Flexible Carpooling: Challenging the Ride Matching Paradigm. Saving Energy by Making it Easier to Share Rides

5  Corresponding Author
Paul Minett,
Co-Founder and Managing Director
Trip Convergence Ltd
PO Box 42
Albany Village
Auckland, New Zealand
Phone: +64 9 412 7452
Fax: +64 9 412 7472
E-mail: paulminett@tripconvergence.co.nz
Website: www.flexiblecarpooling.org

15  John Pearce
Co-Founder and Director
Trip Convergence Ltd
20  276A Victoria Street, Remuera
Auckland, New Zealand 1050
Phone/Fax: +64 9 520 3900
E-mail: johnpearce@tripconvergence.co.nz

25  Abstract
Transportation plays a significant role in energy consumption, accounting for over 42% of New Zealand’s total energy use. In the recent update of New Zealand’s energy strategy, initiatives to increase average vehicle occupancy in the private vehicle fleet were dropped. Significant beneficial adjustments would be required to all planning assumptions if commuters could be encouraged to share more rides. Flexible carpooling (known both as ‘casual carpooling’ and ‘slugging’) has been found to have a very significant impact in two US cities. This paper examines flexible carpooling, considers the reasons for its success, and calculates its energy impact in San Francisco. It explores why a mode of transport that uses less energy than alternative bus services has not spread to more cities. It proposes adaptations that could be tested to deliver commuter transport at lower energy consumption than bus services and that would complement passenger transport during peak commute hours. It suggests that Auckland’s new North Shore Busway would be an ideal location to test these adaptations and estimates the energy savings that are available. It outlines policy implications resulting from the work.

Key Words: carpooling; commuting; transportation
1. The transportation sector is a significant user of energy, much of it in the operation of single occupant vehicles. Policies and strategies that focused on improving average vehicle occupancy have been dropped from New Zealand’s energy strategy.

The Energy Efficiency and Conservation Authority, on its website, shows that the transport sector consumes more energy than any other sector, representing 42 percent of New Zealand’s total energy use (EECA 2008). See Figure 1.

![Figure 1: New Zealand Energy Consumption. Source: (EECA 2008)](image)

Transport is also the fastest growing sector in terms of energy use, with its growth often outstripping the growth rate of the Gross Domestic Product (GDP). Land transport (road and rail) represents around 90 percent of total energy use in the transport sector. Private motor vehicles account for almost 90 percent of total passenger transport energy use. (EECA, 2008). According to the New Zealand Energy Strategy to 2050, New Zealand oil imports cost $4.4 billion per annum (Ministry of Economic Development, 2007).

The National Energy Efficiency and Conservation Strategy, launched in 2001, identified increasing vehicle occupancy rates, along with public transport, cycling, and walking, as a means of reducing energy use and CO₂ emissions from transport (EECA, 2001).

When the strategy was revised in 2007 (now the New Zealand Energy Efficiency and Conservation Strategy), along with the development of the New Zealand Energy Strategy to 2050, increasing vehicle occupancy as a policy alternative had been dropped (New Zealand Government, 2007, Ministry of Economic Development, 2007), notwithstanding at least one submission to the contrary (EECA 2007).

The main strategies in the NZES for reducing transport energy use are the development of alternative fuels (including bio-fuels and electric cars), increasing LPG use, exploring hydrogen cells, and improving energy economy standards of cars (Ministry of Economic Development, 2007). These are essentially institutional strategies with long implementation timeframes. While these strategies could take years to deliver a tangible result, strategies to get more people in each vehicle, aimed at personal rather than institutional behaviour, could deliver an immediate and lasting gain.

The Auckland Regional Land Transport Strategy 2005 outlines plans to spend $11 billion over ten years in the proportions shown in Figure 2 (Auckland Regional Council, 2005). 4%, or about $380 million was allocated to ‘travel demand management’, and only 4.2% of that amount (or about one fifteenth of one percent (0.015%) of the total
spend) is allocated to strategies to increase vehicle occupancy on the journey to and from work (the time of most serious traffic congestion) (ARTA, 2006).

The draft 2008/9 Land Transport Plan for Auckland, published by the Auckland Regional Transportation Authority (ARTA), showed the priorities for budgeting for the following period to be:

1. Make the best use of the existing transport system, and
2. Manage travel demand (ARTA, 2008)

In spite of these being the priorities, the budget for ‘system use’, (the travel demand management activities that would deliver to these priorities), was reduced compared with the budget for the previous year by about 10%, and for the budget year is planned at about 2.5% of total expenditure rather than the 4% in the long term plan (ARTA, 2008, Auckland Regional Council, 2005).

It is difficult to access the rationale for omission of strategies to increase average vehicle occupancy. Conversations with transportation officials seem to suggest it is due either to an ‘anti-car’ theology (that says any initiative that supports car use is ‘bad’), or it is from a belief that the benefits to be gained are not worth the effort, (based on experience of previous failed initiatives to increase vehicle occupancy), or a combination of the two.

The main premise of this paper is that strategies to increase average vehicle occupancy can be successful and should be front and centre of transport and energy planning. Assumptions of average vehicle occupancy are critical in forecasts of energy demand, and even a small increase in the average could result in substantial beneficial adjustments to most plans in terms of energy use, carbon footprint, and infrastructure and service provision expectations.

The main reason that we are promoting this view is that we have identified a carpooling system that is incredibly successful and durable by most standards. This system operates at lower energy cost per passenger kilometer than a public transport alternative. In addition to lower energy costs, because the system uses existing infrastructure, the capital and operating cost of the system, (for all practical purposes), is nil. We believe that with appropriate modifications the system can be replicated in other centres with a
significant increase in average vehicle occupancy, at very low cost, in a way that is supportive of public transport.

Figure 3 shows the kilometers saved per year in Houston TX, San Francisco CA, and Washington DC, compared with two case studies used to demonstrate recent success in the UK.

![Annual Impact of Carpooling Schemes](image)

**Figure 3: Comparative impact of different case study carpooling systems, normalized for a consistent travel distance. The bubbles are accurate representations of the relative success of each system. There is no horizontal scale.**

Sources: (Cairns et al, 2004; Burris and Winn, 2006; Beroldo, 1999; VHB, 2006).

2. **During the energy crisis of the 1970’s carpooling was seen as a way of reducing transportation energy consumption. However after almost a decade, the conclusion about carpooling was that it would never amount to a very large proportion of the overall solution**

Carpooling, also known in the UK as car-sharing, involves people sharing rides in each other’s cars. In its traditional form the ‘carpool’ is usually an ongoing arrangement between two, three or four people to share rides on a regular basis for a particular purpose, often for traveling to work. People are careful about with whom they will carpool, and matching processes involve finding a person with matching schedules and routes and also matching tastes in radio stations, and potentially a wide range of other criteria. The paradigm that is usually associated with the word ‘carpool’ includes ‘turn about’ driving (each person often taking a week in turn) or sharing of costs, the relatively permanent relationship between the two, three, or four people, and the (inflexible) need to be ready at the agreed time to ride with the carpool regardless of what else is happening.

As explained by Cairns et al (2004) fuel price rises and fuel shortages in the early and mid 1970s led to policy interest in carpooling, which in turn led to initiation of a number of different approaches, and in the USA even legislation requiring the encouragement of the practice. However by the end of the decade the results that were being reported concluded that success was limited and complex. In the UK carpooling schemes were considered unlikely to have more than a marginal effect on congestion,
parking requirements or energy use. In the US a similar conclusion was reached that unless a list of conditions existed including HOV lanes, reserved parking, poor public transport, higher prices for fuel, and efficient management of the scheme including strong promotion by employers, carpooling would only ever be marginal. Interest waned, particularly as fuel prices declined in real terms (Cairns et al, 2004).

In spite of these conclusions there has been ongoing interest in carpooling, and the development and refinement of ‘schemes’ to enable greater uptake. In their comprehensive review of UK ‘car-sharing’ Cairns et al (2004) surveyed ten schemes that had been running between 4 months and ten years. They highlighted case studies of two such schemes, Buckinghamshire and Milton Keynes, with estimated daily participant counts of 60 and 1080 respectively. These are schemes that involve ride-matching on the internet, promoted at work sites. Their findings were that the Government should provide:

- more national guidance (for example for local transport plans) about car sharing, including appropriate parking regimes and other complementary measures that can be put in place to ensure that it forms part of the general sustainable transport package, and
- advertising, particularly to businesses, about the benefits of car sharing in association with other publicity and marketing about workplace travel plans, or as part of more general travel awareness work (Cairns et al, 2004).

In the US there have been significant efforts to encourage employees to take alternatives to driving alone. Most large employers (over 100 staff) are required to have a Commute Trip Reduction program. Many states offer web based ride-matching software, and from time to time offer incentives to encourage uptake. An example from a recent news article from New Jersey related rising fuel prices and payment of cash incentives ($100 to carpool for 24 of 60 days, and a further $100 for sticking with it for six months) to an increase in the number of people carpooling (Smith 2008).

We have developed the model shown in Figure 4 to provide a framework for discussion about transport options. In the model the mode choice continuum from left to right reflects increasing capital costs per mode, and generally reducing flexibility for the individual. The break-out of types of carpooling reflects the key distinction we have identified between the hugely successful and the less successful forms of carpooling. This characteristic is user flexibility, or the extent to which the specific ride does not require to be pre-arranged before it occurs.
The carpooling mode in Figure 4 is divided into two components. The traditional carpool component involves arranging to be in a particular seat at a particular time, a condition that we refer to as the ‘straightjacket of traditional carpooling’. The schemes described by Cairns et al (2004) and Smith (2008) fit in the far right box of Figure 4, ride-matching on the internet, and in the second box from the right, workplace based, since many of them are promoted through workplaces. Workplace based carpooling also includes carpools set up through personal contact or bulletin boards in the workplace. Social network based ride matching, using affinity groups on the internet (such as FaceBook (Goloco), or MySpace) are a relatively recent development that we understand is working more for one-off trips than for the daily work commute. The availability of enabling technology is leading to increased interest in ‘high-tech hitchhiking’, in which GPS and mobile phone technology is used to find and arrange rides within a few minutes of the time they are needed.

The flexible component of the carpooling mode involves no prearrangement of the ride, and reflects an expectation that due to critical mass a ride (or riders) will be available. The hitchhiking box in Figure 4 needs no introduction. We categorize the systems in Houston, Washington DC, and the East Bay of San Francisco, generally known as either casual carpooling or slugging, (the topic of Section 3) as informal flexible carpooling. We refer to proposed new flexible carpooling systems (the topic of Section 4) that have more formalized features including membership, pre-screening, and participation record keeping as ‘formal flexible carpooling’.

We have shown flexible and traditional carpooling as two parts of a single mode, and divided all modes into two key groupings of ‘travel alone’ and ‘rideshare’. It may be equally useful to split carpooling into two modes, and alternatively group the modes according to the scheduling of the trip, as shown in Figure 5.

<table>
<thead>
<tr>
<th>Travel On Own Schedule</th>
<th>Travel on Others’ Schedule</th>
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<tbody>
<tr>
<td>Walk</td>
<td>Cycle</td>
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Figure 5: An alternative grouping of travel modes.

Carpooling systems have been studied several times over recent years (Cairns et al, 2004; Ab Rahman, 1993), and the studies generally conclude that while carpooling schemes can contribute to the array of modes available, it is very difficult to get them started, and they have only marginal impact. When informal flexible carpooling has been studied (slug-lines and casual carpooling (Burris and Winn, 2007; Beroldo, 1999; VDOT, 2006) we perceive that it has been approached more from the perspective of describing an anomaly than as a basis for trying to exploit it. The reasons for not seeking to exploit informal flexible carpooling are unclear, though there is some evidence that a preference for bus based or even traditional carpool based solutions might have had some influence. Hence conclusions that carpooling doesn’t work
appear to have been based only on analysis of systems that had poor performance, while the stellar alternatives may have been left out of the mix for philosophical reasons.

We believe that the current world and New Zealand situation with regard to the price and forward availability of energy calls for the systematic questioning of ‘sacred cows’ and ‘conventional thinking’.

In the balance of this paper we will explain informal flexible carpooling in greater detail, calculate its energy impact, and back up our heretical claim that it is more energy efficient than an alternative public transport system. We will outline modifications needed to introduce flexible carpooling into new locations and we will show how flexible carpooling could be implemented on Auckland’s North Shore Busway to save energy in New Zealand. In the concluding section we will outline policy implications resulting from our analysis.

3. Three examples of successful flexible carpooling persist from the 1970’s but seem to be overlooked by transport planners

In Washington DC, San Francisco CA, and Houston TX, there are examples of a completely different system, called casual carpooling or slugging, that achieve the same goal of reducing occupancy rates, but go about it without any of the pre-arrangement involved in the web based ride-matching systems. We refer to this system as informal flexible carpooling.

Participants in informal flexible carpooling do not make any prior arrangements as to which seat they will ride in, whether they will ride or drive, or even whether they will travel on any particular day.

It is as if there is a taxi stand for carpoolers. Cars drive up and people walk up and the front people get into the front car, and are driven to a pre-determined destination. The flexible carpools use high occupancy vehicle (HOV) lanes to achieve a fast and reliable trip, and also often avoid paying tolls or waiting at ramp meters. The current examples exist where there are HOV 3 requirements, meaning the driver and at least two passengers. (TRB, 2006; Burris and Winn, 2007; Beroldo, 1999; VDOT, 2006)

In the largest example, Washington DC, there are multiple pick-up points and multiple destinations, and the pick-up points average about 134 carpools daily. Each carpool is at least three participants, the driver plus at least two others. There are estimated to be 9,689 participants daily (VDOT 2006). There are 24 morning and 16 afternoon pick-up points listed on the website www.slug-lines.com (Slug-lines 2008). The morning pick-up points are generally inside commuter parking lots.

In the San Francisco example there are multiple (at least 15) pick-up points but only one destination, and the main pick up points average about 200 carpools daily. Each carpool is at least three participants. There are estimated to be between 8,000 and 10,000 participants daily (Beroldo, 1999). There are 22 morning pick-up points.

Casual carpool pickup point at Claremont and College in Oakland
listed on the website www.ridenow.org/carpool (Ridenow 2008).

In the Houston example there are three pick up points and a single destination. The pick-up points average 100 carpools daily. Each carpool is at least three participants. There are estimated to be 900 participants daily. About 50% of the participants are female (Burris and Winn, 2007).

Informal flexible carpooling is observed as being an egalitarian activity (TRB 2006). There is no limit on who may participate, however there are some accepted etiquettes in most locations. It is characterised as being free for the riders, and saving the drivers time, with the belief that this represents a fair trade.

It is important to note that while some official recognition exists, for example by setting aside “no-parking” morning pick-up points in Oakland and “no-parking” afternoon pick-up points in downtown San Francisco, these three systems developed without being part of a project or initiative of any transportation authority. In the literature there is some concern that informal flexible carpooling takes passengers from public transport, and that if it didn’t exist there would be fewer cars on the road (for example Beroldo, 1999).

This latter finding seems surprising, but it is supported by survey data from San Francisco that found that, if casual carpooling were not available, 87% of riders said they would otherwise be public transport passengers, and 46% of drivers would switch to the bus (Beroldo, 1999). Following these percentages it can be seen that a casual carpool pick-up point with 600 participants (200 carpools) would alternatively represent 128 single occupant cars and 440 bus passengers. Hence there are 72 more cars (from this location) with casual carpooling than there would be without it, (see Figure 6) or about 1080 more cars in total in San Francisco that there would be without casual carpooling (from all locations).

This data does two things. It confirms that successful carpooling takes passengers off the buses. It also creates a framework for comparison of the energy use of two alternative modes of transport.

Figure 6: Alternative Mode for Casual Carpoolers (note that 8% of riders would take other modes or stop commuting) (based on Beroldo, 1999)
Direct Energy Impact of Informal Flexible Carpooling

In order to compare the energy impact of casual carpooling in San Francisco, Figure 7 shows the energy consumption of
1. 200 casual carpools, and
2. 128 SOVs plus enough buses for 440 people

![Bar graph comparing energy consumption]

**Figure 7: Comparative Energy Consumption of Travel for 600 People.**

The bus and SOV combination uses 24% more energy than the casual carpool option.

The key assumptions are that
- three 55 seat buses are needed,
- they deadhead three times each in order to carry the full number of passengers,
- they use 15 MJ of energy per km. (Strickland 2008)
- The casual carpools use the HOV lane and travel at the average speed for the East Bay HOV lanes, 90 km per hour, while
- the SOVs travel in the East Bay mixed use lanes at 38.5 km per hour.
- Carpool travel in a combination of 10% hybrids (at 1.58 MJ per km) (Strickland 2008) and 90% internal combustion engines (at 2.73 MJ per km) (Strickland 2008).

It is the combination of slower travel in the mixed use lane for the SOVs (and therefore greater energy consumption (Barth and Boriboonsomsin, 2007)) and the deadhead travel for the buses that lead to the counterintuitive conclusion. (If the average energy consumption for the cars is greater the size of the difference declines, but does not disappear until the cars are using an average of 5.0 MJ per km).

As an aside at this point we consider the comparison between HOV cars and buses, and note that assuming they are traveling in the same traffic conditions, a 55 seat bus (consuming 15 MJ/km in free flowing traffic per Strickland 2008) would have to average at least 30% full all the time (including return journeys and shoulder services) to be as energy efficient as a 4 seat car (consuming 2.73 MJ/km in free flowing traffic per Strickland 2008) with 3 people in it, and 40% full all the time to be as energy efficient as the car with 4 people in it. If the bus in this comparison has a route to follow, picking up passengers in general traffic, and a deadhead trip back, while the HOV car is able to travel along an unconstrained HOV lane much of the way to the destination, it can...
easily be extrapolated that the HOV car would be a more energy efficient choice, with better overall service features (shorter waiting times, faster and more comfortable trip) under casual carpooling/slug line conditions.

**Indirect impact of informal flexible carpooling.**

The analysis thus far has not included the energy impact on the rest of the traffic resulting from the casual carpools operating in the HOV lane rather than some subset or multiple of those vehicles operating in the mixed use lanes. There is no question that there would be energy gains from this as well. We note that the calculation of these impacts is complex due to the large number of variables and are best carried out by expert modelers trained in the art. However in order to estimate an order of magnitude impact we present the following calculations which compare the energy use in the traffic flows with and without casual carpooling.

The key variables are the speed in the mixed use lanes with casual carpooling, and the speed of the mixed use lanes without casual carpooling, which in turn is driven by the proportion that the changed traffic has to the existing traffic. Energy impacts will be proportionally greater when the existing traffic speeds are low, resulting in high changes in consumption per unit distance.

We have constructed a simplified speed flow diagram (based on regression analysis of HOV lanes in the San Francisco Bay Area, Caltrans, (2004)), Figure 8, to enable an estimate of the impact. We assume that up to 1100 vehicles per lane per hour the traffic will run smoothly at an optimum speed. As the demand rises above 1100 vehicles per lane per hour the traffic speed will degrade, and we have used a constant rate of 12% speed change for each 100 vehicles added or removed per lane hour. We know that this will be incorrect at the boundaries, but are confident that the order of magnitude is accurate.

![Speed/Flow Diagram](image)

**Figure 8: Simplified Model of Speed vs Flow**

We have constructed a model of the impact on energy consumption of changing traffic speeds. Figure 9 is based on work by Barth and Boriboonsomsin (2007). As traffic moves at slower or higher speeds than the optimum of about 70 km per hour it consumes more energy per unit distance.
We have used the above assumptions and models to estimate the impact on energy use by the traffic in the mixed lanes of the San Francisco Bay Area:

- With existing casual carpooling, and
- If casual carpooling ceased to operate from all locations, with all riders and drivers reverting to an alternative mode in the proportions outlined above.

In other words, is energy being saved in San Francisco because of casual carpooling, and if so, how much?

We found that the 32,880 vehicles arriving at the Bay Bridge Toll Plaza in the mixed use lanes would **consume 35% more energy** as their speed (across the network of highways leading to the Bay Bridge) would be reduced from an existing average of 39.5 km per hour with casual carpooling to an average of 27 km per hour without casual carpooling. The difference in energy use is approximately 500,000 MJ per day. This difference would be greater if the average energy consumption for cars was greater, and also as congestion worsens.

Figure 10 shows the total energy impact of casual carpooling, combining the direct and indirect impacts. If casual carpooling didn’t exist the energy required to move the 9,000 people currently using casual carpooling would be 280% greater.

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1 The work done by Barth and Boriboonsomsin (2007) focused on the carbon impacts of traffic at different speeds. Boriboonsomsin (2008) confirmed that energy consumption and carbon dioxide emissions move in tandem. We converted their carbon dioxide findings into energy impacts to derive the chart.
Comparison of Casual Carpooling to the Public Transport Alternative

![Comparison Graph](image)

Figure 10: Comparing total daily energy use of 9,000 San Francisco casual carpoolers with the total energy use of the community if casual carpooling didn’t exist.

This analysis is at odds with a conclusion drawn by Beraldo (1999) that casual carpooling does little to improve congestion or air quality. And we observe that the system has been operating ever since the energy crisis of the mid 1970s while most other carpooling systems dwindled into obscurity, and it was not the result of any public institution initiative.

As an aside, we have also estimated the non-energy benefits of casual carpooling for San Francisco. In total, allowing for the value of time saved, energy saved, buses not purchased and operated, and bus drivers not paid, we estimate that casual carpooling is saving the San Francisco community at least $30 million per year. This does not include any value for the carbon footprint reduction that is also occurring.

We recognise that there might be some third order effects that we have not included in this analysis. Please see the note about these at the end of Section 5.

Why is Informal Flexible Carpooling not Widespread?

If casual carpooling/slugging is so good, why is it limited to three locations?

To our knowledge the above energy and other impacts have not previously been calculated. In studies of casual carpooling we have found that the investigators display a strong bias towards the public transport alternative, taking it as a given that public transport is superior to any form of car travel, and speculating that one of the benefits of casual carpooling could be that participants might go on to formal carpool arrangements (Beroldo, 1999) with the apparent belief that such arrangements would be superior.

According to Burris and Winn (2007) a major reason the system has not extended beyond the initial three cities is the perceived liability that public authorities could expose themselves to as a result of supporting a system where people share rides without sufficient pre-planning. Burris and Winn go on to say:
Casual carpooling has grown in popularity and should be considered when assessing potential corridor improvements. Although potential liability concerns would likely prevent agencies from actively promoting casual carpooling, they could encourage it passively by constructing park-and-ride HOV facilities that are conducive to the mode. Casual carpooling has the potential to improve the operation efficiency of HOV/HOT facilities by improving person movement. Although there are potential liability concerns, it may eventually become beneficial to promote casual carpooling as a viable mode alternative (Burris and Winn, 2007).

Perhaps the other reason for not expanding informal flexible carpooling is that most studies and reports conclude that it works due to a very special confluence of conditions, namely (from TRB, 2006):

- Significant travel time reduction and reliability gain for the driver through use of the HOV facility—enough to be worthwhile even subtracting out passenger pick-up and drop-off times.
- Need for additional riders to meet HOV access requirements (enhanced by a 3 or greater occupancy requirement).
- Well-known pickup locations having easy driver and rider access and offering good transit service available as backup for prospective riders.
- Very substantial employment concentration(s) as the focus for the morning commute, allowing quick and efficient passenger drop-off and dispersal to ultimate destinations.

We speculate that there must be other locations with all these conditions, but informal flexible carpooling has not started in those locations. Extensive searching to date has not found any evidence of a jurisdiction attempting to start informal flexible carpooling.

Our conclusion is that:

1. to date no-one has appreciated the potential benefits well enough to want to take the perceived risk of promoting flexible carpooling
2. the conventional wisdom that ‘a bus is better’ has blinded officials to the potential energy and other operational savings of the system
3. the findings of the research to date, that suggests the system can work only in very special conditions, has not encouraged transport planners to consider it as an alternative in other locations
4. concerns about liability might have played a part, though it appears unlikely that anyone has put effort into the alternative of finding out how to resolve liability concerns, probably for the reason in the first bullet above. We note that it is normal for liability to exist, and that it is usually mitigated by sound business processes and appropriate insurance.
5. the experience of relatively low uptake of other carpooling initiatives, especially ride-matching on the internet where many register but few achieve lasting ride sharing, has led to a ‘conventional wisdom’ among planners that the mode doesn’t work
6. because no organisation has ever ‘started’ an informal flexible carpooling system, there is no manual, no guidebook, no standard approach, and no generally agreed measure of success
7. because it was never approved as a project no benefit cost analysis needed to be carried out
8. transportation planning tends to devolve authority for all except very major capital projects out to the lowest possible levels of public authorities, where staff are given minimal authority to spend money or test risky new ideas
9. the vast majority of transportation funds are allocated to ‘big ticket’ services and projects controlled by either civil engineers who prefer building infrastructure, or public
transport operators who prefer to add bus or train services, and almost no money is allocated to solutions or research into solutions for alternatives to the ‘big two’ transportation plans are built from the bottom up, local project by local project, often not created or evaluated system wide across municipal boundaries, while any costs of a flexible carpooling system would be incurred in the suburban or exurban community, while the majority of the benefits would be felt by the regional transportation authority, the highway operator, and the destination city authority.

4. A replicable version of flexible carpooling could have significant impact where other forms of carpooling have failed.

Our review of the informal flexible carpooling literature has led us to the conclusion that the key reason for the systems’ success (especially when compared to traditional carpooling), is its flexibility, the fact that there is no need to make a prearrangement for the ride; the fact that participants can show up when they are ready, as a driver or a rider, and the fact that if sick or late, or needing to work late, the system doesn’t require any mitigating action. It is carpooling, but without the hassles.

Almost every report about informal flexible carpooling emphasizes somewhere that flexibility is a key reason that the system is used. For example: "In addition to saving time and money, flexibility was identified as one of the main reasons respondents casual carpool" (Beroldo, 1999) and "The slug line is a direct result of needing to find a system that gives you the flexibility that your working environment requires." (Kogan, 1997), and "Many saw casual carpooling as a winning option because it was flexible, fast, and free. Few had fears of riding with a stranger because they could choose to enter a car or wait for a different one, there were usually at least two unrelated riders in the car, and the experience with casual carpooling has been good for most." (Shirgaokar and Deakin, 2005). However in none of these reports have we found the investigator raising the observation to the level of a conclusion that might lead to design of a trial to emulate the flexibility of the system.

Our conclusion is that the investigators have either not recognised, or have chosen not to emphasise, that flexibility is the key to successful carpooling. We believe that with appropriate encouragement and enhancements flexible carpooling could easily become a substantial provider of transportation capacity in any number of locations, with and without HOV lanes.

We note that the website for the Washington DC slug-lines, www.slug-line.org (Slug-line 2008), has a page dedicated to helping people start a slug-line, however it is in the context of operating in a city where this is already a norm, and since it is clearly up to commuters themselves to take the initiative, we can see that there is not a high rate of new line formation.

Kelley (2007) suggests that casual carpooling could be implemented without the need for HOV lanes, using prescreening for safety, radio frequency identification (RFID) technology to track participation, internet based accounts for rewarding participation, and financial incentives in place of the HOV lanes. He explores the benefits of such a system and outlines a business case for paying carpoolers as an alternative to installing a new HOV lane. The operating and subsidy costs of this casual carpooling (if successful) would be less than the operating costs of the HOV lane, and the entire capital cost of the HOV lane would be avoided.

We propose several enhancements that should be considered and tested. Consistent with Kelley (2007) we believe technology can make it more feasible for pre-screening, membership identity,
record keeping, and transfer of financial benefits to or between participants. Consistent with Burris and Winn (2007) we believe that park and ride facilities should be constructed that enable the mode. In addition to these points, we believe that: branding and commercial style marketing should be used to build awareness and a consistent culture so that the system can spread; there should be a revenue stream from within the system to support these activities; different types of destinations should be tested such as universities and transit stations; and there should be destination end support for dedicated pick-up locations for the evening end of the system. Where HOV lanes exist they should be maximised, and switched to HOV 3 once the system enables greater numbers of people to share rides easily. (We note stories of HOV lanes being converted to mixed use because of being underused by HOV traffic in some centres).

While we believe that HOV lane access is important, we also believe that the system could work where such benefits do not exist. Our rationale for this, even without the financial incentives suggested by Kelley (2007), is that people already carpool where there are no HOV lanes, and they do it for the financial savings and other reasons. Significant additional numbers of people ‘would’ carpool, they just cannot do it inside the straightjacket that traditional carpooling systems would have them wear: the need to be in a particular seat at a particular time, and knowing that being late or absent will result in at least one or two other people being inconvenienced and perhaps angry.

We have outlined the enhancements that we believe are necessary to create a formalized flexible carpooling system. We cannot guarantee that these enhancements will be the exact changes required to enable uptake of the system, but we believe the significant energy gains on offer make it imperative that the system be enhanced and significant effort put into finding out how to make it work.

5. Auckland’s North Shore Busway is an ideal opportunity to test the concept.

Transit New Zealand (an owner and operator of state highways) has recently completed construction of a busway on Auckland’s North Shore. The original approval for the funding of the busway included a provision for 350 high occupancy vehicles per hour in addition to the buses.

The busway has opened, but the mechanisms have not yet been put in place to enable high occupancy vehicles to operate on it.

The busway runs parallel to a very busy and congested state highway. Average speeds of less than 30 km per hour are normal for this route during the morning peak period. It is expected that the fleet of buses that are operating on the busway will draw some people from the mixed use lanes and provide some relief.

We believe that this facility presents an ideal opportunity to test the concepts of formalized flexible carpooling, and for the benefit of other parts of Auckland, other regions of New Zealand, and the rest of the world, to help develop the protocols that could be used to enable the uptake of a more energy efficient mode of transport.

Our analysis suggests that there is a potential market for at least 1,500 flexible carpoolers who would park 1,000 cars in dedicated flexible carpool parking upstream from the busway, and drive 500 cars along the busway and over the Harbour Bridge into downtown Auckland, a weighted average distance of 18.7 km. Locations have been identified for pick-up and drop-off. Figure 11 shows that the 1,500 direct participants would save 76% of their current fuel consumption. (This is more than the expected two thirds because of the slow speed of the mixed use lanes the SOVs travel in).
Using the same methodology that we used for estimating the energy impact in San Francisco, above, we estimate that, between direct users and the rest of the traffic, savings in the order of 30% or 1 million litres of fuel per year are achievable for the morning traffic from Auckland’s North Shore, at current prices worth about $1.8 million. The time savings for the rest of the commuters (at $15 per hour) would add about $8 million to this number. Savings of a similar order are available from implementing the system for the return journey.

**Third order impacts**

“Reducing traffic counts on existing congested roads will attract more traffic”. “Create a space and it will fill up again”. These sentiments are expressed by some traffic planners as a case against action when flexible carpooling is proposed as a partial solution to traffic congestion.

We observe that commuters choose what they consider to be the most effective transport modes and routes from the options available to them. Commuters who switch to SOV use of the motorways when traffic flow improvements arise from the introduction of flexible carpooling on the busway may reduce the magnitude of benefits modeled above.

However this will create equivalent or greater benefits in other parts of the system not modeled. Indicative modeling of the Auckland traffic carried out by the Auckland Regional Council for Trip Convergence Ltd (ARC, 2005) showed a significant net benefit (in the order of $120 million per year) from a proposed introduction of flexible carpooling Auckland wide.

Another third order impact will be the long-run impact on parking. One objection to flexible carpooling is the cost of parking facilities proposed in or near suburbs or exurbs. We observe that parking at the journey origin will generally be more economically efficient (cheaper) than destination parking in the CBD. In the long run city centre (and other destination) parking would be converted to more valuable uses. In this case there might be a conflict of interest for city council parking departments as their revenue streams might be threatened. Clearly whole of system and system wide thinking is required.

6. **Energy, transport and environmental policy should seek to increase vehicle occupancy. In particular, flexible carpooling should have special encouragement.**
It appears to us that transportation planners and environmentalists universally believe that the world would be a better place if everyone took the bus.

This paper questions the conventional wisdom and finds that due to deadhead miles for buses and the relative speeds of traffic in the high occupancy vehicle lanes and the mixed use lanes, carpools with three people can lead to lower energy consumption in total, even if most of the carpoolers would otherwise be bus passengers.

Energy policy in New Zealand is now silent on strategies to increase average vehicle occupancy, though it includes strategies to increase use of public transport, as well as encouraging cycling and walking. At the same time roading networks and bus fleets are being sized (and invested in) to handle peak loads of low occupancy vehicles and public transport passengers. These peak loads could both be reduced if efforts to increase average vehicle occupancy were successful.

When energy prices rose in the early 1970s there was a policy response that called for increased carpooling. A variety of initiatives and schemes were introduced and measured, and most disappeared when energy prices subsequently fell. Evaluation of those initiatives and schemes suggested that carpooling, while beneficial, would only ever have a marginal impact on traffic.

The advent of the internet has given rise to new schemes using matching databases, and these have also been found to have marginal impact. All these initiatives and schemes have in common the requirement that a carpool ride be arranged in advance.

In three US cities a spontaneous system of informal flexible carpooling developed that did not include the pre-arrangement, and this system prevailed in two of those cities from the early 1970s till today. Perhaps because it was not an initiative or scheme of a public authority, but a system that grew of its own accord, it has been overlooked as a potential model for more successful carpooling.

Energy prices are again on the rise, and the specter of energy shortages also loom. Thus far carpooling has not been a part of the policy response, perhaps due to the conclusions from the studies at the end of the 1970s. This paper suggests that innovations and initiatives to raise average vehicle occupancy (including flexible carpooling) should be a significant part of the policy response.

The policy responses that we propose therefore include:

1. Researching to find ways to introduce (formal or informal) flexible carpooling into new locations
2. Increasing deployment of HOV lanes and other preferential treatment of high occupancy vehicles, to encourage carpooling
3. Raising high occupancy vehicle lane requirements to at least three persons per car
4. Increasing deployment of park and ride facilities for flexible carpooling
5. Extending the flexible carpooling concept into flexible vanpooling
6. Calling for an increase in the proportion of ‘full’ transport in peak times in urban areas and reduction of deadhead miles for public transport, working towards a ‘one way’ ‘full only’ transport system for commuters, including a mix of carpools, vanpools, and small buses, for the most energy and cost effective system possible
7. Considering the success of unplanned solutions such as flexible carpooling, giving more weight to encouraging rather than coercing, to incentivising rather than penalising, as a mechanism for encouraging system-wide improvements.
8. Redirecting urban planning to seek to contain sprawl. We might not be able to easily undo the sprawl that already exists, but that doesn’t mean the same set of rules should continue to be applied.
The above list of policy responses are relevant for most jurisdictions with congested traffic. In addition, for New Zealand we propose:

1. Use the North Shore busway as a test bed for implementation of flexible carpooling, giving participants the right to travel along the busway.

2. Rapid roll-out to other congested routes as soon as the system is working on the busway.

And for San Francisco we propose:

1. Put greater support behind the existing implementation and help it to grow by whatever means, with a particular focus on making it a two-way system.
References
Traveler Response to Transportation System Changes, Transportation Research Board, 2006,