Moveable barrier technology – the key to the dynamic highway?

By **Robert Bain**

Supply-side solutions to peak hour traffic congestion have, by and large, fallen out of favour amongst European transport planners and policy-makers. It is a pity, laments Robert Bain who has been known to lean towards the pro-highways end of the spectrum, if only to bring some balance back into the debate. In the following article, Robert reviews an engineering solution which – given certain circumstances – allows highway supply to be adjusted to better match demand; moveable barrier technology. He surveys installations in the US, Brazil, Australia and New Zealand.

THE THEORY

The theory is simple. Take the morning peak period. In many cities the most congested highways are main radial feeders channelling traffic into a downtown central business district. These roads often demonstrate unbalanced flows with perhaps 70% of traffic travelling inbound and only 30% – sometimes even less – travelling outbound. This scenario leads to recurring congestion in the peak direction but free-flow conditions counter-peak.

If it was possible to inject some flexibility into the supply of highway capacity, the existing roadspace could be realigned to better match this profile of demand and an enhanced level of service could be provided to drivers without building any extra capacity (additional lanes or new roads). Moveable barrier technology does just that.

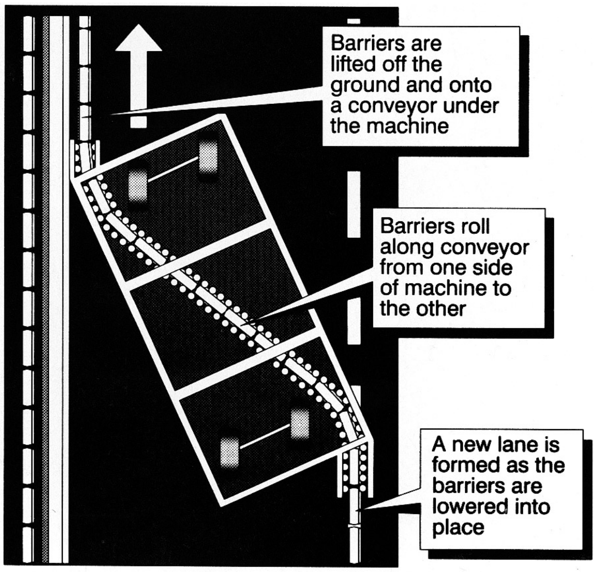
MOVEABLE BARRIER TECHNOLOGY

There are two key components of a moveable barrier solution: a safety barrier comprised of a series of interconnected concrete blocks and a 'transport and transfer' machine capable of displacing the barrier laterally across the pavement. The one-meter-long concrete blocks are interconnected by steel hinges to form a continuous barrier. Their design departs from the conventional pre-cast concrete barriers insofar as they have a T-shaped top.

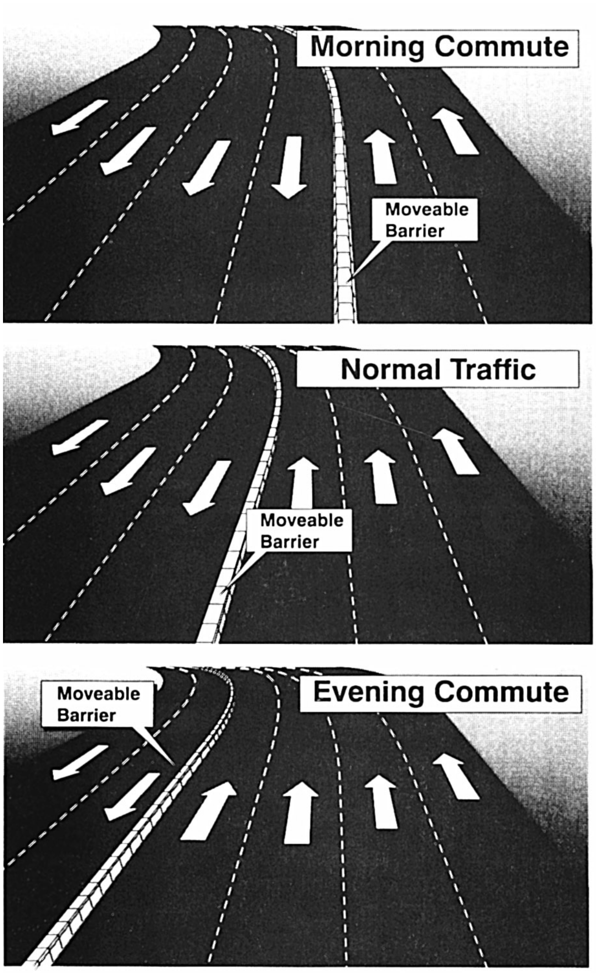
The transport and transfer machine employs an inverted, S-shaped conveyor belt mechanism. Small wheels hook under the T-shaped top of the barrier, lifting and moving it laterally underneath the machine – typically by one lane width (but from anywhere from 4 – 18 feet, depending upon the machine's configuration) – before lowering it back onto

Table 1: A digest of the responses to a survey conducted by the author towards the end of 2000.

Location	Application	Length of Barrier	Comments
Auckland Harbour Bridge, Auckland	Reversible lane	1.4 miles	Elimination of crossover head-on accidents.
Coronado Bridge, San Diego	Reversible lane	1.6 miles	Elimination of crossover head-on accidents.
East RL Thornton Freeway, Dallas	Contraflow HOV lane	5.2 miles	HOV lane users save 9 minutes in the morning and 4.5 minutes in the evening. The HOV lane carries double the person carrying capacity of a freeway main lane. Bus passenger volumes increased by 38%. Car pools increased by 300%.
Golden Gate Bridge, San Fransisco	At the time of the survey this application had just received authorisation.		
H-1, Hawaii	Contraflow HOV lane	9.5 miles	Reduced travel time (by up to 25 minutes/day). Increased bus patronage.
I-93, Boston	Contraflow HOV lane	6.2 miles	10 – 15 minute time savings for HOV lane users. Improved conditions for general traffic. Decrease in pollutants.
PR 2, Puerto Rico	Reversible lane	2.3 miles	Installed for safety reasons (no median) and to provide flexible capacity.
PR 18, Puerto Rico	Reversible lane	2.5 miles	No space available to widen highway.
PR 22, Puerto Rico	Reversible lane	1.0 miles	No space available to widen highway.
PR 26, Puerto Rico	Reversible lane	1.2 miles	No space available to widen highway.
Río Nitrio Bridge, Brazil			System planned.
Sydney Harbour Bridge, Sydney			System planned.
Tappan Zee Bridge, New York	Reversible lane	3.5 miles	Changes direction of the centre lane. Reduced peak commute congestion and improve efficiency of toll collection.
Theodore Roosevelt Bridge, Washington DC	Reversible lane		No information.



Using an automatic guidance system, the machine can travel at speeds of up to 5 miles per hour.



Typical permanent applications of this technology are the provision of a reversible lane. Most usually, the barriers are moved twice a day during weekdays. The barrier on the East R L Thornton Freeway in Dallas is moved four times a day.

the pavement. Using an automatic guidance system, the machine can travel at speeds of up to 5 miles per hour, allowing it to move a mile of barrier in just over 10 minutes. Rather ingeniously, while the transfer is taking place the machine is protected from surrounding traffic by the barrier itself.

Typical uses for moveable barrier technology can be divided into two categories: temporary and permanent. Although permanent applications are the focus of this article (summarised in Table 1) it is worth making some comment about important applications falling into the 'temporary' category.

TEMPORARY APPLICATIONS

Temporary applications of moveable barrier technology generally result from a need to undertake maintenance, repair or construction work on busy highways while:

- ensuring the safety of motorists and construction area personnel;
- minimising the impact of construction-related disruption to traffic flows;
- promoting quick and efficient working practices in a commonly confined workspace.

This is particularly critical in the case of night-time works adjacent to heavy, fast-moving traffic streams, where positive separation techniques are warranted. One key advantage of a moveable barrier is that it allows the active work area to be expanded or reshaped quickly. This, in turn, allows maintenance engineers to revisit and revise their staging plans – a key consideration when lane closure restrictions apply or for contractors incentivised to minimise the duration/impact of works.

Examples of the type of works completed with the help of a moveable barrier include highway reconstruction, paving and resurfacing work, road widening, median and shoulder construction/reconstruction, and repairs to tunnels and bridges.

PERMANENT APPLICATIONS

Towards the end of 2000, the author conducted a review of permanent installations of moveable barriers around the world. Detailed questionnaires were sent to 11 highway authorities (in the USA, Brazil, Australia and New Zealand) identified as those that had adopted the technology or were considering its adoption. Valid (ie. completed) responses were received in connection with 10 applications – see Table 1. Because of space constraints, a selected digest of those responses is presented here. Full results are available from the author.

The typical permanent applications were the provision of a reversible lane (or lanes), or with-flow/contra-flow HOV facilities. Fifty percent were located on heavily trafficked, high capacity expressways; the other fifty percent on bridges (all of which acted as 'choke points' in their network). The bridges in particular represented engineering challenges in terms of the consistent, accurate placement of the barrier. Many of them involved transitions in both vertical and horizontal alignment.

Most usually, the barriers are moved twice a day during weekdays. The barrier on the East R L Thornton Freeway in Dallas, however, is moved four times a day.

Various reasons were given for the adoption of moveable barrier technology. In all cases, a full engineering/cost comparison of this technology with alternative solutions was undertaken. Unsurprisingly, lane reversibility (for the purpose of congestion relief) is the key feature although in a number of cases the moveable barrier was installed where previously no median separated opposing traffic flows. Without exception, in the latter case, this had beem done to eliminate crossover, head-on accidents which had resulted in fatalities. Segregation of roadspace for the provision of HOV lanes was the motivating driver in three applications. In addition, a number of respondents pointed to the fact that a moveable barrier solution could be implemented within a fraction of the time required by alternative engineering solutions, talking in terms of months rather than years (including environmental approval). The average purchase cost of a transport and transfer machine was reported to be $650,000; costs lying in the range $500,000 - $875,000, depending on exact specification. Annual operations and maintenance (O&M) costs were the same order-of-magnitude and as most O&M functions were contracted out, these represented full costs (with few lost or hidden elements). The barrier cost around $500 for a 1-meter block, which would give a total of approximately $800,000/mile. A number of the survey respondents put those costs in the context of the costs of some of the alternatives that they had considered and/or the magnitude of the benefits delivered. Benefit to cost ratios for the applications in Boston and Dallas were 2.2:1 and 6.5:1 respectively.

Towards the end of the questionnaire, respondents were asked what advice they would give to other authorities facing some of the challenges that had led them to a moveable barrier solution. A sample of replies is given below:

- *'Carefully assess all the complex and extensive aspects associated with the installation of a moveable barrier system.' 'Consult other authorities who are already using the technology and visit those sites or at least one site.' 'Be aware of the necessary and essential associated expenditure over and above the barrier and machine costs eg. garaging, possible bridge strengthening, lane remarking, new signs etc.'*

- *'Spend the time to visit, observe, gather data and information, and talk with current Transportation Department officials that have implemented and operate these systems. I believe the practical information and the background experience that they offer on design and operation is invaluable when trying to implement this type of system. When applied correctly, it can be a great traffic and safety enhancement.'*

- *'It's very good, but don't get sucked into thinking that you can solve everything with moveable barrier technology.'*

- *'Use it as a short – medium term solution.'*

CONCLUSIONS

Over recent years it has become trendy within sections of our profession to dismiss, out of court, any mention of supply side solutions to the problems that drivers experience on modern highways. While empathising with many of the underlying reasons for this, the author would caution against such an extreme stance. Moveable barrier technology is expensive and may enjoy only limited application, but it remains another instrument in the traffic engineer's toolkit and, in those situations where it is employed, there may be few practical alternatives.

The appropriateness of the technology relies heavily on unbalanced travel demand. In many cities this is changing and traffic growth is most pronounced in counter-peak directions. This supports the comment from the respondent cited above, that such solutions may have a finite shelf-life. That said, the cost/benefit argument can be won by moveable barrier technology and it is interesting to note, in closing, that each and every respondent to survey described here had identified other specific applications for the technology and was actively pursuing them.

Below: East R L Thornton Freeway in Dallas,Texas. Inset: The transport and transfer machine at work on the Southeast Expressway, Boston.

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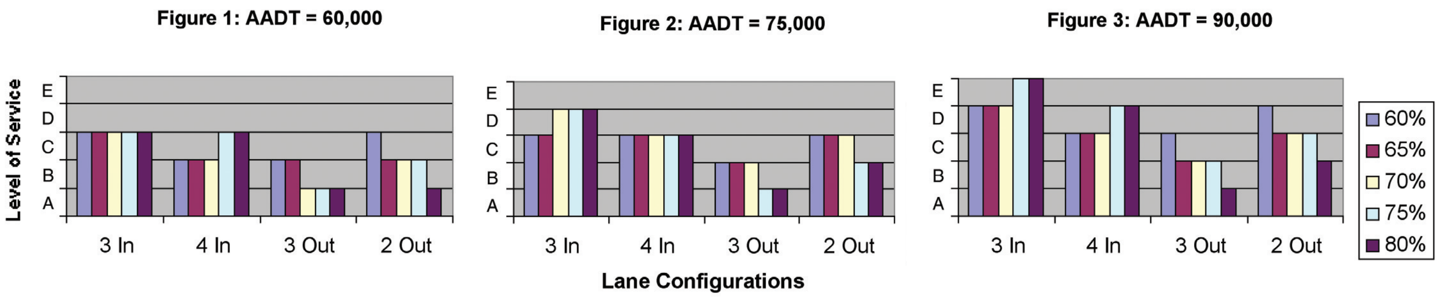

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Free lunch, anyone?

Under what circumstances, if any, would it be possible to abstract a counter-peak lane and 'donate' it to the peak direction without degrading the level of service enjoyed by drivers travelling counter peak? Now this would be a win-win situation (a 'free lunch', if you like).

To answer the question the Highway Capacity Manual - or rather, Highway Capacity Software (HCS)* – was used. What follows is a simplified set of (30) scenarios used for illustrative purposes only. The author does not profess to have conducted a rigorous analysis although the techniques reported here could easily be extended and/or tailored to better reflect specific highway supply and demand characteristics.

The following assumptions were made:

- A six-lane divided highway, a principal radial feeder running into an urban area, was modelled. On this highway it is possible to move a long concrete median laterally, to change from a 3:3 configuration to a 4:2 alternative (4 lanes being provided as required in the peak direction).
- Three levels of demand (AADTs) were compared: 60,000, 75,000 and 90,000 vehicles/day.
- The average AM peak hour was modelled.
- The proportion of the AADT observed in the peak hour (K) was assumed to be 0.07.
- The percentage of traffic travelling in the peak direction (D) was assumed to be 70%. Sensitivity analyses considered different degrees of tidality: 60%, 65%, 75% and 80%.
- The highway was modelled as a limited access 'freeway' (the only option in HCS allowing four lanes to be tested).
- The level of service for a freeway is derived from vehicular density - ie. passenger cars per mile (or kilometre) per lane.
- All other parameters employed were HCS defaults.

The results are summarised in Figures 1, 2 and 3 above. The alternative lane configurations are presented along the horizontal axis (ie. 3 lanes inbound becomes 4 lanes inbound; 3 lanes outbound becomes 2 lanes outbound) and, for each configuration the five degrees of tidality are shown. The resulting level of service can be read from the vertical axis.

Of the 30 scenarios tested, the 'free lunch' was observed in one only (see Figure 1). At 60,000 vehicles/day, with a D of 65% (ie. 65% of total flow travelling inbound; 35% outbound), moving from three to four lanes inbound saw an improvement in the level of service from C to B, whereas counter-peak drivers experienced no change in their level of service (remaining at B). In all of the other scenarios an improved peak-direction level of service was accompanied by a degraded level of service in the counter-peak. Some comments are worth making at this stage:

1. Levels of service are discrete indicators whereas the driving environment moves continuously between congested and free-flow conditions. Thus the driving environment may deteriorate but if that deterioration is insufficient to cross specific threshold values, the reported level of service will remain unchanged.
2. For many practical purposes, level of service C is regarded as being acceptable to design engineers and network managers. Thus an improvement in the peak direction level of service from D to C accompanied by a deterioration in the counter-peak from B to C may still, depending upon circumstance, fulfil a highway agency's objectives.
3. The number of drivers experiencing the benefit (eg. from D to C) will, because of tidality, exceed those experiencing disbenefits (from B to C) – from the example given above, in the ratio 65:35.

This simple illustration highlights the 'trade-off' nature of a moveable barrier. The trade-off may be worth making, but there is no free lunch!

* HCS is developed and maintained by McTrans at the University of Florida. It incorporates procedures documented in the US Transportation Research Board's Highway Capacity Manual.

Robert Bain is a PhD research student at ITS Leeds. Robert can be contacted at: rbain@its.leeds.ac.uk