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2. RR223  A study of the safety of major motorway roadworks in 1987, M Marlow and
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MODIFIED CONTRA-FLOW LAYOUTS FOR MAJOR MAINTENANCE: NARROW LANE AND TIDAL FLOW OPERATION

ABSTRACT

Major motorway maintenance normally uses the full contra-flow layout with two traffic lanes in each direction on one carriageway, using the hard shoulder as a traffic lane. This releases the other carriageway for maintenance. An alternative configuration is the partial contra-flow, where a trafficked lane is provided in one direction on the works carriageway. To improve the operational efficiency, two adaptations of these layouts, which operate with a tidal (or reversible) lane, and narrow lanes, have been developed and successfully tested. This Report describes the design considerations for these new systems, together with layout and signing requirements, derived from the operational experience at worksites on dual 2- and 3-lane motorways. The use of these layouts, in appropriate traffic conditions, shows potential overall savings, with the reduced cost of traffic delay offsetting the expenditure on extra signs and markings.

1. INTRODUCTION

Over the last decade traffic on all Britain’s roads has increased by about a third, but that on the motorway system has more than doubled. The annual total motorway travel is now close to 60 billion vehicle kilometres. This steady rise in motorway use has implications for the maintenance of the network. In particular, it demands improvements in major roadwork traffic management layouts to cope with the higher traffic demands.

The contra-flow layout is used at many major roadworks on dual 3-lane motorways. While one carriageway ('primary') is being reconstructed, the other ('secondary') carriageway carries two traffic lanes in each direction (i.e. 2+2), using the hard shoulder as a traffic lane. The capacity of a typical full contra-flow system is about 3450 vehicles/hour in each direction of travel. Many sites are operating close to or at capacity, and there is a need to develop higher capacity systems.

Narrow lanes (Maclean, 1977) and tidal flow techniques to improve throughput were tried on a limited scale at maintenance sites over a decade ago. This Report examines the applicability of these ideas to the modern contra-flow layout, and presents an outline of the operational experience of recent layout trials during major motorway reconstruction. An indication is given of the cost-benefit implications of these improved traffic management systems compared with the conventional contra-flow layout.

2. CONVENTIONAL LAYOUTS AND THEIR DEVELOPMENT

2.1 CURRENT TRAFFIC MANAGEMENT ARRANGEMENTS

Conventional traffic management layouts use the motorway cross sectional width in a variety of ways. Figure 1 illustrates the range of present configurations in comparison with the standard cross section (14.3m wide) shown in diagram (a). Some concrete carriageways may have additional width, and other links, where the central reserve is paved, may also afford some marginal increase over the standard. However, it would be necessary to ensure that any extended area of central reserve or hard shoulder paving is suitable for carrying traffic, particularly heavy goods vehicles (HGVs), before it can be used as part of the roadwork layout.

At present the full contra-flow system is the most widely used major traffic management arrangement (diagram b). All of the traffic is carried on one carriageway, permitting the primary carriageway to be made available for works operations, apart from the provision of an emergency lane.

Where at least one traffic lane is maintained on the works' carriageway, the layout is termed partial contraflow. Examples of such layouts are depicted in diagrams (c),(d) and (e). During maintenance these layouts are organised to accommodate a running and emergency lane on the works' carriageway as shown in (c) and (d). The work is performed in two phases, alternating the traffic and work between two sections of the primary carriageway. Opposing traffic on the secondary carriageway may be separated by a full width (buffer) lane of 3.65m, or a buffer zone 1.2 m. wide (as shown in (e)).

An additional lane may be provided in one direction by running the secondary traffic on the hard shoulder, with the location of the buffer zone setting the division of lanes (diagrams (f) and (g)). These arrangements are a combination of (b) and (e), but unlike those layouts, these five-lane systems have not been operated extensively.

2.2 POTENTIAL LAYOUTS

The full contra-flow layout could be extended by remarking the secondary carriageway into five sub-standard width lanes (Figure 2, diagram h). However the lane widths indicated in this diagram are narrow, particularly the middle and offside lanes running in the 3-lane direction. Driving in these lanes in heavy but free-flowing conditions would be taxing, and it would be desirable to
Fig. 1 Cross sectional diagrams of conventional and full width layouts
(h) Full contra-flow + narrow lanes (3+2)

![Diagram of Full contra-flow + narrow lanes (3+2)](image)

(i) Full contra-flow + tidal operation (2+2 and 1+3)

![Diagram of Full contra-flow + tidal operation (2+2 and 1+3)](image)

(j) Full contra-flow + tidal operation + narrow lanes (3+2 and 2+3)

![Diagram of Full contra-flow + tidal operation + narrow lanes (3+2 and 2+3)](image)

(k) Partial contra-flow + narrow lanes (3+3)

![Diagram of Partial contra-flow + narrow lanes (3+3)](image)

(l) Partial contra-flow + tidal operation (3+2 and 2+3)

![Diagram of Partial contra-flow + tidal operation (3+2 and 2+3)](image)

Fig 2. Cross sectional diagrams of augmented layouts with narrow lanes and/or tidal operation
increase the width of these lanes, particularly the middle lane in the three-lane direction, to more acceptable dimensions. The use of lanes less than 3m wide will certainly call for additional care and attention on the part of all drivers. This layout may be limited for general use by the number of HGVs using the site, since there is only one lane available in each direction suitable for them.

One other approach to optimising the contra-flow system would be to modify the layout to permit tidal flow operation (or reversible lanes) at sites where there is a marked daily change in the direction of the dominant flow. Under this system, additional lanes are run in the direction of the higher flow, at the expense of the other (less trafficked) direction, reversing, as necessary the configuration to accommodate changes in the balance of flows. On 2-lane motorways the tidal full contra-flow layout would allow some flexibility in operation over the current static configuration (2+1). However, there are limitations to the use of the tidal full contra-flow on 3-lane motorways (diagram i), which arise from the match between lane allocation (1+3 and 2+2) and the peak demand pattern. Only about 5 per cent of motorway links have a marked imbalance (i.e. a ratio of 70/30 or higher) in their directional flows during individual peak periods. In contrast, around 50 per cent of links display tidalities greater than 60/40.

One solution to ease this restriction is to have a minimum of two lanes in each direction, plus a reversible lane. This could be accomplished by having a combination of narrow lanes and tidal flow (diagram j). Unfortunately the addition of a second buffer zone to the full contra-flow narrow lane layout (diagram h) imposes a severe constraint on the lane widths. The running lanes will be 2 x 3.0m lanes (for any vehicle) plus 3 x 2.3m lanes (for light vehicles only); these lanes are all substandard and will present problems for motorists, particularly since one of them runs between continuous buffer zones. A limited trial at TRL, indicated that drivers were more apprehensive when driving along a 2.3m wide lane, bounded on both sides, compared with travel in restricted lanes of 3.0m and 3.15m width. In view of the stress imposed on drivers in this narrow bounded lane, it was concluded that this configuration was not a feasible option.

The combination of narrow lanes, or tidal operation, and partial contra-flow is less restrictive, both to the driver and in application. The layout shown in diagram (k) offers three lanes in each direction, though only one lane is wide enough to carry HGVs. The earlier comments on the limited width lanes in diagram (h) are also applicable to this configuration, and measures should be taken to ease this width constraint. There are no restrictions with the 5-lane tidal partial contra-flow (diagram l), which has two lanes each way, plus a reversible lane to maintain three lanes in the peak direction. All lanes are over 3.0m wide, which would permit allocation of an additional lane to HGVs if required.

3. NARROW LANE LAYOUTS

3.1 GENERAL

The standard width of a motorway lane is 3.65m, but at major maintenance sites, one or more of the running lanes frequently may be between 3.0m to 3.5m wide. These 'narrowed lanes' are not normally identified by signs, but drivers are usually advised of any further width restriction. Maclean (1977) recommended that lanes intended for use by all types of vehicle should not be narrower than 3.25m (with a minimum of 3.0m). Where it is possible to reserve some lanes exclusively for light vehicles, the width may be reduced to 2.75m (with a minimum of 2.5m). Lanes of these restricted widths ('narrow lanes') are not common at major motorway roadworks, though extensive use has been made of narrow lane operation over short lengths during the strengthening and resurfacing of M4-Severn Bridge.

The opportunity to test a full contra-flow layout with narrow lanes was presented during the reconstruction of M40 (Junctions 5-6) in Oxfordshire in 1989. This section of the 3-lane motorway ascends from the Vale of Aylesbury to run through the scarp of the Chilterns. The provision of a climbing lane was planned to ease possible congestion in the London bound (uphill) direction during the works period. Since one carriageway would be occupied by the works, this could only be achieved by remarking the opposing carriageway (consisting of 3 lanes and hard shoulder) into 5 narrow lanes (3 uphill and 2 down).

3.2 LAYOUT PRINCIPLES

The layout is shown schematically in Figure 3, together with details of the cross sectional widths through the contra-flow section. The main features of the layout were the complete removal of all existing road markings before the carriageway was remarked to the new lane configuration, the introduction of a mandatory speed limit, and the segregation of vehicles. The last two measures are in keeping with general DOT policy at major maintenance sites where speed limits (usually 50 mph) operate, and heavy goods vehicles (over 7.5 tonnes gross laden weight) are banned from the right-hand lane of contra-flow sections wherever the HGV flow is normally less than 850 vehicles/hour in either direction. A width limit of 2m was imposed in lieu of the weight threshold at the trial site. At an early stage on the approach traffic was marshalled into the appropriate lanes, prior to the reduction of lane widths and the start of the speed restriction. The narrow lanes were then run in parallel over a 400m section to allow drivers to adjust to the change in lane widths, before any transitions to the hard shoulder and to the opposing carriageway. On these curves, particularly on the multi-lane crossovers, the narrow lanes were widened; the extra width being applied uniformly along the transition curve. Views of the trial narrow lane layout in operation are shown in Plate 1.
M40 (Oxon) Trial site

![Diagram of Schematic layout]

All dimensions in metres

3.0 | 2.35 | 0.9 | 2.35 | 3.0 | 3.0

Mixed traffic | Light vehicles only | Mixed traffic

General application
(see Section 3.4)

![Diagram of Carriageway cross section]

3.0 | 2.5* | 1.1 | 2.5* | 2.75 | 3.0

Mixed traffic | Light vehicles only | Mixed traffic

*b Lane widths are minima. Wherever possible these dimensions should be raised to 2.75m

Fig. 3 Narrow lane layout (3-lane motorway with hard shoulder)
a) and b) General views. Note increased density of lane markings
c) Driver's view from light vehicles-only lane

Plate 1 Narrow lane layout (M40 trial)
3.3 OPERATIONAL CHARACTERISTICS

The narrow lane layout was installed in June 1989 and was in use for 6 months, operating in turn on each carriageway as the reconstruction work progressed. The daily flow was over 30,000 vehicles, with the peak hour flow of 4000 vehicles (2400 veh/h in the peak direction) below the capacity of the layout. Maclean (1977) found that vehicle throughput on narrow lanes was about 15 per cent lower than the lane capacity at conventional work sites. More recent observations on Severn Bridge and on single narrow lanes elsewhere also suggest that lanes of widths less than 3m have an operational capacity of between 1300 and 1400 veh/h.

The provision of the climbing lane worked well; traffic speeds uphill on the three lanes were unaffected by the works. Speeds on the two-lane carriageway (downhill) were reduced by 10 to 15 mph to around 60 mph as a result of the restricted carriageway width. There were no hold-ups under normal running conditions, and only minimal delays following a breakdown or other incident. No particular problems were encountered with wide loads (ie vehicles over 4.1m width) passing through the works, though this type of vehicle was normally escorted by the police. Despite the limited lane widths, there was an even distribution of lane usage; the narrow offside lane on the two-lane section carried 45 per cent of the total traffic in that direction. In the two lane direction, the restricted width and steady speeds of traffic through the works, did not encourage overtaking and several vehicles travelled in echelon with the nearside vehicle in the contra-flow section. Observations of vehicle positions in the lanes indicated that only about 10 per cent of the traffic were baulked in the overtaking manoeuvre.

Recovery operators' records showed that nearly 400 recovery incidents were attended during the contract period. This total was less than the expected value, assuming a rate at restricted sites of 25 incidents per million vehicle kilometres (Department of Transport, 1982). The number of personal injury accidents (all slight) was small, displaying a rate similar to that experienced at other major (conventional) roadwork sites (Marlow and Coombe, 1989). Communication links worked well, particularly after the provision of a radio handset for each recovery vehicle.

3.4 LAYOUT CONSIDERATIONS

Although the narrow lane layout did not run to capacity, the trial enabled the signing requirements to be identified and highlighted several factors which need to be taken into account when implementing this type of system. Experience gained from the trial has been incorporated in the layout and signing details for a narrow lane system on a dual 3-lane motorway shown in Figure 4. Several factors influence the ability of a driver to stay within a lane, including the lane delineation, pavement condition and width of lane. Clear lane markings are important in any traffic management layout, and are particularly important with narrow lane operation. All original mark-ings were thoroughly removed before the carriageway was remarked to the new configuration. To emphasise the new arrangement and improve the conspicuity of the lane delineation on the concrete surface, the markings were enhanced to 6m on and 3m off (Plate 1), compared with the conventional spacing of 2m on, 7m off. These enhanced markings will help to maintain continuity of delineation across areas where there are changes in the surface characteristics of the carriageway. Sections where there are marked changes in the condition of the pavement may require treatment to ensure a more uniform appearance prior to remarking. The reconfiguration of the carriageway may place the longitudinal joints or the original road stud bases within the new lanes and in some cases in line with the vehicle wheeltrack. Consideration should be given to removing the road stud base, as well as the rubbers and their reflectors, and reinstating the carriageway before introducing traffic to the narrow lane layout.

The division of the carriageway for the trial (Figure 3 (b)) was dictated by the requirement to provide two 3 metre wide lanes for mixed traffic in one direction. This could only be achieved by reducing the width for the light vehicle-only lanes below the 2.5m minimum threshold (see Section 3.1). Although no problems were encountered with this cross-section when operating at the low to medium flows, the tendency observed for drivers to stagger their lane occupancy is likely to become more pronounced as the traffic density increases, with a consequent loss in throughput. With the available width at a premium, the width of the buffer zone was reduced from 1.2m to 0.9m. This width represents the minimum, and it would be inadvisable to reduce it further. Current buffer zones have 750mm high cylinders spaced at 9m centres, between parallel lines of yellow road studs placed at 1 to 2m intervals. Any vehicle running along this line of studs generates an audible warning to the driver of an infringement of the buffer zone, and the offset between the stud and cylinder lines offers some latitude for the driver to correct his path before crossing the cylinder boundary. Buffer zones of width less than 0.9m would remove any offset to the point where it offers no worthwhile latitude to the driver.

Consideration needs to be given to the allocation of lane widths when planning to operate more than two narrow lanes in the same direction. Two-lane designs have fixed boundaries from which drivers may judge their lateral clearances - the carriageway edge for lane 1 and the buffer zone for lane 2. However, the judgement of drivers in a middle lane will be influenced by the changing positions of traffic in the adjacent lanes. To compensate for the 'moving' boundaries of this lane, additional width should be allocated to it to improve vehicle clearance. The mandatory 50 mph speed limit at work sites would permit the required 1.2m minimum clearance to the safety fence to be halved, releasing 0.6m to the running lanes on sections where the paving is extended to the centre reserve. This combined with a small reduction in the width of the buffer zone would enable the width of the middle narrow lane to be raised to the preferred minimum for light vehicles only of 2.75m (Figure 3(b)). An
Fig. 4 Signing details - narrow lane layout

- Advance signing for pull in
- Repeat at 450m intervals between consecutive signs on alternate sides of carriageway, with a maximum of 700m between signs on same side of carriageway
- Breakdown advice through contra-flow
- Set at 300m intervals between signs on same side of carriageway
- Set at 450m intervals between signs on alternate sides of carriageway
- Repeat at 1500m for wide loads with provision for pull in

Note: All signs and markings are to be clearly visible and in good condition.
The carriageway edge condition needs to be considered if the hard shoulder is to be used as a running lane, particularly when operating reduced lane widths. Allowance should be made for the presence of kerbing, since this will reduce the running lane width as passing traffic shies away. Motorway fixtures, such as emergency telephones may also intrude onto the rear of the hard shoulder. Drainage facilities on the verge can also give rise to problems. If the filter medium is loose, then should the nearside wheels of a heavy goods vehicle momentarily leave the main carriageway, they can become trapped in the drain material leading to loss of control.

It is essential to have an efficient recovery service and well defined operational procedures in the event of an incident. The problem may be offset by reliable communications between contractors, recovery, and traffic management staff and by effective surveillance of the site. Traffic characteristics should also be reviewed before these systems are employed. High proportions of commercial vehicles may preclude some layout designs where only one lane in each direction is allocated to heavy goods vehicles. Finally consideration needs to be given to the installation procedure. These layouts take longer to set out (and to change phases) than conventional systems. Given the amount of equipment which needs to be installed and the requirement that the layout cannot be left in an unsafe temporary configuration, a feasibility study is needed at the design stage of the scheme. This would need to take account of the traffic flows and windows of opportunity.

4. TIDAL SYSTEMS

4.1 GENERAL

Several permanent tidal flow systems are used on urban links in Great Britain, and their characteristics are well understood. In contrast, little is known about the applicability of such techniques to temporary situations. A limited tidal system was used on M11 in the early 1980’s, and tidal techniques were successfully operated during bridgework near Mainz in Germany (Maier, 1986). There the contra-flow layout operated with three lanes, the centre lane being reversible. The traffic was controlled by overhead traffic signals installed on 9 gantries along the 1200m long site.

The design and operational considerations of tidal layouts during major maintenance on dual 2- and 3-lane motorways were examined initially in a desktop study. The principle has been refined and established following field trials over three years at five motorway sites where full and partial contra-flow systems, operating tidally, were employed.

4.2 LAYOUT PRINCIPLES

Figure 5 shows a schematic diagram of a full contra-flow tidal layout. One important principle is to minimise the number of features which require changing between the two operating conditions (1+2 and 2+1). This reduces the risk of mistakes when resetting the layout, as well as reducing the lost operating time between changes. To this end, approaching traffic is marshalled into physically divided lanes, which then guide the vehicles through the contra-flow. Access to the tidal lane is controlled by four ‘gates’ at key locations, as shown in Figure 5(a). Each ‘gate’ is formed by a 200m line of cones, at 1 to 2m centres. This simple lane control design is in marked contrast to the elaborate gantry system which was used in Germany (see Section 4.1), but offers additional flexibility, since it requires little or no preparation work prior to the installation of the layout.

The two operating conditions shown in Figure 5(a) are summarised below. In the Figure a convention is adopted that a gate is “open” if it lies parallel to the carriageway lane lines, and “closed” when it is drawn at an angle across the lane.

Condition 1+2: As with the conventional contra-flow layout, traffic on the primary approach is diverted to the hard shoulder and lane 1. The right lane at the splitter island is now closed by a cone taper (gate 1), which channels the approaching traffic into a single lane, running along the hard shoulder. This single traffic lane is carried across the central reserve to run along the contra-flow on lane 2 of the secondary carriageway. The return is accomplished using the left hand lane of the two-lane crossover, before restrictions are lifted and the traffic reverts to normal running. In the opposing direction, a lane 2 closure directs traffic to run on the hard shoulder and lane 1. Traffic in lane 1 is separated from that on the hard shoulder by a splitter island (gate 4, open), and runs through the contra-flow contiguous with, but physically separate from, the hard shoulder (gates 2 and 3, open). At the end of the works the restrictions on lane 1 are removed, traffic on the hard shoulder regains the main carriageway and normal motorway operating conditions apply.

Condition 2+1: As previously, traffic on the primary approach is transferred to run on the hard shoulder and lane 1. The two lanes are run either side of a splitter island (gate 1, open), channelling the traffic into two contiguous, but physically separate lanes. These are carried together across the central reserve, using a variant of the two-lane crossover to run on lanes 1 and 2 of the secondary carriageway (gates 2 and 3, closed). A second two-lane crossover returns the traffic to the primary, where the delineator between the two lanes is removed and traffic reverts to normal operation. On the secondary approach, the two-lane traffic is initially transferred to the hard shoulder and lane 1 before reduction (gate 4, closed) to single lane running on the hard shoulder to run through the contra-flow. At the end of the works, vehicles are returned once more to the main carriageway (lane 1), before resuming normal two-lane operation.
Cone gates

Condition 1 + 2

Condition 2 + 1

(a) Schematic layout

All dimensions in metres

(b) Carriageway cross section

Fig. 5 Tidal full contra-flow layout (2-lane motorway with hard shoulder)
A mandatory speed limit (50 mph) is imposed, and the traffic segregated. It was thought advisable not to run HGVs along the tidal lane, which is of reduced width and bounded each side by buffer zones of plastic cylinders at 4.5m centres. Figure 5(b) illustrates the cross sectional widths through the contra-flow section on a dual 2-lane motorway. The reflective studs, which mark the edge of the buffer zone, are offset from the centre line to avoid excessive narrowing of the tidal lane.

As discussed in Section 2.2, tidal principles may also be applied to partial contra-flow layouts. The main layout elements and cross sectional widths for this system on a dual 3-lane motorway are shown in Figure 6.

Although the use of a tidal layout at work sites is a new concept, the design elements for the scheme were drawn extensively from current practice, so that the individual features did not depart from standard (Department of Transport, 1991). Examples of tidal layouts on dual 2- and 3-lane motorways are shown in Plates 2 and 3.

4.3 OPERATIONAL CHARACTERISTICS

Over a three-year period, five major motorway layouts used tidal techniques. The first trial was conducted in 1988 during repairs to the concrete carriageway on a 3-lane section of M40 (junctions 6-7) in Oxfordshire and established the basic signing and layout details for a full contra-flow arrangement. The daily flow at this site was over 30,000 vehicles, and the distribution was such that, whilst a conventional 2+2+2 contra-flow layout could operate satisfactorily there were periods of tidality (mainly at weekends) when 1+3 operation was more appropriate. The tidal techniques were refined during the second and third trials in 1989 and 1990 on 2-lane sections of M2 (junctions 5-6) in Kent, which carried about 32,000 vehicles per day when the works were in progress. These sites were strongly tidal, with the peak flows switching direction mid-morning. The variable 1+2/2+1 system was ideally suited, offering increased flexibility over the conventional static 2+1 layout. Queues were reduced on the single lane approach which had previously occurred during the morning peak and afternoons at weekends. The adaptability of this design (1+2/2+1) was further demonstrated on an urban 2-lane section of M1 (junctions 43-47). This site at Leeds in West Yorkshire carried daily flows of 23,000 vehicles during the works period. The final trial was on a 3-lane section of M3 (junctions 3-4) in Surrey, which had daily flows of over 100,000 vehicles. To cope with the heavy peak demand, a 5-lane tidal partial contra-flow layout was used, which could be reconfigured early morning and afternoon to provide 3 lanes in the peak direction.

All five sites operated well, with drivers adapting quickly to the new arrangements. The Kent and Surrey sites operated under high demand, with single lane throughput running at capacity (around 1800 pcu/h). The tidal lane was well utilised, with between 45 and 70 per cent of drivers selecting this lane in preference to the mixed (heavy and light) traffic lanes. There was good compliance with the width ban.

There was some reduction in speed at the sites, reflecting the influence of the layout geometry and the mandatory speed limit. The proportion of HGVs in the mixed traffic single lane (up to 45 per cent at some sites) was a prime factor determining the speed, which fell below 35 mph at peak times. The tidal lane, although bounded both sides, had the highest speed; around 55 mph in light traffic, falling to below 40 mph with peak flows.

Total travel at the five tidal sites of over 60 million vehicle kilometres generated fewer incidents than expected, reflecting a rate about two thirds the accepted value of 25 per million vehicle kilometres (Department of Transport, 1982). In contrast, the personal injury accident rate was higher than anticipated, though the figure is biased by data from one site where the increase in accidents was influenced partly by poor surface conditions rather than layout design. The most frequent type of accident (70 per cent) was the nose to tail shunt in the contra-flow section. This high value compares with the roadwork 'average' of 50 per cent (Marlow and Coombe, 1989), and reflects the restricted running in the single bounded lane, with its limited room for manoeuvre.

4.4 LAYOUT CONSIDERATIONS.

The five contra-flow sites at which tidal flow techniques used were provided insight into the signing and layout requirements over a range of traffic characteristics in both urban and rural locations. The principal signing and design features for a tidal full contra-flow layout on a dual 2-lane motorway are shown in Figure 7. Equivalent details for a partial contra-flow system on a dual 3-lane motorway are presented in Figure 8.

Experience gained in the trials showed that the splitter islands on the approach to the tidal layout play a major role, dividing and guiding the traffic into the tidal lane. Measures should be adopted to enhance their appearance (e.g. good edge delineation and alignment, markings in advance of the nose of the island, etc.) to encourage drivers to take their lane decision at an early stage. Clear and unambiguous carriageway markings, coupled with the bounded lanes in the tidal layout, help keep the level of additional signing to a minimum in comparison with a conventional layout. Plastic traffic cylinders (750mm high) at 4.5m centres, between parallel lines of yellow road studs, serve to delineate the tidal lane, and yet allow access to this lane in an emergency.

The changeover procedure requires the close coordination of the operating staff, who work systematically through the site. Initially, the advance signs on one approach are changed prior to closing the tidal lane gate. The closure of this lane offers the opportunity to maintain the delineators (i.e cones, cylinders, etc.) as the team progress through the site, changing the direction arrow boards and switching the gates at the crossovers. The tidal lane gate at the far end is opened and the signing on that approach changed to indicate the new configuration. A small, well briefed, consistent team of about five people seems ideal, with the team leader checking each stage. The layout changes required to reverse the 4km tidal lane typically took 30 to 40 minutes. The changeover
Fig. 6 Tidal partial contra-flow layout (3-lane motorway with hard shoulder)
a) Tidal full contra-flow layout operating 1+2
b) Tidal layout operating 2+1
c) Driver's view from tidal lane. Note arrow sign (on right), confirming traffic directions to drivers, particularly in low flow conditions (two lanes in direction of driver, one opposing lane)

Plate 2 Tidal full contra-flow layout (M2)
a) traffic approach channelled from 3 lanes to 2 lanes by cone gate
b) Cone gate open; light vehicles passing either side of splitter island. Traffic in right-hand lane is led into tidal lane
c) Tidal partial contra-flow layout operating 3+2
d) Design of tidal (centre) lane permits errant wide vehicles to run without mishap. Note offset studs in buffer zones
Condition 1

Repeat at 1 minute intervals through contra-flow

Repeat at 450m maximum between consecutive signs on alternate sides of carriageway, with a maximum of 700m between signs on same side of carriageway.

Breakdown advice signs through side

Mount at minimum height of 5m

Use 1500mm sign

Advance signing for wide load, with grandsign for guidance

Condition 2

Fig. 7 Signing details - tidal contra-flow layout
Fig. 8 Signing details - tidal partial contra-flow layout
procedure can be assisted by efficient sign design, which can eliminate handling difficulties when switching between alternate operating conditions. Flapped or ‘hymn board’ signing, roller blind units to cover signs not in use, and variable display devices (mechanical or electrical) can all help the changeover operation.

Incident procedures should be well defined. Both light and heavy recovery facilities should be present on site for 24 hours a day, and operated by trained and experienced staff. The tidal layout with its bounded single lanes is particularly vulnerable in the event of an incident. However, in an emergency the tidal lane can be closed and cleared, either to assist access by the emergency services to the incident, or operated in the reverse direction, should an incident cause a blockage on the opposing lane(s). The tidal lane has sufficient latitude to carry mixed traffic in these circumstances, and may be used to redirect traffic to bypass the obstruction. At night when traffic flows are low, the tidal lane may be closed, to serve as a buffer lane between opposing flows and as a refuge for vehicles in the event of a breakdown. At any site (conventional, narrow lane or tidal layout), where the hard shoulder is used as a running lane, the provision of hard-standing, temporary lay-bys (suitably signed) can encourage failing vehicles to stop off the travelled way. The bays should be sited at not more than 500m intervals, adjacent to the rear of the hard shoulder and, where width permits, on the centre reserve.

At any major layout, good communications and effective surveillance can help to coordinate recovery and emergency services, and reduce the incident duration. The use of closed circuit television (CCTV) to monitor roadworks is becoming more common, but to be effective the camera locations need to be carefully selected to ensure comprehensive coverage both through the contra-flow and on the approaches. The control centre will normally be in the site compound, and should serve as the main communications link to recovery, contractual and engineering staff and the emergency services. The operatives should be well trained and appreciate the key role which they play in ensuring the smooth operation of the layout. CCTV facilities at one urban tidal site were particularly useful in providing accurate reports to the motoring organisations, police and local radio stations on any traffic problems during the peak periods.

It is essential, of course, during the design stage to determine the tidality of the traffic flow, not only to be able to predict the suitability of the proposed traffic management system, but also to determine the time when the lanes should be changed. In common with the narrow lane layout, these systems involve a large quantity of traffic management equipment, and need careful planning and time to set out.

5. COSTS AND BENEFITS OF THE SYSTEMS

An indication of the potential benefits which may accrue from these innovative systems, compared with the conventional full and partial contra-flow layouts, was obtained using the economic evaluation program QUADRO2 (Department of Transport, 1982). For each type of layout, the basic parameters were fixed, varying only the number of available lanes and their capacity. The narrow lane systems were represented by reducing the standard lane capacity by 15 per cent, while the tidal systems were modelled by varying the configuration of lanes by time of day and operating more lanes in the peak direction. Estimates were made for the additional direct costs associated with the new layouts, such as the supplementary expenditure arising from the signing and markings, and labour costs to switch the tidal layout.

These direct cost estimates were offset against the QUADRO2 user costs to give estimates for the total (i.e. direct and indirect) cost implications of each type of layout. Figure 9 shows these cost estimates as a percentage of the costs associated with the conventional (2+2) full contra-flow layout, for a total daily demand flow of 90,000 vehicles.

At this level of daily flow, the five-lane narrow lane layout showed savings of about 15 per cent over the conventional full contra-flow system. There can also be substantial savings with the tidal system when the layout configuration matches the prevailing traffic tidality at the site. The tidal layouts on the 2-lane motorway (2+1, 1+2) in Kent (Section 4.3) met this requirement and the total net savings at this site were of the order of £580,000; a 10 per cent saving compared with a fixed (1+2) contra-flow layout.

Additional benefits are achievable by the application of these new designs to the standard partial contra-flow, despite the cost penalty of running traffic on the work’s carriageway. The tidal derivative of this layout offers a variable 3/2 lane split, mirroring the typical 60/40 motorway tidality, and potentially offers a 50 per cent saving over the conventional full contra-flow costs. The trial M3 site, for example, showed cost savings of over 60 per cent (about £140,000 per day). The greatest improvement may be achieved from a partial contra-flow using three fixed lanes in each direction, though, as noted in Section 2.2, its general applicability may be limited by the provision of only one lane each way to accommodate heavy goods vehicles.

6. CONCLUSIONS

Derivatives of the conventional contra-flow layout have been developed and successfully operated at a number of major maintenance sites. The new layouts employ either a reversible (tidal) lane or narrow lanes, and may be adapted to both the full and partial contra-flow system. The use of these layouts, in appropriate traffic conditions, show potential overall savings, with the reduced cost of traffic delay offsetting the expenditure on extra signs and markings.
Fig. 9 Cost estimates of alternative traffic management arrangements (expressed as a percentage of costs associated with the conventional (2+2) full contra-flow layout)

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8. REFERENCES


