Traffic congestion has become a serious problem for many cities around the world. In the United States alone, almost five billion hours are lost to congestion each year at an annual cost of US$115 billion. The challenge for 21st century highway engineers is to utilize cost-effective methods and technologies in order to meet increasing roadway demand.

Current congestion mitigation approaches can generally be divided into two categories. The first is the addition of capacity with major construction by adding new roadways or by increasing the size of existing roadways either outward with widening, upward in elevated structures, or downward in tunnels. These approaches require the dedication of substantial time and resources.

The second category is focused on utilizing the existing roadway capacity more efficiently, with little or no additional construction. This includes improving construction work zone traffic management, increasing Bus Rapid Transit use, implementing ITS strategies, encouraging ride sharing and tele-commuting, and implementing managed lanes. These concepts are growing in popularity as many countries search for alternatives to expensive new construction.

Moveable barrier technology is used for managed lanes and construction applications to create “Safe, Dynamic Highways” that offer real-time roadway reconfiguration while maintaining positive barrier protection between lanes. For managed lane facilities, moveable barrier is used in areas where there is a tidal traffic flow to redistribute unused capacity from the off-peak traffic direction to give more lanes to peak traffic. For construction applications, moveable barrier is used to expand the work zone to accelerate construction through the elimination of stages or entire construction seasons, while reducing congestion and increasing safety for workers and motorists.

Moveable barrier installations around the world report increases in both safety and capacity. Additional benefits include reduction of air pollutants, improved travel times, improved fuel efficiency, and faster system implementation compared to new construction.
Creating Safe, Dynamic Highways with Moveable Barrier Technology

1. Introduction

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2. Managed Lanes: Identifying Underutilized Capacity

Peak traffic flows can be divided into two general classifications: “Temporal Peak” flows and “Directional Peak” flows. In the case of Temporal Peak flows, the traffic on both sides of the road is a mirror image, both in and out of the city. Both sides of the highway reach peak traffic capacity in the mornings and evenings, with some reduced flows in midday and then further reduced flows later in the evening and in the early morning hours. With Directional Peak flows, the traffic in one direction, usually inbound to the city, will peak during the AM commute, while the opposite (outbound) direction will have relatively little traffic. For the PM commute, the case would be reversed (Figure 1).
In most cities the typical traffic pattern includes some roads with Temporal Traffic and some with Directional Traffic. Whenever the directionality of the peak direction traffic flow is substantial, there is usually a significant amount of underutilized capacity in the off-peak direction (Figure 2).

In these cases, Managed Lanes can redistribute the traffic to match the resources available. Managed Lanes can utilize many strategies, including HOV, HOT, Reversible Lanes, Contraflow Lanes, real-time road information, and congestion pricing to name a few, or any combination of these. Depending on the design phase, a Managed Lane facility can work safely with either moveable or fixed barriers. When a Managed Lane facility is designed from scratch, a fixed barrier can be used to separate lanes. In many cases where the Managed Lane concept is implemented on an existing highway to mitigate congestion, a moveable barrier system is the best approach.

3. **The Case for Positive Protection**

In some cases, a contraflow or reversible lane is put in place using delineator devices only (cones, pylons, overhead lights, etc.), but this has always had serious safety implications and usually results in head-on collisions and casualties.
On the Auckland Harbour Bridge in New Zealand, an adjustable lane configuration that relied on plastic delineation to separate traffic suffered five casualties from head-on, crossover accidents in a 10-year span before implementing positive protection between traffic directions. With the positive protection of moveable concrete barrier, there have been no crossover accidents in 22 years, and the facility still maintains the ability to reconfigure the roadway for peak traffic several times per day. Statistics show that the safe implementation of either Reversible Lanes or Contra-flow lanes requires a crashworthy positive separation barrier (Figure 3). Moveable barrier is often the best solution to add positive protection between lanes of oncoming traffic while allowing the road to be reconfigured in real time based on the needs of peak traffic.

Figure 3. Managed lanes using plastic delineation for separation

4. The Moveable Barrier System for Managed Lanes

Moveable barrier is a two-part system. The first part consists of one-meter sections of highly reinforced concrete that are pinned together at each end to form a continuous barrier wall. The barriers have a modified “T” top, which acts as a lifting surface for the transfer machine. The second part of the system is a Barrier Transfer Machine (BTM), which lifts the barrier and passes it through an inverted conveyor system, transferring the barrier from 8 to 24 feet (2.4 m to 7.3 m) in one pass. When necessary, the ends of the barrier are protected with a water-filled crash cushion that is also pinned together with a “T” top so that it can articulate through the transfer machine for seamless operation of the entire system (Figure 4).

Figure 4. The moveable barrier system includes a “T-Top” barrier and a BTM
5. Creating Managed Lanes with Moveable Barrier

There are two main types of Managed Lane facilities that can be created with moveable barrier: moveable medians and contraflow lanes.

**Moveable Medians**

The Moveable Median is most commonly applied to bridges and in other highway applications with few center structures. Viaducts or elevated structures also fit this model (Figure 5).

![Figure 5. Moveable medians use a single, flexible concrete barrier](image)

The moveable median is perhaps the most simple way of optimizing highway capacity. In this case, there is no fixed barrier on the highway, and the moveable barrier is the only barrier on the highway. The barrier is moved back and forth multiple times per day to reconfigure the roadway based on the needs of peak traffic.

**Contraflow Lanes**

There are cases where a single moveable median barrier is not practical. This may be because the two directions of the highway are on different elevations or structures, because there is a substantial existing median barrier, or because there are many center structures such as bridge piers and significant signposts, any of which would inhibit the movement of a moveable median system. In these cases, two moveable walls are used, one on each side of the roadway, in order to take or borrow a lane from the off-peak side of the road and allow traffic from the peak side of the road to utilize that lane, thus gaining additional capacity. This system provides the same optimization and efficiency as a moveable median but requires two separate walls to achieve the same results because of the geometric challenges (Figure 6).
In cases where the peak traffic is worse in either the morning or evening, the system may be installed in one direction only. This is the case in Hawaii on the H1 highway in Honolulu, where only an AM system is installed. In this situation, an equal number of vehicles enter the city in the morning and leave in the evening, however, the morning peak is much shorter in duration and more intense, while the evening peak is spread out over a wider time period and is therefore less congested.

6. Managed Lanes: The Dynamic Highway

While the general classification of “managed lanes” can be applied to many cases, (some with moveable barrier, some without barrier, even some with fixed barrier), there is one noteworthy case, now being implemented in Southern California, to which the operating agency has applied the name “Managed Lanes”. This system will be almost 50 Km long when completed.

In this case there are four reversible lanes in the center of a 12-lane highway. The four lane section is isolated from the main roadways by fixed barriers. In the center of that four-lane section is a moveable barrier. The typical alignments are 4+1/3+4, 4+2/2+4, and 4+3/1+4, thus providing five to seven lanes in each direction at different times of the day (Figure 7).

The center four lanes will be utilized as Public Transit (Bus Rapid Transit-BRT) Lanes, HOV Lanes and Tolled Lanes at different times during the day and in different combinations. In an emergency, it will be possible provide up to eight lanes in either direction, as required.

Figure 6. Contraflow Lanes take advantage of unused capacity in the off-peak direction

Figure 7. A “Dynamic Highway” in San Diego, CA
7. **Moveable Barrier for Work Zones**

A freeway with standard width lanes can handle a throughput of 1500 – 1700 vehicles per lane per hour before traffic flow is compromised and speeds decrease (Figure 8). A work zone that reduces the number of available lanes, or narrows the existing traffic lanes, has effectively reduced the number of vehicles per lane per hour that can pass through the work zone, and congestion will occur with a much lower vehicle count. To optimize the work zone for both mobility and safety requires a reassessment of best practices and a review of modern, innovative strategies for work zone safety and flexibility.

![Figure 8. Vehicle traffic flow is compromised above 1700 vehicles per lane per hour.](image)

In a construction work zone, there must be a balance between the number of lanes that are available for motorists and the space requirements of the contractor. Typically, this is addressed in one of three scenarios. First, to give the maximum number of lanes to traffic, the size of the work zone must be reduced. In this scenario, congestion is minimized, but the work zone is confined and inefficient. This creates a work zone environment that is prone to accidents, and it extends the construction schedule (Figure 9).

![Figure 9. Traffic is free-flowing, but the work zone is inefficient and confined.](image)

In the second scenario, the work zone is expanded. This allows for larger, more efficient equipment to accelerate the construction schedule, and more space means a safer work zone. The impact on traffic is seen as the number of vehicle lanes is now minimized, creating congestion and potentially increasing vehicle accident rates (Figure 10).

![Figure 10. The work zone is safe and efficient, but severe congestion and user delay costs will result.](image)
In these first two scenarios, the static, inflexible work zone is optimized for either the motoring public or the contractor, but it cannot be optimized for both. Fortunately, in either of these scenarios we can increase safety by separating vehicles and workers from each other with concrete barrier. This positive protection virtually eliminates vehicle encroachments into the work zone, which account for a large percentage of work zone fatalities. Positive barrier protection is a critical safety element, and agencies are often willing to sacrifice mobility and work zone efficiency for the safety of barrier separation.

The third scenario is the most efficient use of the roadway. In this case, the maximum number of lanes is made available to motorists during peak traffic hours, and the road is reconfigured to increase the size of the work zone during off-peak traffic hours. This allows the contractor to create dedicated haul lanes, use larger equipment, accelerate the construction schedule, and create a safer working environment, while maximizing mobility and vehicle throughput for traffic (Figure 11).

Figure 11. Traffic has more lanes during peak hours, and the work zone is expanded in the off-peak, but safety is compromised.

8. Optimizing for Both Work Zone Safety and Flexibility

Unfortunately, implementing a flexible divider between vehicle traffic and the construction work zone is traditionally accomplished by using plastic cones, barrels, and flexible delineators that offer no positive protection. Historically, road channelizers that can be reconfigured quickly enough to respond to the needs of peak traffic conditions must by definition lack the crashworthy physical attributes of positive protection. This is the essential tension between safety and mobility: work zone intrusion accidents must be eliminated if safety and mobility are to be optimized together.

One solution to this problem is moveable concrete barrier. Moveable barrier is a crashworthy lane separator that can be reconfigured in real time to give more lanes to peak traffic or expand the work zone during off-peak hours. Vehicle mobility is maximized without compromising the safety of positive protection.

9. Moveable Barrier for Work Zones

As with managed lanes, moveable barrier for construction is a two-part system consisting of the “T-Top” barrier and the BTM. The smaller size of the BTM results in a more
narrow transfer width, from 4 to 18 feet (1.2 m to 5.5 m) in one pass. Any exposed barrier ends are protected with a water-filled crash cushion that can articulate through the transfer machine for seamless operation of the entire system (Figure 12).

Figure 12. Moveable barrier is transferred under traffic to expand the work zone.

Benefits to safety and mobility can be realized during shoulder, median and partial closure construction.

Shoulder / Median Work

For shoulder and median work, the barrier can be stored at the edge of the road and moved out during off-peak traffic periods to increase the size of the work zone. The barrier is returned to the stored position during peak traffic periods to give the maximum number of lanes to traffic. The barrier can be moved many times per day to meet the needs of both construction crews and motorists (Figure 13).

Figure 13. Traffic has more lanes during peak hours, and the work zone is expanded in the off-peak.

Partial Closures

During partial closure construction, one side of the road is completely shut down for construction and all traffic is diverted to the other side. Moveable barrier is used as a “moveable median,” shifting multiple times per day to reconfigure the road to give more lanes to the peak traffic direction (Figure 14).
10. **Moveable Barrier for Work Zones: Case Studies**

The following case studies explain these concepts and the benefits derived from using moveable barrier in real world situations.

**Case Study #1: 3500 South, Salt Lake City, UT USA (Shoulder / Median Work)**

3500 South is a busy arterial in Salt Lake City, Utah. The first phase of the reconstruction called for two traffic lanes to be open for traffic in each direction, and plastic barrels were used to separate directional traffic and to delineate the work zone. The work zone area was confined and restricted, and it lacked positive protection, which created dangerous conditions as confused motorists occasionally turned into the work zone. For the second phase of the project, it was decided that a moveable barrier system would be used to create a larger work zone, while minimizing the impact on traffic and limiting left-hand turns. It was determined that moveable barrier could keep two lanes open to traffic in the peak direction by using a total of only three lanes, instead of the four lanes required when using barrels. This would give the contractor an extra lane to expand the work zone, keeping workers safe and accelerating construction. The barrier was moved multiple times daily to create a 1/2, 2/1 traffic pattern based on peak traffic needs.

The benefits of using moveable barrier included:

- Project was completed seven months early & saved one construction season
- Savings from early completion were estimated at US $1.3 to $1.4 million
- Reduced user delay costs
- US $1 million in crash cost reductions
- Total moveable barrier benefits were estimated at US $2.4 million
- Moveable barrier benefit/cost ratio of 4:1 to 10:1

**Case Study #2: Hollandsche Brug, A6, Netherlands**

On the Hollandsche Brug, heavy road maintenance impacted traffic and led to unacceptable user delays. During the last four months of the project, moveable barrier was deployed to accelerate the construction schedule and reduce user delay costs. The benefits of the moveable barrier system included:

- Construction schedule accelerated by five weeks
- 28,500 vehicle hours saved
- € 460,000 (US $655,270) saved in user delay costs
11. Summary

The many costs of congestion are rising around the world. Increased user delay costs, CO\textsubscript{2} emissions, extended construction schedules, and injury accidents and fatalities are all related to increased congestion.

For managed lane facilities, moveable barrier offers the unique option of being able to reclaim underutilized capacity and provide more lanes in the peak direction with little or no new construction. Using moveable medians and contraflow lanes with moveable barrier, agencies can solve their congestion problems for a fraction of the time and resources required by traditional construction methods.

For construction applications, moveable barrier is used to expand the work zone to accelerate construction through the elimination of stages or entire construction seasons, while reducing congestion and increasing safety for workers and motorists. Moveable barrier creates real savings in time-related overhead, project costs, user delay costs, and the costs associated with accidents and fatalities, while reducing harmful emissions created from work zone congestion.

References:


