High occupancy vehicle lanes – worldwide lessons for European practitioners

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Abstract

Europe has long provided bus lanes and on-street bus priority measures. High Occupancy Vehicle (HOV) programs expand that practice to include private shared-ride vehicles (carpools) and other priority vehicles. There are a few HOV lanes in operation in Europe, and interest is growing in their potential applicability in congested urban roadways. With over 200 HOV lane projects now in use on streets and highways around the world, there are useful lessons to be learned by those considering the HOV option in the European context.

The reasons for project successes and failures are outlined, with particular attention paid to the constraints and operational issues prevalent in the European environment. Critical issues such as enforcement, conversion from general purpose use, design, and underutilization are explored. The documented effectiveness of HOV facilities in influencing mode choice is summarized.

Finally, the future of HOV priority within the urban transport system is discussed, touching on high-tech enforcement solutions, HOV priority within tolled facilities, and the integration of HOV initiatives within broader Transportation Demand Management programmes.
Keywords: High Occupancy Vehicle, HOV, carpools, High Occupancy Toll, HOT, priority, Transportation Demand Management, TDM, 2+, 3+.

1 Introduction

High Occupancy Vehicle (HOV) lanes are lanes on streets and highways restricted to use by buses and multiple-occupant vehicles during all or part of the day. The aim is to provide HOVs with faster, more reliable travel than non-HOVs (primarily single occupant autos) during congested periods. This is intended to attract more travellers to bus and shared-ride travel rather than

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driving alone, thereby increasing the person-carrying capacity of the roadway, reducing per-capita emissions and energy consumption, and promoting a more sustainable urban transport situation.

Bus lanes aimed at improving the functionality and attractiveness of public transport are in common use in urban centres around the world. Many HOV lanes have begun as bus lanes or have bus priority as their primary goal. However, the HOV designation augments the public transport function and allows the priority measure to reach out to other forms of efficient shared-ride travel. This paper focuses on HOV lanes rather than bus-only lanes.

The presence of a significant number of carpools in the urban transport system, even in the absence of any direct incentive or priority measures, testifies to the significance of that mode. It is common for there to be more people travelling in private shared-ride vehicles than by public transport in an urban area, despite the attention and funding provided to structured public transport.

Many jurisdictions have therefore found a place for HOV lanes in the Transportation Demand Management component of their regional transportation plans.

HOV lanes have been implemented in a few places in Europe, but they are far more common elsewhere. Given that the reasons for considering HOV solutions are the same anywhere – skirting congestion, reducing emissions, drawing more people to public transport, reducing dependence on single-occupant auto use – there is good reason to add HOV lanes to the European urban transport planning toolkit.

2 HOV lane operational design criteria

An HOV lane is a relatively simple marketing device aimed at promoting HOV use, but it has to be properly planned, designed and operated to be effective.

The best potential HOV lane situations are found where:

- there is severe and recurring traffic congestion
- the HOV solution offers significant and reliable travel time savings (typically 5 minutes minimum, to overcome the inconvenience and time taken pick up a passenger)
- the HOV lane will carry at least as many people as the lane would if it were to operate under a general purpose designation
- the number of buses and cars using the HOV lane meets local thresholds of acceptability (avoiding the “empty lane” syndrome)
- implementation results in an improvement in the person-moving capacity of a roadway
- there is political, police, roadway agency, transport operator, and public support
- it is enforceable and a commitment to its enforcement is made
- it is cost-effective
- it is physically feasible to implement a safe, accessible facility.

International experience has demonstrated that HOV lanes which do not meet those criteria are at a high risk for sub-par effectiveness or outright failure (i.e. closure and conversion to general purpose use). While substantial public transport use is a major attribute, it is not necessarily a prerequisite for success.

HOV lanes therefore require thoughtful analysis on a case-by-case basis; there is no one "correct" design, and there are examples of successful application of almost every configuration and set of operating rules.

A connecting network of HOV lanes, or even better, the systematic and integrated development of a combination of HOV lanes, preferential parking for carpools, improved bus service, park and ride lots, employer-based incentives, and ridematching will strengthen the effectiveness of each element in the system.

3 HOV lane examples

HOV lanes are in operation in nearly a dozen countries around the world. There are over 4,000 lane km in use, spread among approximately 80 arterial projects and over 130 motorway applications.

While the U.S. has been the most active HOV lane proponent (primarily on motorways) dating back to their first application in 1969, arterial and motorway HOV applications have found some support in Europe, Canada, Australia, and elsewhere.

3.1 European examples

3.1.1 European motorway HOV lanes

There are few European examples of motorway HOV lanes from which to draw experience – Madrid, Amsterdam, and – currently under development – the M1 in the UK are the only projects to date. The fact that all three are of different designs demonstrates how difficult it is to generalize about HOV lane planning.

Figure 1: In Spain, Madrid's N-VI median reversible HOV lanes (left photo) have operated successfully since 1995 [1]. The N4 near Amsterdam (right photo) was a barrier-separated HOV 3+ facility that opened in 1993. It suffered from public criticism and was opened to general traffic in 1994 [2].

3.1.2 European arterial road HOV lanes

The principle of transit priority is well-established in cities across Europe. In recent years a few centres (Leeds, Bristol, Trondheim, Linz) have expanded on that concept to plan and implement HOV lanes on arterial roads.

Figure 2: The left photo shows UK's first HOV Lanes on A647, Leeds [3], and on the right is the HOV 3+ lane on Elgeseter Street, Trondheim, Norway [4].

Figure 3: In Linz, Austria, the sign on B127 (opened 1998) notes that "*This (bus) lane can also be used by (1) small cars with minimum 3 passengers and (2) livestock trucks*" [5].

3.2 International examples

3.2.1 International motorway HOV facilities

HOV lanes emerged in the U.S. in the early 1970s as a policy measure aimed at reducing fuel consumption. The concept has grown to become a key element in the Transportation Demand Management toolkit of most North America cities. In doing so, HOV strategy has gone on to tackle broader issues of personal mobility, air quality, and the impact of commuting on infrastructure needs, operational efficiency, and the environment.

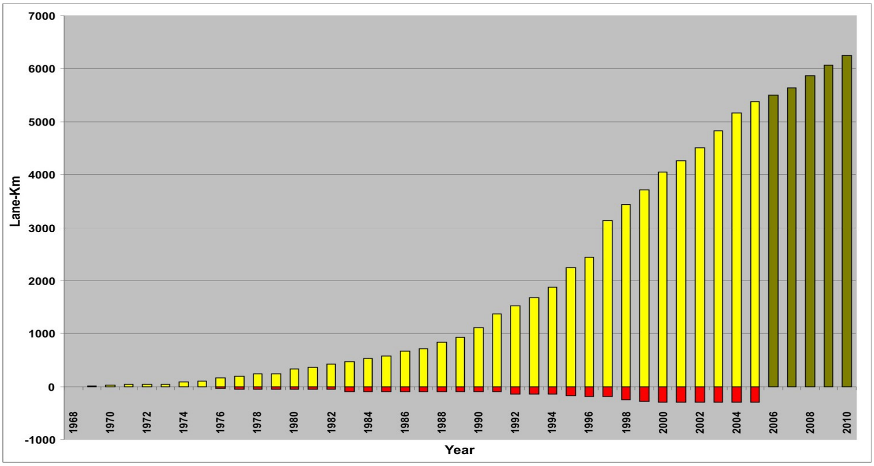

Figure 4: This graph demonstrates the steady and continuing growth in North American motorway HOV lanes (yellow). Despite a few projects garnering attention as high-profile "failures" (red) the vast majority of U.S. and Canadian HOV lanes continue to operate well and more are planned (green) [6]. HOV lanes have, in recent years, been implemented on Australian motorways as well.

North American HOV lanes have been implemented in every conceivable configuration:

- concurrent flow, contraflow, or reversible;
- new construction, widening, retrofit, or converted from other use;
- barrier-separated, painted buffer separation, or non-separated;
- solid or dashed lane separator line;
- median side or outside;
- peak period only or 24 hour per day operation;
- 2+, 3+, 4+, 6+, or bus-only use;
- direct HOV-only ramps and motorway-to-motorway links;
- limited or unlimited lane ingress / egress;
- short queue jumps and long corridors;
- free access or tolled; and
- with or without carpool parking lots, park & ride lots, on-line public transport stops / stations, and supporting programs.

The fact that all of the above variations are needed to meet particular corridor needs and opportunities demonstrates the flexibility of the HOV lane principle. In most cases, HOV lanes have had to be retrofit into congested, constrained situations as a "last-ditch" congestion management response. "Ideal" design standards have had to be compromised.

Given this experience, it is now common in North American to consider HOV lane needs and opportunities early in the planning and design stages, and to protect adequate cross section for future HOV lane implementation.

Figure 5: These photos from Toronto, Canada (left) [7] and Brisbane, Australia (right) [8] illustrate typical buffer-separated HOV lanes with designated areas for HOV lane access / egress, extensive signage, and a wide shoulder adjacent to the HOV lane for enforcement purposes.

Figure 6: This direct ramp in Los Angeles (left) allows HOVs to enter and leave the median HOV lanes without having to weave across congested general traffic lanes [9]. I-15 in San Diego (right) has a 13 kilometre long barrier-separated reversible two-lane core available to HOVs and for a price (which varies according to congestion levels) to non-HOV users [10]. Part of the toll revenue goes to enhancing I-15 bus service.

Figure 7: This photo illustrates a right-side HOV 3+ lane in Seattle, USA, that can be used by motorists for access to mid-block entrances [13].

3.2.2 International Arterial HOV Facilities

Arterial HOV lanes operate in close to eighty corridors worldwide.

Figure 8: A reversible HOV 2+ lane is used in Ottawa, Canada to maximize the person-carrying capacity of a three-lane bridge crossing [11].

Figure 9: HOV lanes are called "Transit Lanes" in Sydney, Australia (left) [12], and in Auckland, New Zealand (right) [15].

Figure 10: In Brisbane, Australia (as in several U.S. centres), HOVs are provided with bypass lanes at signal-controlled motorway entrance ramps [14].

4 Results

4.1 Successes

With a broad selection of HOV facilities in operation worldwide, it is relatively easy to highlight projects that have yielded positive results:

- N-VI, Madrid, Spain: Public transport mode share grew from 23.5% to 34.8% after implementation; single occupancy vehicle use on N-VI dropped from 70% of autos to 48% [16].
- I-5 in Portland, OR, US: HOV lane carries 33% more people than the adjacent non-HOV lane [17].
- Barnet-Hastings Highway, Vancouver BC, Canada: HOV lane triggered an increase in Average Vehicle Occupancy (AVO) from 1.22 to 1.35 persons per vehicle in the AM peak hour, thereby increasing the person-carrying capacity of the highway by 11% [18].
- Long Island Expressway, NY, US: After 6 months of operation, the HOV lanes produced an increase in AVO from 1.14 to 1.30 in the AM peak period, and from 1.24 to 1.42 in the PM peak [19].
- I-15, San Diego, CA, US: The first 6 years of HOV lane operation showed non-HOV person trips on I-15 increased by 17% while person trips in HOVs grew 109%. The AVO increased from 1.25 to 1.38 [20]
- San Francisco Bay Area, CA, US: 33% of carpool drivers changed from driving alone to carpooling in order to use HOV lanes. 6% changed route and 16% changed time. The rest had been carpooling already [21].

It is worth noting from the above results that there is no HOV project anywhere that has transformed thousands of single-occupant motorists into carpoolers and bus riders to the extent that traffic congestion is eliminated or even eased significantly.

Conversely, many facilities have had impacts far beyond their volume and travel time results. A large part of a “successful” project is how it fits within the regional transportation strategy and how other related initiatives can leverage increased benefits off the HOV facility’s presence. An employer-based Transportation Demand Management program or a community-based ridesharing initiative, for example, can be made much more attractive when there is an HOV facility in play. A physical, demonstrated public commitment to HOV infrastructure makes a powerful statement as to society’s priorities. This in turn can be a high-profile marketing tool for raising public awareness of transportation issues, options, and solutions.

4.2 Enforcement

International experience with enforcement of HOV lane operating rules can largely be characterized as “successful”, even though violation rates in some projects are unacceptably high. Since HOV lanes are always implemented in congested corridors, there is a natural tendency for motorists to want to use all available road capacity, balanced against the public's general adherence to reasonable rules.

The Los Angeles HOV system reports violation rates of less than 2% [22], while Houston's barrier-separated lanes have similar results. These project feature a combination of a commitment to enforcement, fine levels that are an effective deterrent (in California's case, close to $US300), and physical provisions (e.g. wide shoulders, buffers, barriers) that allow police to do their work safely and efficiently.

Arterial HOV lanes have been notably more difficult to enforce; violation rates of over 50% are common, largely due to the lack of the above enforcement tools (commitment, adequate fine levels, and physical provisions).

HOV lane enforcement to date has been entirely by manual means – police physically observing vehicles on the road, stopping non-compliant ones, and issuing a citation. Ticket-by-mail (i.e. observing a violator and sending a citation to the vehicle owner rather than stopping them in the field) has faced public and legal concerns over privacy and reliability.

The use of out-of-vehicle cameras has numerous concerns and inherent limitations but is just now coming into use in controlled environments (e.g. Forth Bridge, Scotland [23]). A more promising long-range solution lies in the integration of in-vehicle occupancy sensors (which most vehicles now have, as part of their air bag systems) with transponders and roadside reader / communications systems [24]. Widespread implementation of automated occupancy detection systems has the potential to transform HOV lane operations by eliminating violations, allowing targeted incentive programs, resolving arterial HOV lane enforcement issues, and creating toll buy-in opportunities.

4.3 Problems

Although there is a long list of problems that can be cited in the HOV lane field, only a few have proven to be significant enough to result in lane closure. Although there are project-specific problems that can be drawn from almost any HOV facility, they can be generalized as follows.

- Underutilisation: If the lane does not carry at least as many people during peak periods as it would as a general traffic lane, then it would be a better use of limited road space to allow the lane to be used by general traffic. If the lane appears to be under-used while general traffic experiences severe congestion, public concern will be aroused and pressure will mount on elected officials to open it to general use.
- Enforcement: If there are no provisions to allow enforcement to take place, and/or if there is an inadequate commitment by the enforcement agency to implement an effective enforcement program, and/or the penalties in place are an insufficient deterrent to HOV lane violators, the lane will attract an unacceptably high level of non-HOVs. This harms the operational integrity of the facility, but the more critical

problem is that it engenders public cynicism and lack of support for the HOV lane in particular and HOV programs in general.

- Safety: If the lane design does not adequately isolate HOVs from other vehicles (particularly in intermediate access / egress zones and at HOV lane terminus) and does not provide adequate breakdown areas, the facility is at higher risk of collisions, and operating speed and reliability will be compromised. Public perception may also be affected.
- Connectivity: A lane must be long enough to offer significant time savings to its users; in many places this requires linking segments of HOV lane together via costly HOV ramps. If the financial commitment to complete an effective network is not in place, all the component segments may not be effective enough on a standalone basis to be worthwhile.
- Jurisdictional Co-ordination: HOV projects require the long-term co-operation – and often joint funding – of many agencies and authorities that often do not otherwise work together. Without a mechanism to make effective use of the strengths and responsibilities of each partner, HOV facilities run the risk of being "orphans" with no single proponent or "champion" to lead the project through adverse situations.

It should be noted that most of the problems likely to face an HOV project are readily identified in the project planning stage. If problems are recognized and dealt with at that point, the project will be implemented with little risk of failure. The vast majority of HOV projects are successful once implemented. Furthermore, if problems arise after implementation, there are numerous operational tools available to a jurisdiction committed to maintain an HOV facility.

4.4 Lessons learned – European applicability

The first few HOV "pilot projects" on European streets and motorways have demonstrated that the principle of prioritizing certain "desirable" modes or classes of road traveller is as valid in Europe as elsewhere. The continued day-to-day operation of HOV facilities around the world further demonstrates the universality of the principles behind promoting the most efficient means (in terms of time, space, and cost) of urban travel.

HOV lanes are, however, inherently problematic from their very concept through to their day-to-day operation. Since HOV lanes are only applied (and are effective) in situations of severe recurring congestion, they are conceived as solutions to problems, not as aspirations in and of themselves. If the streets and motorways and public transport systems are all working well, then HOV lanes are not needed.

It is therefore necessary to carry out an informed debate among transport planners, public transport operators, elected officials, and motorist groups as to what the reasonable and realistic objectives of the regional transport plan are before settling on HOV lanes as potential elements in that plan.

Every HOV lane project must be chosen carefully – in many places where an HOV lane has "failed", it has been many years before that jurisdiction has attempted another such facility.

Expectations for HOV programs must be carefully managed. They are targeted corridor-level programs that are not likely to, on their own, have significant regional-scale impacts, nor will HOV lanes eliminate (or even reduce) chronic congestion. They do fit well, though, in a cultural environment of environmental responsibility, management and optimization of infrastructure and traffic operations, sustainability, and constraints on growth.

Where the HOV concept has proven particularly valuable has been in the creation of priority lanes benefiting public transport on roads where buses by themselves are not numerous or frequent enough to warrant a bus-only lane. Once the priority lane is established, bus service may then grow over time and the lane subsequently shifted to bus-only use (Toronto illustrates this process).

The use of dynamic and differentiated pricing schemes to manage traffic flow is rising in popularity, and HOV priority can readily be incorporated in such schemes.

5 The future

The heady predictions of the 1970s – fuelled by energy and pollution concerns – that HOV lanes would help carpooling and transit use to become a way of life for millions of commuters have been tempered by experience and realism. Energy use and air quality have been found to be more effectively tackled at the source through rules and tax regimes that influence all travellers. Motorists have been reluctant to give up their cars, while the massive auto industry continues in its dedication to making auto use as attractive as possible. Socio-demographic and economic trends have pushed urban commuters towards more, rather than less, auto use.

Nevertheless, the role of HOV facilities within a regional transportation strategy has come to be understood and their value, even despite inherent limitations, has meant that they continue to be operated and implemented around the world. In 2005, for example, the UK Minister for Transport, Alistair Darling, announced that the UK would trial HOV lanes on a segment of the M1, noting that "It works elsewhere and there is no reason why it can't work here as well." [25]. Ontario, Canada, implemented its first motorway HOV lanes in December 2005 after lengthy deliberation and examination of practice elsewhere.

European transport jurisdictions, in focusing on other aspects of the transportation system while North American and Australian centres implemented HOV projects, now have the advantage of being able to draw from others' experience in developing locally-relevant transport solutions and in avoiding the repetition of others' mistakes.

Trends in transportation technology are very supportive of HOV objectives – computerised ridematching, automated occupancy detection, ubiquitous transponder systems, reduced technology costs, better management of public transport vehicles, improved communications capacity, and greater ability to monitor traffic conditions and communicate that information to motorists will all come in to play in future HOV facilities. The most forward-thinking planners are incorporating or providing for these developments in new HOV projects.

One area where European practitioners may have an advantage over those in North America is in the ability to tie together workplace-based bus and ridesharing incentives (primarily related to the relative paucity of open space for free parking), a well-established systemic approach to priority for public transport vehicles and users, and a generally more "sympathetic" populace in terms of attitudes towards the natural environment and "green" transport initiatives. HOV facilities fit well within this context.

Another area of HOV focus in Europe may well be on arterials rather than motorways; with effective design and operating controls, bus lanes could be adapted to achieve broader goals without diminishing their transit priority function. Furthermore, HOV lanes can be a means by which transit priority can be established in situations where buses alone would not warrant the investment.

Continued evolution of motorways towards "managed" facilities appears inevitable, although the pace at which that will occur remains difficult to discern. There are already several HOT facilities in operation in the U.S. (San Diego, Los Angeles, Houston, Minneapolis).

A Managed Lanes project will be most viable and attractive as a two- or three-lane facility rather than as a single lane. Operation of a single HOV lane is governed by the slowest vehicle on it, and at least half of its capacity will be used by non-tolled HOVs, so a two-lane HOT facility is desirable in order to attract enough tolled traffic to both make the facility self-financing and to have a significant impact on general traffic conditions. The scenario then arises of adding one new lane per direction to a motorway but designating both that lane and one existing lane as Managed lanes, thereby creating an effective HOT facility without diminishing operating conditions for general traffic.

One concern with Managed Lanes is that HOV objectives – to promote use of public transport and ridesharing – may be subverted in the process. If, for example, the HOT lane becomes congested, will the policy be to tighten access for tolled vehicles and continue to promote HOVs, or will it be to "skim off" HOV 2+ vehicles in order to make room for more toll revenue? A successful (full) HOV lane has little potential to accommodate tolled vehicles, but others will argue that the HOV program should continue to push towards more efficient 3+ occupant vehicles and buses in any case (by including two-occupant vehicles in the "tolled" group rather than in the "HOV" group).

Another option, of course, is to apply pricing mechanisms and controls directly to all vehicles so as to manage traffic throughout the road network.

So it may be that HOV lanes per se are already passé, and that their greatest potential will be realized in the future as Managed lanes, in which HOV-related objectives can be realised along with more substantial mobility achievements. The key is to use the best available techniques now, while preserving the ability to manage the future evolution of that 4 m wide strip of asphalt into a piece of infrastructure that achieves its maximum functional potential within the urban transportation system.

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