffic. The entry arm traffic on link 49 flows from time 23 seconds to time 38 seconds so may be blocked by the queue building on link 55. As the flow on link 49 is only 250 pcu per hour, this is unlikely to be a problem.

Whilst careful checking of graphs can tell a great deal about the behaviour of the roundabout, it is vital to check the signal timings when first installed. The TRANSYT output does, of course, highlight possible problem areas where attention should be directed first.

6 EXAMPLE 2—AN URBAN ROUNDABOUT/GYRATORY

The example roundabout described in this section further illustrates the method of applying TRANSYT described in previous sections. The subject is a gyratory-system which forms a roundabout at the junction of the A413 and the B4443 to the south-east of Aylesbury town

centre. The signals had been installed in an attempt to improve capacity. The TRANSYT model described is of the morning peak period and it shows a typical urban situation in which the junction has reached or exceeded capacity during the peak periods. Prior to TRRL becoming involved, the original timings resulted in unacceptably long queues on entries and indeed a reduction in capacity—TRANSYT had been used to find the original signal plans, but the model took no account of the special circumstances at signalised roundabouts. Once the method set out by TRRL had been applied, a reasonable plan for the AM peak was produced. This example illustrates how such a junction can operate in an acceptable fashion, even when demand exceeds capacity, by using TRANSYT to obtain signal timings that control where the queues form.

6.1 DESCRIPTION OF THE ROUNDABOUT

The roundabout is triangular in shape (see Figure 6) with four main junctions, plus a signalised pedestrian crossing on the exit to the north. The

longest circulating link is 150 metres and the shortest just 40 metres. Each link has two lanes at each stop-line. Due to physical restrictions (such as buildings and a railway) engineering changes that might normally have been made to the roundabout, to take advantage of signalisation, were not possible.

The roundabout lies on a commuter route to and from the town centre to the north-west. The A413 is a major route bringing traffic in from nearby towns and villages in the mornings, whilst the B4443 serves various housing estates and is also an alternative route for the longer distance traffic. The flow is tidal and in the morning the largest proportion of the traffic flow is towards the town centre. The proportion of flow that comes from the town centre is smaller, but still significant. In the evening peak the situation is reversed with the heavier flow coming from the town centre.

6.2 MODELLING THE JUNCTION

The link diagram in Figure 7 and the TRANSYT input data (Table B1, Appendix B) show how the

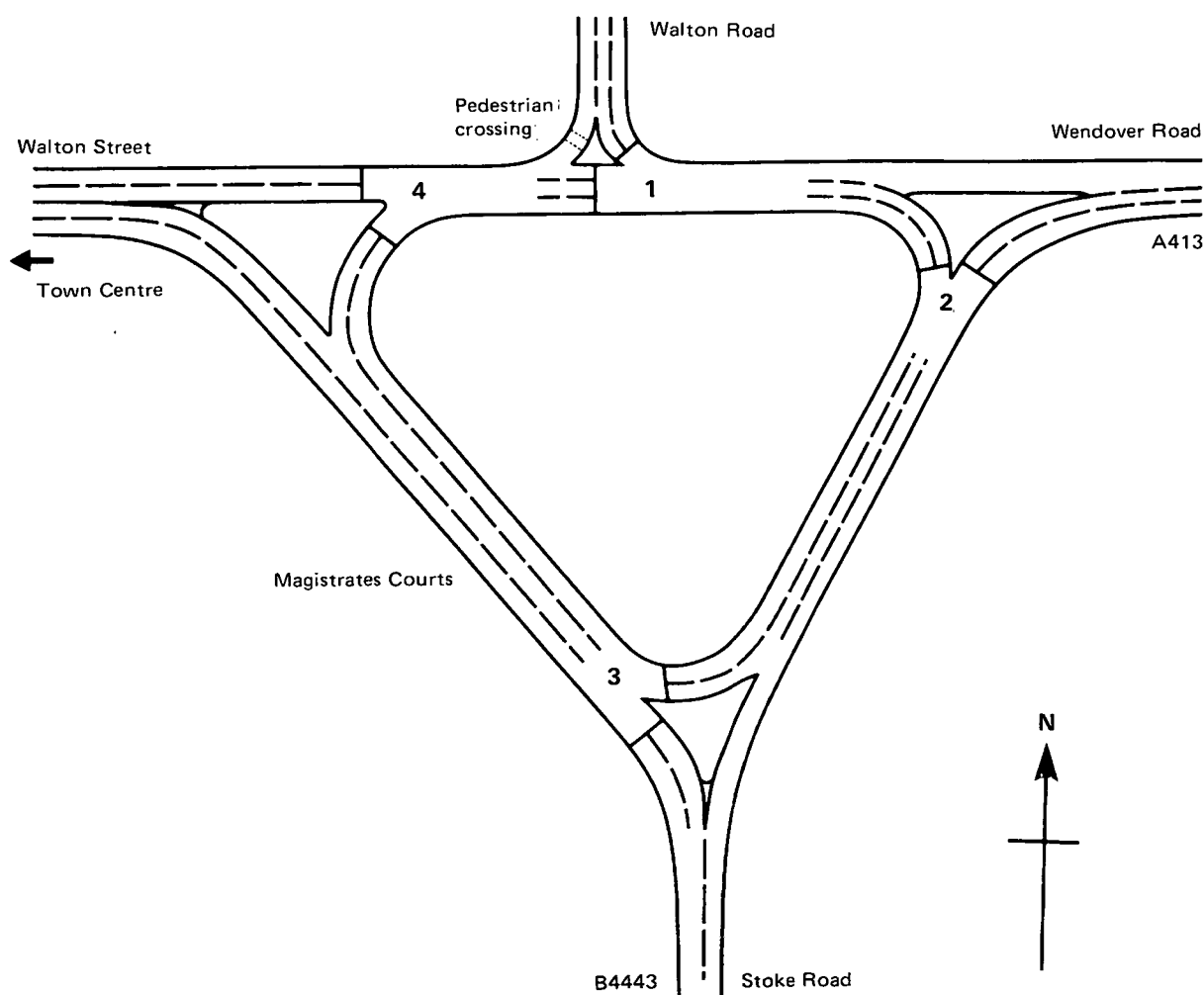


Fig.6 Site diagram of the Walton Street roundabout, Aylesbury

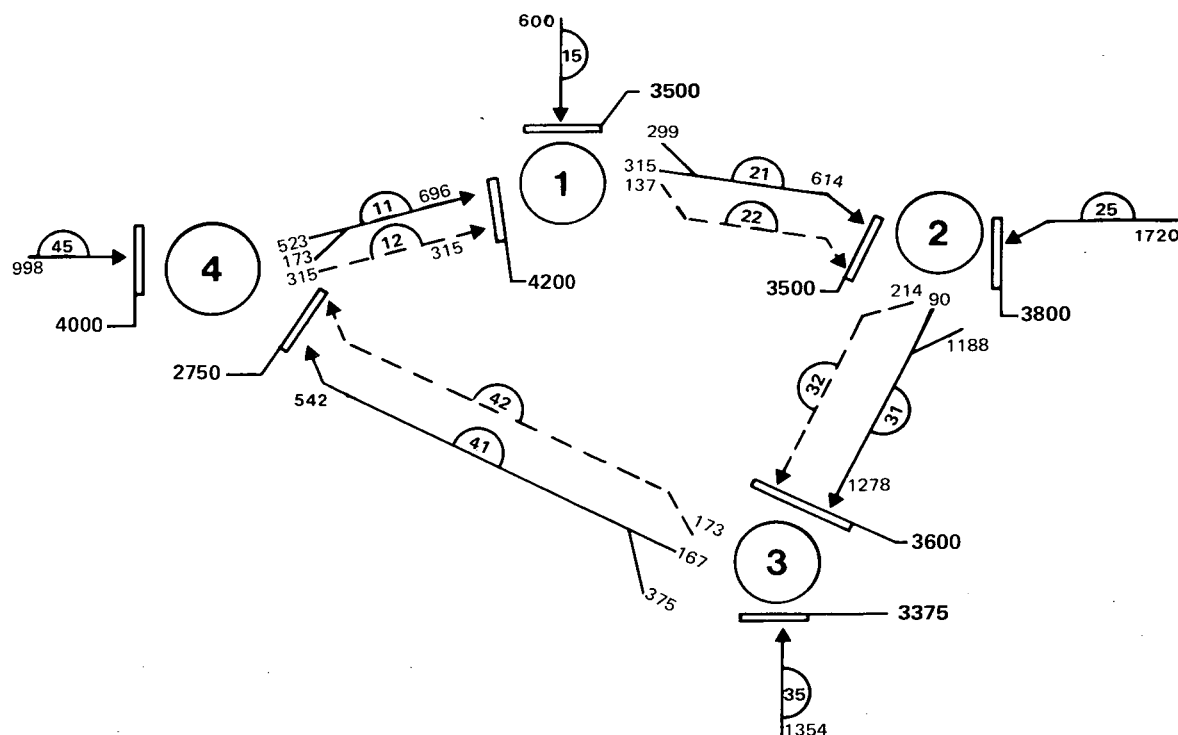


Fig.7 Link diagram for the Walton Street roundabout

roundabout is modelled. Flows are based on Origin-Destination (OD) data supplied by Buckinghamshire County Council. The link structure in this example differs from the example in section 3. In the earlier example, f_{13} and f_{14} were represented by the major link at stop line X--X and f_{43} was represented by the minor link. Here, traffic exiting after the immediate downstream stop line (f_{13} and f_{43} for example) is represented by the major links and traffic continuing past that point (f_{14}) is represented by minor links. Hence, *all* the traffic represented by the minor link is added to the downstream major link and *all* the traffic represented by the major link is modelled as a free-left-turn (after crossing the stop line). This avoids the incorrect situation illustrated in Figure 3(d) and described in section 3.5 where TRANSYT continues to model traffic that would, in reality, have exited. The link structure would not model the OD movements correctly if there were significant U-turners or if there were five or more entries.

6.2.1 Saturation flows

All the saturation flows were estimated originally using TRRL Report RR67 (Kimber et al, 1986) and then reduced to account for factors such as road curvature, lane lengths and possible weaving. One link has a flared approach (link 35) with one lane flaring into two close to the stop-line. The flare has room to accommodate up to 7 extra pcu. The discharge rate of the flare is two-lane saturation

flow; after the flared has emptied, the discharge rate reduces to one-lane saturation flow. To calculate the average saturation flow throughout the green for link 35, the method described in section 3.3.2 was applied. Initially, a green-time was obtained by running TRANSYT with an approximation to the average saturation flow. This green-time was then used to calculate a new average saturation flow. The procedure was repeated until the calculated saturation flow matched the green-time for link 35 found by TRANSYT. The whole procedure had to be followed every time a new cycle-time was tried.

6.2.2 Choice of cycle-time

Finding the most appropriate cycle-time is an important factor in a roundabout type network. Section 3.1 suggests that the TRANSYT routine CYOP (see LR888, Vincent et al, 1980) can be used to predict the cycle-time at which the best Performance Index would be achieved. However, due to the fact that CYOP only *predicts* the PI at a given cycle-time *treating each node as being isolated*, a number of parameters, likely to be included when using TRANSYT to model a roundabout, are neglected. It neglects the effects of coordination, limit-queues (section 3.6.1), and Link Weighting (section 3.6) (except in calculating the Performance Index after finding the timings). Furthermore, it neglects variation with green-time of the average saturation flow on flared approaches. The latter point is particularly

significant in this case because the flared entry link (link 35) was part of a particularly critical node. Under the critical conditions at this node, the performance of link 35 has a significant effect on the overall performance of the roundabout. Therefore, the best cycle-time predicted by CYOP is heavily dependant on the saturation flow value for link 35. However, for the initial saturation flow (which was arbitrarily taken as the the value mid-way between one-lane and two-lane saturation flow, ie 2700 pcu/hour) CYOP predicted that the best Performance Index would be achieved at a cycle-time of 70 seconds.

To take account of the factors neglected by CYOP, which, never-the-less, affect the choice of cycle time, full TRANSYT runs with optimisation were carried out over a range of cycle times. For each run, the saturation flow on the flared approach (link 35) was adjusted to suit the new green time. With the over-saturation of the roundabout, the main consideration is to keep the circulating links free from blocking-back; achieving the lowest Performance Index is of secondary importance. Therefore, the choice of cycle time depends on the ease with which queues on the circulating links can be kept under control, particularly on the critical links (links 31 and 32). In particular this depends on the coordination between nodes 2 and 3. Fortunately, there is only one platoon of any importance between these nodes and it contains the traffic entering from link 25, most of which crosses the stop-line at node 3 en route to node 4. Another compromise must be made between presenting traffic with short reds (by keeping the cycle-time low) and keeping the proportion of lost-time in the cycle low (by keeping the cycle-time long). In this case (and for most signalised roundabouts for that matter) the balance will be in favour of short reds (hence a short cycle-time). A cycle time of 40 seconds was found to give a better result than the 70 second cycle predicted by CYOP.

6.2.3 Weighting factors

One of the key points in modelling roundabouts with TRANSYT is the use of stop and delay weighting to help ensure circulating links get any spare green time at a node (section 3.6.2). In this example, the entry links are weighted so that the cost of stops is zero and the cost of delay is 20 percent of the normal figure used in TRANSYT. The circulating links have normal (100%) weighting. The effect of the weightings is to keep the percentage saturation high on entry links and lower on circulating links. The weightings also ensure that when over-saturation does occur, it occurs on entry links where excess demand can be stored without locking-up the system, rather than on circulating links.

6.2.4 Limit queues and queue penalties

Since the roundabout is over-saturated during the morning peak, an important consideration is to keep the queue-lengths on circulating links short. To assist TRANSYT in finding signal timings that keep circulating queue-lengths within acceptable levels, limit queues and queue penalties were applied for all circulating links (as described in section 3.6.1). The limit-queue lengths used at this roundabout were approximately two-thirds of the number of pcu that could be physically stored on the link (the left turning traffic have their own lanes so these were not considered when setting the limit-queue values). The queue-penalties used were 4000 pence/pcu-hour. The queue lengths on the circulating links were kept below the desired length as a result.

6.3 TRANSYT OUTPUT

The output from a TRANSYT run with a cycle time of 40 seconds is given in Table B2 (Appendix B). Studying the saturations on each link show that the aim of giving spare green to circulating links has been achieved. However, it can clearly be seen that nodes 2 and 3 are over-saturated, with long queues predicted for the entry links (links 25 and 35). It is necessary to put this oversaturation onto the entry links so that the amount of traffic entering the roundabout is restricted, thus reducing the possibility of blocking back. For these predictions to accurately depict on-street behaviour, the simulation time (card type 1, column 20) should equal the length of time over which the flow conditions have been averaged. In this case the flows are averaged over one hour, so the simulation time is 60 minutes.

The circulating links for node 3 (link 31 and 32) also have a high degree of saturation and it will be necessary to check the queue-length to see if blocking-back may occur. The graphs (Figure B1, Appendix B) for links 31 and 32 show the large platoon made up of traffic entering the roundabout on link 25. With just the one platoon, good coordination between node 3 and the upstream node (node 2) is easily achieved. Hence, despite high saturation, queue lengths are comparatively short. However, a small error in, say, cruise speed, could result in some of the on-street platoon being stopped and it would not take much of an error to give rise to large on-street queues. This highlights the importance of correct information for critical nodes.

For the remainder of the roundabout, the graphical output shows that it has been possible to coordinate well for all the platoons around the roundabout. Only on link 21 is there a significant platoon which is stopped by the signals. As for links 31 and 32, this good coordination plays a major role in keeping the queues on circulating links short.

6.3.1 Excess demand flows

To check that the gyratory continued to function without locking up under conditions of higher than average flow, the final signal plan was tested with flows increased by 20 per cent of their modelled values (as suggested in section 3.6.2). Under these circumstances, the increase in circulating traffic was small, but, as would be expected, the queues predicted for entry links were large, particularly at nodes 2 and 3 (Table B3, Appendix B). This was tolerable at this roundabout since no significant hazard was caused by large queues on these two approaches, and this is preferable to blocking the roundabout.

6.4 INITIAL INSTALLATION OF TIMINGS

The traffic signals had been installed and running at the roundabout for some months prior to TRRL being involved. The original timings were characterised by a very long cycle-time. The timings developed by TRRL from early TRANSYT runs were installed on site and on-street behaviour observed. The behaviour differed in a number of respects from the TRANSYT model predictions.

6.4.1 Predictability of traffic flows

One problem with the site is the unpredictability of the flows; Aylesbury town centre is served by 5 major radial routes, many of which join on the outskirts of the town. Hence traffic has many radials from which to choose a route into the town centre. The traffic flows, which were collected before the signalling of the junction, appear to have altered significantly since the signals had been commissioned. For the roundabout to cope with changes in traffic flow, it is important that the signal timings limited the amount of traffic that entered the roundabout. This is where it is important to arrange TRANSYT to give any spare green-time to the circulating links, and then testing the timings under conditions of excess demand. On the day observed, only the A413 coming out of the town remained under-saturated; the other three entry arms all had long queues during at least some part of the peak period. On the over-saturated links, the flow into the roundabout was controlled by the green-time. If the green-time had been too long, too much traffic would have entered the roundabout, probably leading to locking-up. However, with the TRRL TRANSYT timings, for most of the period observed, traffic continued to circulate freely.

6.4.2 Blocking back

There was a problem with blocking-back on links 31 and 32 for a brief period where the queue at the start-of-green more than filled these links. This

meant that the traffic from link 25 joined onto the back of the existing queue and the links filled completely preventing any more traffic entering. A significant amount of green was given (hence wasted) to this link whilst traffic was unable to enter the roundabout (see discussion in section 3.6.3). This problem was solved quickly on site by manually bringing forward the start-of-green for links 31 and 32 by a few seconds to give the existing queue time to discharge before the traffic from link 25 arrived. Subsequently, the model was re-run with the limit-queue reduced from 25 to 15 pcu. This gave an early green for links 31 and 32 similar to that implemented manually, indicating that the storage capacity of the link had been over-estimated initially.

6.4.3 Validation of saturation flows

Whilst on site, the saturation flows were validated as far as possible. Links 15 and 35 were found to have saturation flows that differed from those predicted.

Link 15 has two lanes which stretch back about 75 metres. Despite this, the nearside lane was used by the occasional left turner only and was empty on many cycles. Most of the remaining traffic wished to exit along the B4443 (node 3) and, therefore, wanted to enter the roundabout on the nearside lane (link 21) at node 2. Due to lack of space, merging from the two lanes on link 15 onto the nearside lane (link 21) was very difficult. Hence the saturation flow on link 15 was only half the modelled value.

With link 35, the flared approach, the problem was that, after the initial burst of eight or 10 cars, drivers were very slow in moving off; leaving large gaps between vehicles. The behaviour was seen to improve over the period observed, maybe because drivers were beginning to realise the green was now much shorter than previously. In fact observations showed that drivers had started to use the flare to better advantage with an extra 6, sometimes 7 cars using it. Even so the average saturation flow (over the quite long green used with these new timings) was estimated to be no better than 2000 pcu/hour.

6.5 IMPROVED MODEL

With the experience gained on site it was decided to produce an improved data set. Some new flow measurements were taken and the saturation flows were adjusted. With the revised flows the queue lengths predicted by TRANSYT were closer to those observed on street than before, giving confidence in the new model. The timings from the new model have been installed at the roundabout and have been observed working satisfactorily. Never-the-less, measurements taken by Buckinghamshire County Council revealed that

there was no significant change in capacity before and after signalisation in the morning peak (see section 7).

7 CONCLUSIONS AND DISCUSSION

With increasing traffic flows it is becoming necessary to signalise roundabouts to reduce queues, especially during peak periods. Several studies have shown signalising can increase capacity and allow the traffic engineer to control where and when queues form. It has been demonstrated that TRANSYT, when used with appropriate care, is suitable for modelling traffic behaviour on signalised roundabouts, and is capable of producing timings that provide good coordination, and avoid traffic 'locking up'.

However, an increase in capacity cannot be taken as certain. Indeed, it is thought likely that capacity will often be improved only if signalisation goes hand-in-hand with engineering changes such as widening of the circulating carriageway to create extra lanes, and flaring of entries to increase the density of entry traffic, particularly in the early part of the green.

Made in isolation, such engineering changes are unlikely to improve traffic behaviour enough to overcome the disadvantages of priority control at a roundabout in heavy traffic; a single circulating vehicle can still delay several vehicles waiting to enter a roundabout. Similarly, signalising a roundabout without any engineering changes may also result in little or no improvement in capacity. It may well be necessary to use signal timings which constrain entry capacity, to prevent blocking-back on circulating links which would reduce the improvements in capacity, possibly to zero.

At the roundabout/gyratory in Aylesbury, the throughput of traffic (ie capacity) was found not to have improved before and after signalisation in the morning peak. This was probably because some caution had to be exercised with the timings due to the unpredictable nature of the flows at this site (see section 6.5.1) and the need to keep excess demand traffic queued on entry links rather than circulating links.

8 RECOMMENDATIONS

- Use shared links for accurate representation of origin-destination movements.
- Use reduced delay weightings on entry links so that TRANSYT considers circulating links as more important.

- Keep the cycle time short to avoid long queues on circulating links and to make the best use of flared entries.
- Apply limit queues and queue penalties to circulating links to further discourage long queues.
- Use the formulae in section 3.3.2 to calculate the average saturation flow of flared approaches.
- Make use of the TRANSYT flow pattern graphs and queue graphs to check coordination and queuing behaviour.
- Compare the predicted queues, flow patterns and degrees of saturation with the on-street behaviour (and re-model the junction if necessary).

9 ACKNOWLEDGEMENTS

The work described in this report was carried out in the Traffic Management Division (Head Dr P B Hunt) of the Traffic Group of the TRRL. The authors are grateful to Mr N Lamprell of Berkshire County and Mr K Laughlin of Hampshire County for supplying measurements of saturation flows at junction 11 on the M4; to Mr J Molyneux of Buckinghamshire County for assistance at Handy Cross; and Mr R Denham, also of Buckinghamshire County Council for assistance at Aylesbury.

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APPENDIX A:

COMPUTER PRINTOUTS FROM EXAMPLE 1—A MOTORWAY ROUNDABOUT

TABLE A1.

Example 1—TRANSYT input data

Program TRANSYT EXAMPLE 1: MOTORWAY ROUNDABOUT

DATA INPUT :-

CARD NO.	CARD TYPE	TITLE:- EXAMPLE 1: MOTORWAY ROUNDABOUT														
CARD NO.	CARD TYPE	CYCLE TIME	NO. OF STEPS PER CYCLE	TIME PERIOD 1-1200 MINS.	EFFECTIVE-DISPLACEMENTS START (SEC)	GREEN-END (SEC)	EQUISAT SETTINGS 0=NO 1=YES	0=UNEQUAL CYCLE 1=EQUAL	FLOW SCALE 10-200 %	CRUISE-SPEEDS SCALE 50-200 %	CARD32 0=TIMES 1=SPEEDS	OPTIMISE 0=NONE 1=O/SET 2=FULL	EXTRA COPIES FINAL OUTPUT	HILL-CLIMB 1=FULL	DELAY VALUE P PER	STOP VALUE P PER
2)=	1	60	60	60	2	3	1	0	0	0	1	2	1	0	570	90
CARD NO.	CARD TYPE	LIST OF NODES TO BE OPTIMISED														
3)=	2	1	2	3	4	5	6	0	0	0	0	0	0	0	0	0
CARD NO.	CARD TYPE	HILLCLIMB INCREMENT LIST														
4)=	4	15	40	-1	15	40	1	-1	1	0	0	0	0	0	0	0
CARD NO.	CARD TYPE	ACCURACY PARAMETER LIST														
5)=	6	1000	1000	100	100	10	10	1	1	0	0	0	0	0	0	0
LINKS HAVING SHARED STOPLINES																
CARD NO.	CARD TYPE	FIRST SET.....					SECOND SET.....					THIRD SET.....				
6)=	7	11	12	13	0	0	21	22	23	24	0	31	32	33	34	0
7)=	7	41	42	43	0	0	51	52	53	0	0	61	62	63	64	0
CARD NO.	CARD TYPE	NODE NO.	STAGE 1		STAGE 2		STAGE 3		STAGE 4		STAGE 5		STAGE 6		STAGE 7	
			CHANGE	MIN	CHANGE	MIN	CHANGE	MIN	CHANGE	MIN	CHANGE	MIN	CHANGE	MIN	CHANGE	MIN
8)=	12	1	0	10	0	10	0	0	0	0	0	0	0	0	0	0
9)=	12	2	0	10	0	10	0	0	0	0	0	0	0	0	0	0
10)=	12	3	0	10	0	10	0	0	0	0	0	0	0	0	0	0
11)=	12	4	0	10	0	10	0	0	0	0	0	0	0	0	0	0
12)=	12	5	0	10	0	10	0	0	0	0	0	0	0	0	0	0
13)=	12	6	0	10	0	10	0	0	0	0	0	0	0	0	0	0
LINK CARDS: FIXED DATA																
CARD NO.	CARD TYPE	LINK NO.	EXIT NODE	START STAGE	LAG	END STAGE	LAG	START STAGE	LAG	END STAGE	LAG	LINK LENGTH	STOP WT.X100	SAT FLOW	DELAY WT.X100	DISPSN X100
14)=	31	10	1	2	5	1	0	0	0	0	0	100	-9999	3400	60	0
15)=	31	11	1	1	5	2	0	0	0	0	0	200	0	3300	0	0
16)=	31	12	0	0	5	0	0	0	0	0	0	200	0	0	0	0
17)=	31	13	0	0	5	0	0	0	0	0	0	200	0	0	0	0
18)=	31	15	1	1	5	2	0	0	0	0	0	200	0	1650	0	0
19)=	31	19	1	2	5	1	0	0	0	0	0	200	-9999	1750	0	0
20)=	31	20	2	2	5	1	0	0	0	0	0	100	-9999	3500	20	0
21)=	31	21	2	1	5	2	0	0	0	0	0	80	500	5400	0	0
22)=	31	22	0	0	5	0	0	0	0	0	0	80	0	0	0	0
23)=	31	23	0	0	5	0	0	0	0	0	0	80	0	0	0	0
24)=	31	24	0	0	5	0	0	0	0	0	0	80	0	0	0	0
25)=	31	30	3	2	5	1	0	0	0	0	0	100	-9999	3500	20	0
26)=	31	31	3	1	1	2	0	0	0	0	0	90	500	6600	0	0
27)=	31	32	0	0	5	0	0	0	0	0	0	90	0	0	0	0
28)=	31	33	0	0	5	0	0	0	0	0	0	90	0	0	0	0
29)=	31	34	0	0	5	0	0	0	0	0	0	90	0	0	0	0
30)=	31	40	4	2	5	1	0	0	0	0	0	100	-9999	3500	60	0
31)=	31	41	4	1	5	2	0	0	0	0	0	200	0	3300	0	0
32)=	31	42	0	0	5	0	0	0	0	0	0	200	0	0	0	0
33)=	31	43	0	0	5	0	0	0	0	0	0	200	0	0	0	0
34)=	31	45	4	1	5	2	0	0	0	0	0	200	0	1650	0	0
35)=	31	49	4	2	5	1	0	0	0	0	0	200	-9999	1750	0	0
36)=	31	50	5	2	5	1	0	0	0	0	0	100	-9999	4760	20	0
37)=	31	51	5	1	5	2	0	0	0	0	0	105	500	3300	0	0
38)=	31	52	0	0	5	0	0	0	0	0	0	105	0	0	0	0
39)=	31	53	0	0	5	0	0	0	0	0	0	105	0	0	0	0
40)=	31	55	5	1	5	2	0	0	0	0	0	105	500	1650	0	0
41)=	31	60	6	2	5	1	0	0	0	0	0	100	-9999	3500	20	0
42)=	31	61	6	1	5	2	0	0	0	0	0	80	500	4950	0	0
43)=	31	62	0	0	5	0	0	0	0	0	0	80	0	0	0	0
44)=	31	63	0	0	5	0	0	0	0	0	0	80	0	0	0	0
45)=	31	64	0	0	5	0	0	0	0	0	0	80	0	0	0	0

LINK CARDS: FLOW DATA																
					ENTRY 1			ENTRY 2			ENTRY 3			ENTRY 4		
CARD NO.	CARD TYPE	LINK NO.	TOTAL FLOW	UNIFORM FLOW	LINK NO.	FLOW	CRUISE SPEED	LINK NO.	FLOW	CRUISE SPEED	LINK NO.	FLOW	CRUISE SPEED	LINK NO.	FLOW	CRUISE SPEED
46)=	32	10	750	0	0	0	35	0	0	0	0	0	0	0	0	0
47)=	32	11	450	0	60	450	35	0	0	0	0	0	0	0	0	0
48)=	32	12	550	0	61	550	35	0	0	0	0	0	0	0	0	0
49)=	32	13	50	0	62	50	35	0	0	0	0	0	0	0	0	0
50)=	32	15	850	0	60	300	35	61	400	35	62	100	35	63	50	35
51)=	32	19	250	0	0	0	35	0	0	0	0	0	0	0	0	0
52)=	32	20	1000	0	0	0	35	0	0	0	0	0	0	0	0	0
53)=	32	21	750	0	10	750	35	0	0	0	0	0	0	0	0	0
54)=	32	22	450	0	11	450	35	0	0	0	0	0	0	0	0	0
55)=	32	23	550	0	12	550	35	0	0	0	0	0	0	0	0	0
56)=	32	24	50	0	13	50	35	0	0	0	0	0	0	0	0	0
57)=	32	30	1000	0	0	0	35	0	0	0	0	0	0	0	0	0
58)=	32	31	750	0	20	750	35	0	0	0	0	0	0	0	0	0
59)=	32	32	450	0	21	450	35	0	0	0	0	0	0	0	0	0
60)=	32	33	150	0	22	150	35	0	0	0	0	0	0	0	0	0
61)=	32	34	50	0	23	50	35	0	0	0	0	0	0	0	0	0
62)=	32	40	750	0	0	0	35	0	0	0	0	0	0	0	0	0
63)=	32	41	450	0	30	450	35	0	0	0	0	0	0	0	0	0
64)=	32	42	150	0	31	150	35	0	0	0	0	0	0	0	0	0
65)=	32	43	50	0	32	50	35	0	0	0	0	0	0	0	0	0
66)=	32	45	750	0	30	300	35	31	300	35	32	100	35	33	50	35
67)=	32	49	250	0	0	0	35	0	0	0	0	0	0	0	0	0
68)=	32	50	1500	0	0	0	35	0	0	0	0	0	0	0	0	0
69)=	32	51	450	0	40	450	35	0	0	0	0	0	0	0	0	0
70)=	32	52	150	0	41	150	35	0	0	0	0	0	0	0	0	0
71)=	32	53	50	0	42	50	35	0	0	0	0	0	0	0	0	0
72)=	32	55	750	0	40	300	35	41	300	35	42	100	35	43	50	35
73)=	32	60	1000	0	0	0	35	0	0	0	0	0	0	0	0	0
74)=	32	61	1250	0	50	1250	35	0	0	0	0	0	0	0	0	0
75)=	32	62	450	0	51	450	35	0	0	0	0	0	0	0	0	0
76)=	32	63	150	0	52	150	35	0	0	0	0	0	0	0	0	0
77)=	32	64	50	0	53	50	35	0	0	0	0	0	0	0	0	0

GRAPH PLOT CARDS									
CARD NO.	CARD TYPE	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.
78)=	35	41	42	43	45	40	55	0	0

LINK DATA: QUEUE CONSTRAINTS									
CARD NO.	CARD TYPE	LINK NO.	LIMIT QUEUE	QUEUE WEIGHT	LINK NO.	LIMIT QUEUE	QUEUE WEIGHT	LINK NO.	LIMIT QUEUE
79)=	38	21	18	4000	31	20	4000	51	20

*****END OF SUBROUTINE TINPUT*****

TABLE A2.

Cycle time information tables

Program TRANSYT EXAMPLE 1: MOTORWAY ROUNDABOUT

INFORMATION TO AID CYCLE TIME SELECTION
(NODES CONSIDERED AS ISOLATED JUNCTIONS)

PERCENTAGE SATURATIONS BY NODE AND CYCLE

CYCLE TIME (SECONDS)														
	30	35	40	45	50	60	70	80	90	100	120	140	160	180
NODE														
1	103	97	94	90	89	86	84	82	81	80	79	78	78	77
2	86	83	78	76	75	71	71	69	68	68	67	66	65	65
3	58	57	57	56	55	54	53	53	52	52	52	51	51	51
4	92	88	86	82	81	78	76	75	74	73	72	71	71	70
5	105	100	97	95	93	90	88	87	85	84	83	82	81	81
6	95	90	85	82	80	78	77	75	74	73	72	71	71	70
MAXIMA	105.0	100.2	96.9	94.5	92.6	90.0	88.2	86.5	85.2	84.1	82.6	81.6	81.3	81.0

Program TRANSYT EXAMPLE 1: MOTORWAY ROUNDABOUT

INFORMATION TO AID CYCLE TIME SELECTION
(NODES CONSIDERED AS ISOLATED JUNCTIONS)

PERFORMANCE INDICES BY NODE AND CYCLE

CYCLE TIME (SECONDS)		30	35	40	45	50	60	70	80	90	100	120	140	160	180								
NODE																							
1	200 >	121 >	100 >	91 >	87	86*	88	91	95	100	D	110	D	120	D	131	D	142	D				
2	69	71	68	67*	68	72	D	78	D	80	D	86	D	89	D	101	D	110	D	120	D	129	D
3	44*	47	49	49	52	57	D	62	D	68	D	71	D	77	D	86	D	97	D	106	D	117	D
4	80 >	68	64	62*	62	64	67	71	D	75	D	79	D	88	D	97	D	107	D	116	D		
5	251 >	153 >	115 >	99 >	92 >	88	87*	92	94	96	102	D	108	D	115	D	124	D					
6	94 >	95	88	86	85*	86	93	95	D	99	D	102	D	113	D	121	D	132	D	141	D		
TOTALS	737.9 >	555.4 >	484.0 >	454.3 >	446.4*>	453.5	475.0	497.6	519.7	543.1	598.9	653.4	710.4	768.9									
DOUBLES	737.9 >	555.4 >	484.0 >	454.3 >	446.4 >	437.2*	452.9	452.8	453.4	449.9	453.5	475.0	497.6	519.7									

KEY:- > A LONGER CYCLE TIME IS RECOMMENDED, TO GIVE SATURATION NOT EXCEEDING 90%

* MINIMUM PERFORMANCE INDEX FOR THIS NODE

D DOUBLE CYCLING GIVES LOWER PERFORMANCE INDEX AND SATURATION NOT EXCEEDING 90%.

TOTALS COLUMN TOTALS - ALL NODES OPERATING SINGLE CYCLING.

DOUBLES COLUMN TOTALS - BUT WITH P.I. FOR NODES MARKED D TAKEN FROM HALF CYCLE COLUMN.

TOO LOW CYCLE TOO SHORT FOR MINIMUM GREENS ON AT LEAST ONE NODE

PROGRAM TRANSYT FINISHED

TRANSYT output from optimised settings

FINAL SETTINGS OBTAINED WITH INCREMENTS :- 9 24 -1 9 24 1 -1 1
- (SECONDS)

Program TRANSYT EXAMPLE 1: MOTORWAY ROUNDABOUT
60 SECOND CYCLE 60 STEPS

	CRUISE	DELAY	STOPS	TOTALS
	LITRES PER HOUR	LITRES PER HOUR	LITRES PER HOUR	LITRES PER HOUR
FUEL CONSUMPTION PREDICTIONS	136.5	+ 124.9	+ 109.9	= 371.3

NO. OF ENTRIES TO SUBPT = 15
NO. OF LINKS RECALCULATED= 486

TABLE A4.

Output from optimised timings with flows increased by 20 percent

Program TRANSYT EXAMPLE 1: MOTORWAY ROUNDABOUT

60 SECOND CYCLE 60 STEPS

INITIAL SETTINGS

- (SECONDS)

LINK NUMBER	FLOW INTO LINK	SAT FLOW (PCU/H)	DEGREE OF SAT (%)	MEAN TIMES PER PCU CRUISE (SEC)	MEAN TIMES PER PCU CRUISE (SEC)	UNIFORM DELAY (U+R+O=MEAN Q) (PCU-H/H)	RANDOM+ OVERSAT OF (Q) (PCU-H/H)	COST OF DELAY (\$/H)	STOPS /PCU (%)	COST OF STOPS (\$/H)	MEAN MAX. AVERAGE EXCESS (PCU)	PERFORMANCE INDEX. WEIGHTED SUM OF () VALUES (\$/H)	EXIT NODE	GREEN TIMES START END 1ST 2ND (SECONDS)
10	900	3400	106	10	153	6.3 + 32.0	(218.6)	222	(11.8)	47	+	230.5	1	0 14
11	525<	3300S	57	21	7	0.8 + 0.3	(6.1)	30	(1.0)	10		7.1	1	19 55
12	582<	11L	57	21	5	0.5 + 0.3	(4.9)	41	(1.6)	10		6.5	1	19 55
13	59	11L	57	21	14	0.2 + 0.0	(1.3)	92	(0.3)	10		1.6	1	19 55
15	949<	1650	93	21	32	2.6 + 5.9	(48.2)	102	(6.2)	20		54.4	1	19 55
19	300	1750	69	21	33	1.7 + 1.1	(15.8)	104	(1.9)	6		17.7	1	0 14
20	1200	3500	114	10	266	9.8 + 78.8	(505.1)	259	(18.3)	101	+	523.5	2	42 59
21	850<	5400S	66	8	2	0.2 + 0.4	(3.3)	21	(1.1)	17		4.5	2	4 37
22	525<	21L	66	8	11	1.3 + 0.3	(9.0)	68	(2.2)	17		11.1	2	4 37
23	582<	21L	66	8	10	1.3 + 0.3	(8.9)	35	(1.4)	17		10.3	2	4 37
24	59	21L	66	8	3	0.0 + 0.0	(0.3)	7	(0.0)	17		0.3	2	4 37
30	1200	3500	103	10	103	6.8 + 27.6	(195.9)	191	(13.6)	48	+	209.5	3	33 52
31	788<	6600S	39	9	1	0.2 + 0.2	(1.9)	16	(0.8)	8		2.7	3	53 28
32	510<	31L	39	9	6	0.7 + 0.1	(4.8)	24	(0.8)	8		5.5	3	53 28
33	175	31L	39	9	5	0.2 + 0.0	(1.5)	29	(0.3)	8		1.8	3	53 28
34	52	31L	39	9	8	0.1 + 0.0	(0.7)	52	(0.2)	8		0.9	3	53 28
40	900	3500	103	10	114	6.0 + 22.5	(162.2)	198	(10.5)	38	+	172.7	4	4 18
41	525<	3300S	36	21	14	1.9 + 0.2	(11.8)	72	(2.3)	9		14.0	4	23 59
42	157<	41L	36	21	9	0.3 + 0.1	(2.3)	66	(0.7)	9		3.0	4	23 59
43	57	41L	36	21	5	0.1 + 0.0	(0.5)	27	(0.1)	9		0.6	4	23 59
45	837<	1650	82	21	23	3.1 + 2.3	(30.5)	90	(4.8)	14		35.3	4	23 59
49	300	1750	69	21	33	1.7 + 1.1	(15.8)	104	(1.9)	6		17.7	4	4 18
50	1800	4760	113	10	249	13.6 + 110.7	(708.9)	255	(27.1)	142	+	736.1	5	47 6
51	525<	3300S	43	11	2	0.0 + 0.3	(1.6)	3	(0.1)	2		1.7	5	11 42
52	175	51L	43	11	6	0.2 + 0.1	(1.6)	30	(0.3)	2		2.0	5	11 42
53	53	51L	43	11	13	0.2 + 0.0	(1.1)	43	(0.2)	2		1.2	5	11 42
55	862<	1650	98	11	52	1.8 + 10.8	(71.5)	116	(6.1)	21	+	77.7	5	11 42
60	1200	3500	103	10	103	6.9 + 27.6	(196.6)	191	(13.6)	48	+	210.2	6	19 38
61	1323<	4950S	79	8	4	0.5 + 1.2	(9.3)	9	(0.8)	15		10.1	6	43 14
62	525<	61L	79	8	20	2.4 + 0.5	(16.3)	100	(3.2)	15		19.5	6	43 14
63	175	61L	79	8	16	0.6 + 0.2	(4.5)	88	(0.9)	15		5.4	6	43 14
64	53	61L	79	8	17	0.2 + 0.0	(1.4)	74	(0.3)	15		1.7	6	43 14
TOTAL		TOTAL	MEAN	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	PENALTY	TOTAL			
DISTANCE		TIME	JOURNEY	UNIFORM	RANDOM+	COST	COST	COST	STOPS	FOR	PERFORMANCE			
TRAVELLED		SPENT	SPEED	DELAY	OVERSAT	OF	OF	OF	OF	EXCESS	INDEX			
				DELAY	DELAY	DELAY	DELAY	DELAY	STOPS	QUEUES				
(PCU-KM/H)		(PCU-H/H)	(KM/H)	(PCU-H/H)	(PCU-H/H)	(PCU-H/H)	(PCU-H/H)	(PCU-H/H)	(PCU-H/H)	(PCU-H/H)	(PCU-H/H)	(PCU-H/H)	TOTALS	
2314.8		463.0	5.0	72.2	324.7	(2262.1)	+	(134.4)	+	(0.0)	=	2396.5		

Program TRANSYT EXAMPLE 1: MOTORWAY ROUNDABOUT

60 SECOND CYCLE 60 STEPS

		CRUISE	DELAY	STOPS	TOTALS
		LITRES PER HOUR	LITRES PER HOUR	LITRES PER HOUR	LITRES PER HOUR
FUEL CONSUMPTION PREDICTIONS		163.8	+ 555.6	+ 214.5	= 933.9

NO. OF ENTRIES TO SUBPT = 1

NO. OF LINKS RECALCULATED= 56

[illegible]

APPENDIX B:

COMPUTER PRINTOUTS FROM EXAMPLE 2—AN URBAN ROUNDABOUT

TABLE B1.

TRANSYT input data

Program TRANSYT EXAMPLE 2: URBAN GYRATORY, BEST SETTINGS, WEIGHTINGS REMOVED

DATA INPUT :-

CARD CARD
NO. TYPE

(1)= TITLE:- EXAMPLE 2: URBAN GYRATORY, BEST SETTINGS, WEIGHTINGS

CARD NO.	CARD TYPE	CYCLE TIME (SEC)	NO. OF STEPS PER CYCLE	TIME PERIOD 1-1200 MINS.	EFFECTIVE-GREEN DISPLACEMENTS START (SEC)	END (SEC)	EQUISAT SETTINGS 0=NO 1=YES	0=UNEQUAL CYCLE 1=EQUAL CYCLE	FLOW SCALE 10-200 %	CRUISE-SPEEDS SCALE 50-200 %	CARD32 0=TIMES 1=SPEEDS	OPTIMISE 0=NONE 1=0/SET 2=FULL	EXTRA COPIES FINAL OUTPUT	HILL-CLIMB OUTPUT 1=FULL	DELAY VALUE P PER PCU-H	STOP VALUE P PER 100
2)=	1	40	40	60	2	3	0	0	0	0	1	0	1	0	570	90

CARD CARD
NO. TYPE

LIST OF NODES TO BE OPTIMISED

3)=	2	1	2	3	4	0	0	0	0	0	0	0	0	0	0	0
-----	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

CARD NO.	CARD TYPE	FIRST SET.....						SECOND SET.....						THIRD SET.....			
4)=	7	11	12	0	0	0	21	22	0	0	0	31	32	0	0	0	
5)=	7	41	42	0	0	0	0	0	0	0	0	0	0	0	0	0	

CARD NO.	CARD TYPE	NODE NO.	STAGE 1 CHANGE	MIN	STAGE 2 CHANGE	MIN	STAGE 3 CHANGE	MIN	STAGE 4 CHANGE	MIN	STAGE 5 CHANGE	MIN	STAGE 6 CHANGE	MIN	STAGE 7 CHANGE	MIN
6)=	12	1	21	12	0	12	0	0	0	0	0	0	0	0	0	0
7)=	12	2	5	12	25	12	0	0	0	0	0	0	0	0	0	0
8)=	12	3	0	12	20	12	0	0	0	0	0	0	0	0	0	0
9)=	12	4	33	12	16	12	0	0	0	0	0	0	0	0	0	0

CARD NO.	CARD TYPE	LINK NO.	EXIT NODE	STAGE	LAG	STAGE	LAG	STAGE	LAG	STAGE	LAG	LINK LENGTH	STOP WT. X100	SAT FLOW	DELAY WT. X100	DISPSN X100
10)=	31	11	1	1	5	2	0	0	0	0	0	50	0	4160	0	0
11)=	31	12	1	0	0	0	0	0	0	0	0	50	0	0	0	0
12)=	31	15	1	2	5	1	0	0	0	0	0	200	0	3500	0	0
13)=	31	21	2	1	5	2	0	0	0	0	0	80	0	3500	0	0
14)=	31	22	2	0	0	0	0	0	0	0	0	80	0	0	0	0
15)=	31	25	2	2	5	1	0	0	0	0	0	200	0	4000	0	0
16)=	31	31	3	1	5	2	0	0	0	0	0	130	0	3750	0	0
17)=	31	32	3	0	5	0	0	0	0	0	0	130	0	0	0	0
18)=	31	35	3	2	5	1	0	0	0	0	0	200	0	3375	0	0
19)=	31	41	4	1	5	2	0	0	0	0	0	125	0	2750	0	0
20)=	31	42	4	0	0	0	0	0	0	0	0	125	0	0	0	0
21)=	31	45	4	2	5	1	0	0	0	0	0	200	0	4160	0	0

CARD NO.	CARD TYPE	LINK NO.	TOTAL FLOW	UNIFORM FLOW	ENTRY 1 LINK NO.	ENTRY 1 FLOW	ENTRY 1 CRUISE SPEED	ENTRY 2 LINK NO.	ENTRY 2 FLOW	ENTRY 2 CRUISE SPEED	ENTRY 3 LINK NO.	ENTRY 3 FLOW	ENTRY 3 CRUISE SPEED	ENTRY 4 LINK NO.	ENTRY 4 FLOW	ENTRY 4 CRUISE SPEED
22)=	32	11	696	0	42	173	25	45	573	25	0	0	0	0	0	0
23)=	32	12	315	0	45	346	25	0	0	0	0	0	0	0	0	0
24)=	32	15	600	0	0	0	43	0	0	0	0	0	0	0	0	0
25)=	32	21	614	0	12	315	20	15	299	20	0	0	0	0	0	0
26)=	32	22	137	0	15	137	20	0	0	0	0	0	0	0	0	0
27)=	32	25	1720	0	0	0	43	0	0	0	0	0	0	0	0	0
28)=	32	31	1278	0	22	90	30	25	1188	30	0	0	0	0	0	0
29)=	32	32	214	0	25	214	30	0	0	0	0	0	0	0	0	0
30)=	32	35	1354	0	0	0	43	0	0	0	0	0	0	0	0	0
31)=	32	41	542	0	32	167	30	35	375	30	0	0	0	0	0	0
32)=	32	42	196	0	35	196	30	0	0	0	0	0	0	0	0	0
33)=	32	45	1098	0	0	0	43	0	0	0	0	0	0	0	0	0

CARD NO.	CARD TYPE	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.	LINK NO.
34)=	35	11	12	21	22	31	32	41	42	0	0	0	0	0	0	0

*****END OF SUBROUTINE TINPUT*****

TABLE B2.

TRANSYT output from optimised timings

Program TRANSYT EXAMPLE 2: URBAN GYRATORY, BEST SETTINGS, WEIGHTINGS REMOVED

40 SECOND CYCLE 40 STEPS
INITIAL SETTINGS - (SECONDS)

NODE NO	NUMBER OF STAGES	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	STAGE 6	STAGE 7
1	2	21	0					
2	2	5	25					
3	2	0	20					
4	2	33	16					

LINK NUMBER	FLOW INTO LINK (PCU/H)	SAT FLOW (PCU/H)	DEGREE OF SAT (%)	MEAN TIMES PER PCU CRUISE (SEC)	MEAN TIMES DELAY (SEC)	-----DELAY----- UNIFORM RANDOM+ COST (U+R+O=MEAN Q) DELAY (PCU-H/H) (\$/H)	----STOPS---- MEAN COST OF STOPS /PCU STOPS (%) (\$/H)	----QUEUE---- MEAN AVERAGE MAX. EXCESS (PCU) (PCU)	PERFORMANCE INDEX. WEIGHTED SUM OF () VALUES (\$/H)	EXIT NODE	GREEN TIMES START END 1ST 2ND (SECONDS)
11	694	4160S	65	7	7	0.8 + 0.6 (7.9)	36 (0.7)	4	8.6	1	26 0
12	314	11L	65	7	5	0.1 + 0.3 (2.3)	16 (0.1)	4	2.5	1	26 0
15	600	3500	40	17	10	1.3 + 0.3 (9.5)	64 (3.5)	5	13.0	1	5 21
21	613	3500S	54	14	9	1.1 + 0.5 (8.8)	64 (0.8)	5	9.6	2	10 25
22	137	21L	54	14	10	0.3 + 0.1 (2.1)	42 (0.1)	5	2.2	2	10 25
25	1720	4000	108	17	154	7.1 + 66.5 (419.2)	251 (38.5)	86 +	457.8	2	30 5
31	1194<	3750S	93	16	20	1.7 + 5.0 (38.4)	75 (4.2)	17	42.6	3	5 20
32	198<	31L	93	16	20	0.3 + 0.8 (6.2)	71 (0.7)	17	6.8	3	5 20
35	1354	3375	100	17	64	4.6 + 19.4 (136.7)	182 (21.9)	34	158.7	3	25 0
41	527<	2750S	55	15	8	0.7 + 0.5 (6.5)	45 (1.1)	4	7.6	4	38 16
42	194	41L	55	15	5	0.1 + 0.2 (1.6)	25 (0.2)	4	1.8	4	38 16
45	1098	4160	81	17	19	3.8 + 2.1 (33.7)	97 (9.5)	13	43.2	4	21 33
TOTAL DISTANCE TRAVELLED		TOTAL TIME SPENT		MEAN JOURNEY SPEED		TOTAL UNIFORM DELAY	TOTAL RANDOM+ OVERSAT DELAY	TOTAL COST OF STOPS	PENALTY FOR EXCESS QUEUES	TOTAL PERFORMANCE INDEX	TOTALS
(PCU-KM/H)		(PCU-H/H)		(KM/H)		(PCU-H/H)	(PCU-H/H)	(\$/H)	(\$/H)	(\$/H)	
1351.2		154.8		8.7		21.8	96.3	(673.0) + (81.3)	+ (0.0)	= 754.3	

TABLE B3.

Output from optimised timings with flows boosted by 20 percent

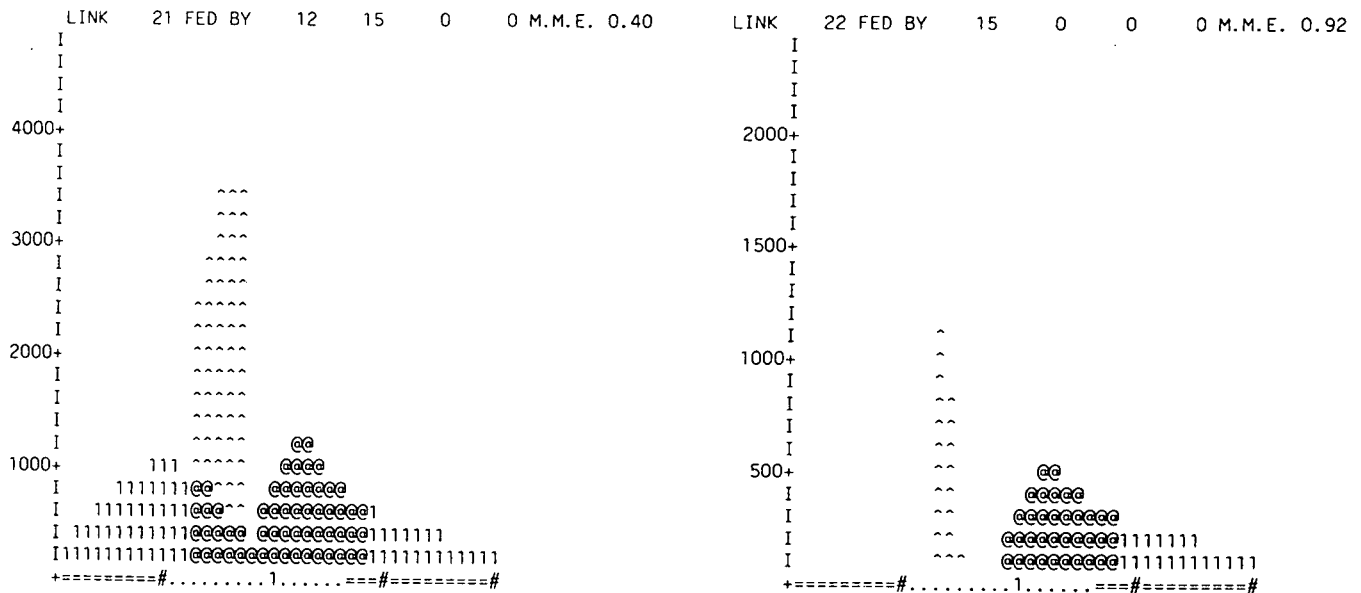
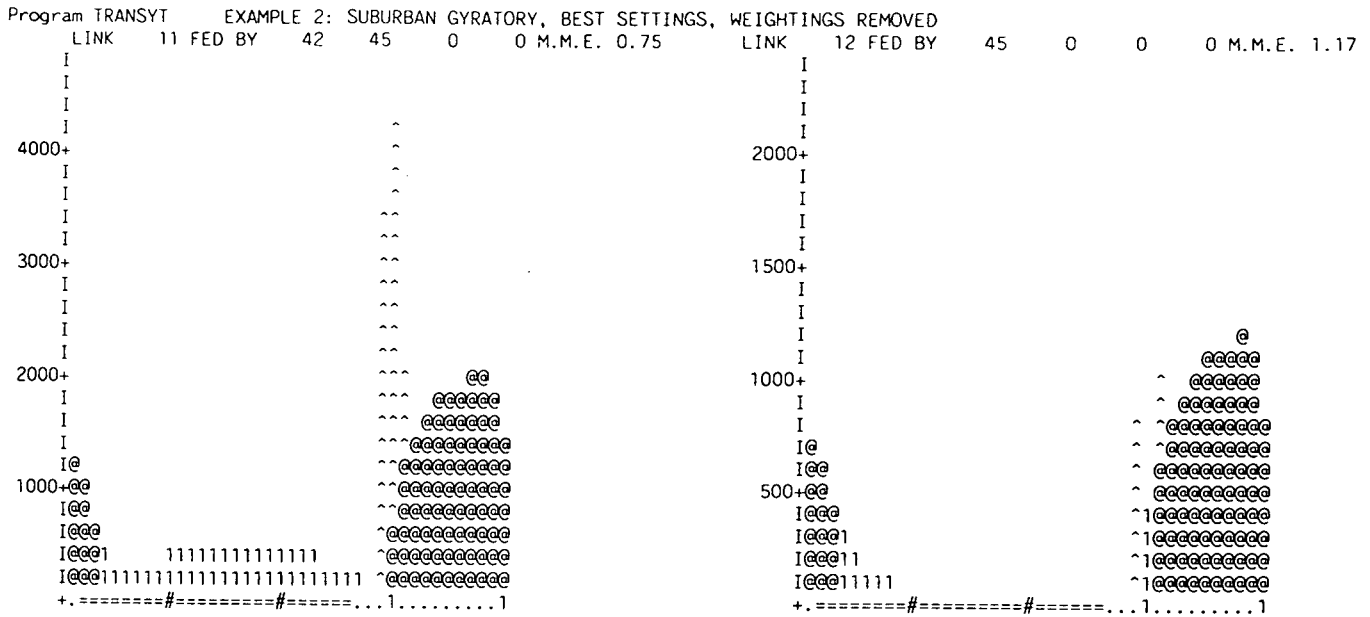
Program TRANSYT EXAMPLE 2: URBAN GYRATORY, BEST SETTINGS, FLOWS X120%

40 SECOND CYCLE 40 STEPS
INITIAL SETTINGS - (SECONDS)

NODE NO	NUMBER OF STAGES	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	STAGE 6	STAGE 7
1	2	21	0					
2	2	5	25					
3	2	0	20					
4	2	33	16					

LINK NUMBER	FLOW INTO LINK (PCU/H)	SAT FLOW (PCU/H)	DEGREE OF SAT (%)	MEAN TIMES PER PCU CRUISE (SEC)	MEAN TIMES DELAY (SEC)	-----DELAY----- UNIFORM RANDOM+ COST (U+R+O=MEAN Q) DELAY (PCU-H/H) (\$/H)	----STOPS---- MEAN COST OF STOPS /PCU STOPS (%) (\$/H)	----QUEUE---- MEAN AVERAGE MAX. EXCESS (PCU) (PCU)	PERFORMANCE INDEX. WEIGHTED SUM OF () VALUES (\$/H)	EXIT NODE	GREEN TIMES START END 1ST 2ND (SECONDS)
11	801<	4160S	75	7	9	1.0 + 1.0 (11.5)	39 (1.0)	5	12.5	1	26 0
12	377	11L	75	7	7	0.2 + 0.5 (4.2)	23 (0.3)	5	4.5	1	26 0
15	720	3500	48	17	11	1.7 + 0.5 (12.2)	68 (4.3)	6	16.5	1	5 21
21	736	3500S	64	14	10	1.4 + 0.7 (12.1)	69 (1.0)	7	13.0	2	10 25
22	164	21L	64	14	11	0.3 + 0.2 (2.8)	46 (0.1)	7	3.0	2	10 25
25	2064	4000	129	17	430	12.1 +234.2 (999.9)	275 (50.6)	259 +	1454.5	2	30 5
31	1212<	3750S	94	16	23	1.8 + 5.9 (44.0)	70 (4.7)	19	48.6	3	5 20
32	198<	31L	94	16	22	0.3 + 1.0 (7.0)	65 (0.7)	19	7.7	3	5 20
35	1625	3375	120	17	331	8.9 +140.4 (850.9)	277 (40.2)	160 +	891.1	3	25 0
41	527<	2750S	55	15	8	0.7 + 0.4 (6.5)	37 (1.0)	4	7.5	4	38 16
42	194<	41L	55	15	5	0.1 + 0.2 (1.6)	20 (0.2)	4	1.8	4	38 16
45	1318	4160	97	17	45	4.9 + 11.5 (93.6)	152 (17.9)	26	111.5	4	21 33
TOTAL DISTANCE TRAVELLED		TOTAL TIME SPENT		MEAN JOURNEY SPEED		TOTAL UNIFORM DELAY	TOTAL RANDOM+ OVERSAT DELAY	TOTAL COST OF STOPS	PENALTY FOR EXCESS QUEUES	TOTAL PERFORMANCE INDEX	TOTALS
(PCU-KM/H)		(PCU-H/H)		(KM/H)		(PCU-H/H)	(PCU-H/H)	(\$/H)	(\$/H)	(\$/H)	
1621.6		474.0		3.4		33.4	396.5	(2450.3) + (122.0)	+ (0.0)	= 2572.3	

FIGURE B1. TRANSYT graphical output



[illegible]

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I
I      ^ ^ ^ ^ ^
I      ^      ^ ^ ^ ^
I      ^      ^ ^ ^ ^ ^
I      ^      ^ ^ ^ ^ ^ ^
500+    ^      ^ ^ ^ ^ ^ ^
I      ^^      ^ ^ ^ ^ ^ ^ @@@
I      ^^      ^ ^ ^ ^ @@@@@
I      ^^      ^ @@@@@@@@@
I      ^^      ^ @@@@@@@@@@
375+    ^^      ^ @@@@@@@@@@@
I      ^^      ^ @@@@@@@@@@@@
I      ^^      ^ @@@@@@@@@@@@@
I      ^^      ^ @@@@@@@@@@@@@@
I      ^^      ^ @@@@@@@@@@@@@@
250+    ^^      ^ @@@@@@@@@@@@@@1
I      @@@@@@@@@@@@@@@@@@11
I      @@@@@@@@@@@@@@@@@@11
I      1@@@@@@@@@@@@@@@@111
I      1@@@@@@@@@@@@@@@@1111
125+    1@@@@@@@@@@@@@@@@11111
I      11@@@@@@@@@@@@@@@@111111
I      11@@@@@@@@@@@@@@@@1111111
I      11@@@@@@@@@@@@@@@@11111111
I      11@@@@@@@@@@@@@@@@1111111111
I      11@@@@@@@@@@@@@@@@111111111111
+=====...1.....1.=====#####

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