Estimating the Energy Consumption Impact of Casual Carpooling

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ABSTRACT

Some of the transport energy consumed during peak commuter periods is wasted through slow running in congested traffic. Strategies to increase average vehicle occupancy (and reduce vehicle counts and congestion) could be expected to be at the forefront of energy conservation policies. Casual carpooling (also called 'slugging') is a system of carpooling without pre-arrangement. It operates in three US cities, and has been suggested in New Zealand as a strategy for managing transportation challenges when oil prices rise. The State of Washington will pilot a formalized version of the system during 2010. The objective of the paper is to find out if casual carpooling saves energy, and if so how much. New models are developed for thinking about the issues and making estimates. Energy consumption by single occupant vehicles; casual carpool vehicles; and a mix of buses and single occupant vehicles; are estimated and compared. The paper concludes that energy could be saved by encouraging systems that emulate casual carpooling and suggests that policy should encourage development of carpooling without pre-arrangement as a mechanism for saving energy.

Key Words: carpooling; casual carpooling; flexible carpooling; sustainable transport; transport demand management;

1. INTRODUCTION

1.1 Background

The transportation sector is a significant user of energy. Encouragement of carpooling[1] is one known strategy for reducing traffic that some suggest is second only to a driving ban in its potential for reducing energy use (*1*).

The authors' interest in traffic reduction had led them (in 2002) to hypothesize a high volume 'flexible' carpooling solution that, when it happens, will look like 'park and ride' but without the buses, using carpoolers' own vehicles instead, and leaving two thirds of the carpoolers' vehicles in suburban parking lots, and carpooling either for the full trip to the employment destination or as a feeder to transit services (see www.flexiblecarpooling.org). The key difference between the system the authors envisage and existing carpooling systems will be that the flexible carpooling system will involve no pre-arrangement of rides. It will operate to high volume destinations on routes that are attracting lots of single occupant vehicle (SOV) drivers, and people will form fuller cars in whatever order they arrive at a convergence-point meeting-place.

The authors had found that this approach resembles, to some extent, the casual carpooling systems which arose, apparently spontaneously, in Washington DC and in San Francisco, California, during the early 1970s, and had spread to Houston, Texas during the 1990s and which continue to operate successfully in all three cities.

The authors' approach also resembles, to some extent, the 'park and share' concept in use in Ireland, parts of the UK, the US, and Canada, where 'carpool parking' is provided as a meeting place for pre-arranged carpools.

The authors had proposed to the Auckland Regional Council (ARC) that ARC support the introduction flexible carpooling in Auckland, and ARC had estimated the impact on local congestion costs. The ARC used the Auckland Traffic Model, and used as inputs the origins and destinations of 5,000 SOVs that the authors predicted the system could take off the road (in 2,500 three person carpools). The output from the model had suggested significant energy savings, both for the participants and for the rest of the traffic (*2*).

While this paper was being prepared the authors had success convincing a jurisdiction to carry out a pilot project of the proposed flexible carpooling system, and during 2010 Seattle, WA, will test flexible carpooling. In addition, a feasibility study is underway funded by the Transit IDEA program of the Transportation Research Board, entitled "Flexible Carpooling to Transit Stations", developing a methodology for assessing the potential for such routes and developing an implementation proposal for one such route including estimates of the costs and benefits of such an implementation, but not including actual implementation
(see http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2697 .

1.2 Objective of Paper

The authors' objective in writing the paper was to find out if casual carpooling saves energy, and if so how much. This had not been done before, and the authors had found that many disputed their contention that this form of carpooling would save energy.

The authors expected to use standard modeling techniques that they supposed existed for estimating transport energy use. They found that there are no such standard techniques, or that those that exist are extremely complex and beyond the scope of what they could do. They therefore had to create some new models and suggest new ways of thinking about the issues at hand. The paper is therefore a collection of evidence and opinion and an estimate of the impact of casual carpooling on energy consumption using models developed for the paper. It reports the volume of activity in the casual systems in San Francisco, CA; Washington, DC; and Houston, TX; and the findings of the ARC modeling, and suggests that an adaptation of casual carpooling should become part of the formal transportation system as a means of reducing energy consumption.

1.3 Outline

Section 2 reviews the literature about casual carpooling. Section 3 uses new models to estimate the energy impacts of casual carpooling. Section 4 draws conclusions and Section 5 suggests policy implications.

2. CASUAL CARPOOLING LITERATURE AND RESEARCH

A carpool is usually an ongoing arrangement amongst a group of individuals to regularly share rides for a particular purpose, often for traveling to work, using a car belonging to the driver. Carpooling systems typically involve 'turn about' driving (each person taking a week in turn, for example), or sharing of costs. Establishing a carpool involves finding people with matching schedules and routes. Other criteria may also be considered, such as matching tastes in radio stations. There is a relatively long term relationship between members of the carpool, which may involve two, three, or four people. Members must be ready at the agreed time and place to ride with the carpool, regardless of what else is happening.

A casual carpool retains the feature of shared rides, but is very different in the way it is created. Casual carpooling systems (operating only in San Francisco CA, Washington DC, and Houston TX, and called 'slug lines' in the latter two locations) are based around morning pick-up points. Riders queue at these pick-up points, as if they are waiting at a taxi stand. Drivers pick up the appropriate number of riders and drive to the pre-determined destination. Many of the pick-up points are located in commuter parking lots. Pick-up points and destinations are 'local knowledge', also accessible on the websites for each of the systems. When multiple destinations are served from a single pick-up point, drivers might call out their destination and the person at the front of the line will repeat it loudly for the rest of the line to hear.

Participants make no 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 or at any particular time. This system has been described (often as 'amazing' and 'a phenomenon') in many newspaper and magazine articles over the years (for recent examples see (*3*), (*4*) and (*5*)).

Access to HOV lanes provides carpoolers with a faster journey, with less risk of delay, than SOVs. In the three casual carpooling examples (San Francisco, Washington DC, and Houston), the HOV lanes are reserved for vehicles carrying a driver and at least two passengers, and are designated "HOV3+" (*6*); (*7*); (*8*); (*9*); (*10*); (*11*).

Casual carpooling is observed as being an egalitarian activity (*10*). There is no limit on who may participate, however there are some accepted etiquettes in most locations, such as which radio station will be listened to, and who is allowed to start a conversation. The system is characterized as being free for the riders, and saving time for the drivers. In the Houston example about 50% of the participants are female (*7*), which suggests that the system is considered to be safe.

Table 1 summarizes the characteristics of these casual carpooling systems.

The San Francisco and Washington DC systems are supported by websites. Washington DC's website (www.slug-lines.com) has information such as rules, etiquette, and the locations of pick-up points, which are generally located in commuter parking lots (parking lots provided for users of the transit system). A list of morning pick-up points for the San Francisco system is published on the Ridenow website (www.ridenow.org/carpool). Figure 1 shows how extensive the system is.

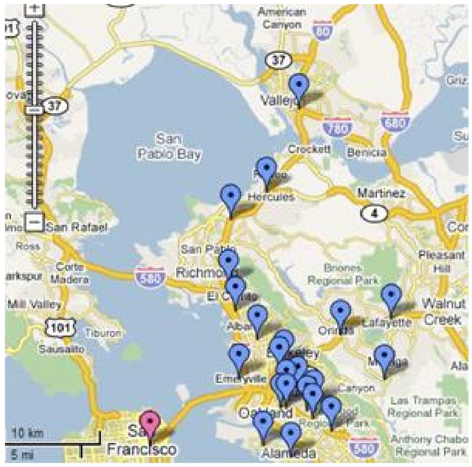
TABLE 1 Casual Carpooling Locations and Characteristics

Location	Morning Pick-up Pts	After-noon Pick-up Pts	Average daily car-pools per pick-up point	Participants per day (year of last report)
Wash-ington DC	24	16	134	9,689 (2006)
San Francis-co, CA	22	1	approx 200	8,000 -10,000 (1999)
Hous-ton, TX	3	1	100	approx 900 (2007)

Studies of casual carpooling conclude that it works because of a very special confluence of conditions, namely (*10*):

- 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). (The authors note that it is generally more difficult to form a three person carpool than a two person carpool under a traditional carpooling model. Under the casual carpooling model it is simple to form a three person carpool).
- 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.

FIGURE 1 Casual Carpool Pick-up Points, San Francisco



As far as the authors have been able to determine, these conclusions were reached without defining or carrying out tests that would establish whether they are valid. There are other locations that satisfy these conditions (for example Seattle from the East Side of Lake Washington, and Los Angeles from El Monte), but casual carpooling has not arisen spontaneously in reportable volumes other locations. The reasons for this are not clear.

Only a single report has been found of an attempt to establish casual carpooling in a new corridor. In 1979/80 the Golden Gate Bridge Highway and Transportation District carried out a project to test the feasibility of 'flexible registered ridesharing' from Marin County to downtown San Francisco. The demonstration successfully answered questions regarding institutional constraints, insurance coverage, market selection criteria, the value of an in-person registration process, and the effectiveness of a member boarding pass for this form of ridesharing. It also served to highlight a number of issues critical to the successful operations of a flexible registered ridesharing program and to identify areas in need of further study. Governance issues, low levels of uptake, and the lack of an ongoing budget to cover administrative costs (this was many years before the internet) resulted in discontinuation of the pilot (*12*).

Although HOV lanes are an integral feature of existing casual carpooling systems, Kelley (*13*) outlines a business case for paying carpoolers as an alternative to installing a new HOV lane. He suggests that the operating and subsidy costs of this form of casual carpooling would be less than the operating costs of an HOV lane, and the entire capital cost of the HOV lane could be avoided.

A New Zealand review suggested implementation of casual carpooling as a strategy for managing transport challenges when oil prices rise, (*14*).

According to Burris and Winn (*7*) a major reason casual carpooling has not extended beyond the initial three cities is the perceived financial liability that public authorities could expose themselves to as a result of supporting a system where people share rides without sufficient pre-planning.

Concern has been expressed that casual carpooling takes passengers from public transport, and that if casual carpooling did not exist there would be fewer cars on the road. This is supported by survey data from San Francisco that found that, if casual carpooling were not available, 87% of riders would otherwise be public transport passengers, and 46% of drivers would switch to the bus (*6*). The following sections show that even with more cars on the road, energy savings are probably being achieved.

3. ANALYSIS: ENERGY IMPACT OF CASUAL CARPOOLING

It seems intuitive that carpools save energy when compared with the same people driving alone. But if some casual carpoolers would otherwise be bus riders the question becomes more complex. This section attempts to address this complex question, including giving consideration to the impact of this type of carpooling on the energy consumption the other traffic on the same roads.

The Auckland Regional Council modeled the potential impact of 2,500 three person flexible carpools in Auckland, (using the Auckland Traffic Model). The modeling assumed that the source of the carpool riders would be existing SOV drivers. The authors have compared the results of the modeling, which showed overall energy savings, with the amount of energy that would be saved by the participants themselves. Compared with 'all SOV driving', the modeling suggested energy savings by all the traffic (the flexible carpoolers and everyone else) in the order of four times the energy that would be saved by the flexible carpoolers themselves (*2*).

In the case of casual carpooling, however, many of the riders were known to be switching from a public transport alternative. And when the authors had proposed flexible carpooling as a potential solution many transportation professionals objected on the grounds that it would take people from buses.

To find out if casual carpooling saves energy compared with a mix of people riding in buses and single occupant cars, and whether it therefore saves energy overall, this section brings together three simple energy consumption models.

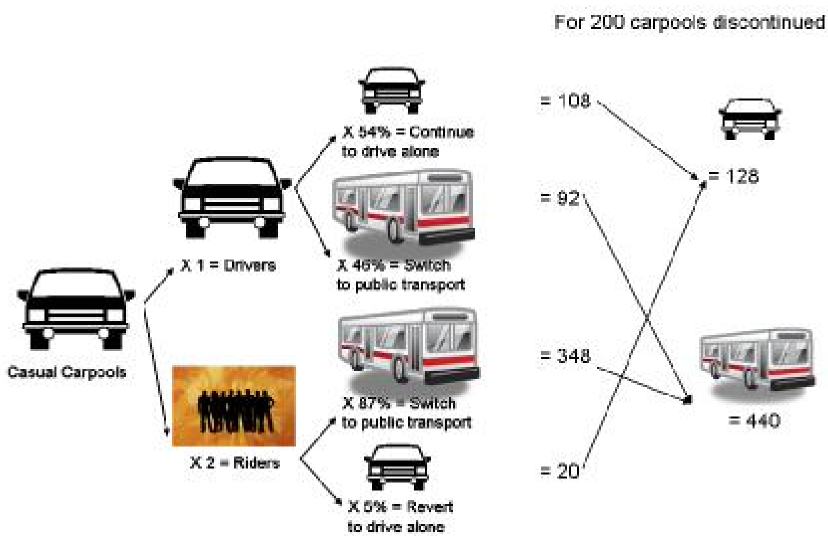
1. In 3.1 the energy use is estimated for casual carpoolers in a single casual carpooling route, compared with a mixture of bus riding and SOV driving.
2. In 3.2 a simple model is created for estimating the impact of casual carpooling on other traffic in the same corridor, and
3. In 3.3 the simple model is used to estimate the total impact of casual carpooling in San Francisco.

3.1 Comparing the Energy Use of a Single Casual Carpooling Route with a Bus/SOV Alternative.

It would be possible to create a completely hypothetical situation to compare casual carpooling with bus/SOV, but this is not needed because some actual data exists. A comparison is therefore made between the real situation of casual carpooling, with hypothetical services that some of the casual carpoolers would use if casual carpooling did not exist.

Data from a survey of casual carpoolers in San Francisco (*6*) enables prediction of what traffic patterns would be like if casual carpooling didn't exist. Based on that data, it can be calculated that a casual carpool pick-up point with 600 participants (200 carpools) would instead involve 128 single occupant cars, 440 bus or train passengers, and 32 people who would either not travel, or who would use traditional carpools. Hence there are currently 200 – 128 = 72 more cars (from such a location) with casual carpooling than there would be in the hypothetical alternative, (see Figure 2) or about 1080 more cars in total in the traffic in San Francisco than there would be without casual carpooling (from all locations) ((9,000 from all locations / 600 from one location) x 72 more cars one location = 1,080 more cars).

FIGURE 2 Alternative Mode for Casual Carpoolers (based on (*6*)). Note that 32 riders either stop commuting or revert to traditional carpools.

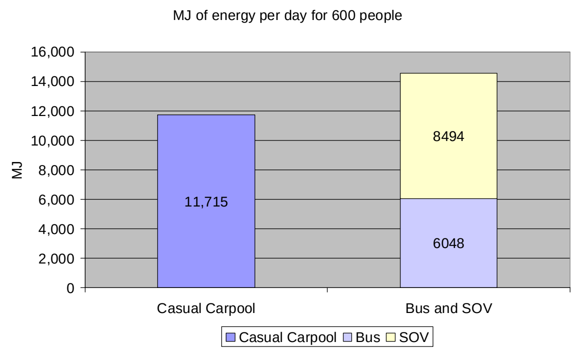


Because the participants are using casual carpooling it is not possible to be sure of the features of the service that participants would take if they could not use casual carpooling. A hypothetical bus service is created to carry these riders. For the following calculation assumptions have been made about such a bus service. The assumptions are stated below.

Figure 3 compares the energy requirements of casual carpooling from such a San Francisco casual carpooling location with the energy requirements for the combination of buses and SOVs that would replace them. It shows two scenarios, each of which involves 600 travelers, traveling a distance of 22.4 km (the weighted average length of all the San Francisco casual carpooling routes).

1. 200 casual carpools, (600 travelers) and
2. 128 SOVs plus enough buses for 440 people, (600 travelers less 5.3% who indicated that they would change their commute if they didn't casual carpool. These 32 people have been excluded from the number of commuters who would switch to the bus).

FIGURE 3 Comparative Energy Consumption of Travel for 600 People



The key assumptions are:

- Three 55-seat buses will be used (Some may argue that San Francisco commuters would switch to BART rather than to buses. It is noted that this could be correct, however there are capacity constraints on BART as described in Consider Congestion Pricing for BART, (*15*), and while individual passengers would probably be able to make the change, a wholesale switch from casual carpooling would probably swamp the system. Further, whether three 55 seat buses would be used, or some other configuration of bus size and frequency, would be a management decision for the operator. A different configuration would deliver a different energy consumption answer).
- Table 2 shows a potential trip pattern.

TABLE 2 Bus Schedule for 440 Passengers

	Passengers			
Departure	Bus 1	Bus 2	Bus 3	Cumulative
6:30	27			27
6:45		55		82
7:00			55	137
7:15	55			192
7:30		55		247
7:45			55	302
8:00	55			357
8:15		55		412
8:30			28	440
Trips per bus	3	3	3	9
Distance per round trip				44.8
Total KM bus travel				403.2
MJ/Km for bus				15
MJ consumed				6048

- Buses deadhead (return empty) three times each in order to carry the full number of passengers, an average load factor of 44.4%,
- Buses use 15.0 MJ of energy per km. (*16*)
- 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.
- Carpools consist of 10% hybrids (at 1.58 MJ per km) and 90% conventional internal combustion engines (at 2.73 MJ per km) (energy factors from Strickland (*16*)), Table 3.

TABLE 3 Casual Carpool Fuel Use

Casual Carpools Fuel Use			
	Hybrid	Standard	Total
Distance	22.4	22.4	22.4
Cars	20	180	200
Total KM	448	4032	4480
MJ/Km	1.58	2.73	
MJ consumed	707.84	11007.36	11715.2

The conclusion is that the bus and SOV combination uses 24% more energy than the casual carpool scenario. It is the combination of the deadhead travel for the buses and slower travel in the mixed-use lane for the SOVs (and therefore greater energy consumption (*17*)) that leads to the counter-intuitive result.

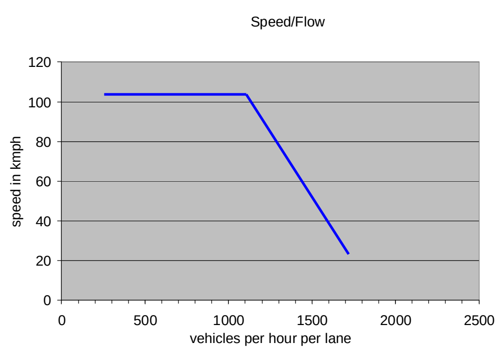
This analysis compares only the energy consumption of the participants' transport in cars or buses. It does not include the energy impact on the other traffic in the corridor resulting from the casual carpools operating in the HOV lane instead of a subset or multiple of those vehicles operating in the mixed use lanes. This is considered in the next two subsections.

3.2 A Simple Model for Estimating the Impact of Reduced Traffic on Fuel Consumption

In order to estimate an order of magnitude impact on the rest of the traffic the following calculations compare the energy consumption in the traffic flows with and without casual carpooling. In a model developed for this paper the key variables used are the estimated speeds in the mixed use lanes with and 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, and proportionally smaller when the existing traffic speeds are high (and there is less congestion).

Figure 4 is a simplified speed/flow diagram, based on regression analysis (by Pearce, 2004, unpublished) of HOV lanes in the San Francisco Bay Area (*18*).

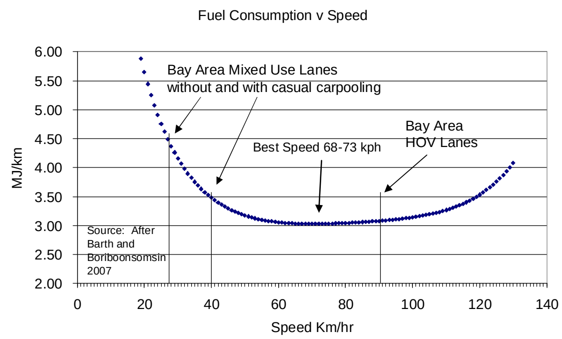
FIGURE 4 Simplified Model of Speed vs. Flow



This speed/flow relationship assumes that the traffic runs smoothly at freeway speeds for rates up to 1,100 vehicles per lane per hour. When demand exceeds 1,100 vehicles per lane per hour the traffic speed can be expected to degrade. The model uses a constant rate of 12% speed change for each 100 vehicles added or removed per lane hour, a gross simplification of the complex relationship between speed and flow. This will be incorrect at the boundaries, but it is expected that the order of magnitude is reasonable. Some lanes move greater numbers of vehicles at lower speeds (there are reports of up to 2,500 vehicles per lane hour, for example), while stop-start traffic achieves well below these levels.

Figure 5 models energy consumption against changing traffic speeds, based on work by Barth and Boriboonsomsin (*17*). (The work done by (*17*) focused on the carbon dioxide emission impacts of traffic at different speeds. Their carbon dioxide findings were converted into energy impacts to derive the chart).

FIGURE 5 Consumption Impact of Different Traffic Speeds



As traffic moves at slower or higher speeds than the optimum of about 70 km per hour, energy consumption per unit distance increases.

3.3 Estimating the Total Impact of Casual Carpooling

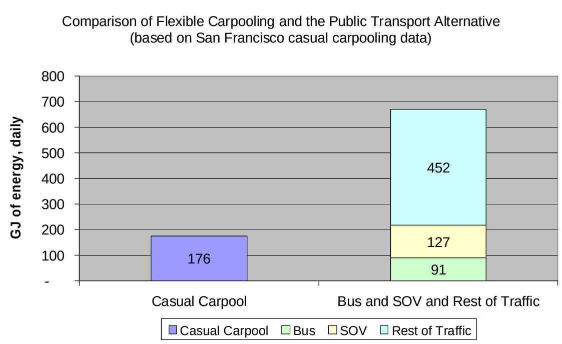
The above assumptions and models allow estimation of the impact of casual carpooling on energy consumed by the traffic in the mixed lanes of the San Francisco Bay Area:

- With existing casual carpooling, and
- If casual carpooling ceased to operate from all locations, participants switching mode according to the survey findings reported by (*6*): (if casual carpooling were not available, 87% of riders would otherwise be public transport passengers, and 46% of drivers would switch to the bus).

Analysis suggests 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. Using these figures casual carpooling therefore appears to save approximately 500 GJ per day (or the equivalent of 900,000 US gallons (3.5 million liters) of gasoline per year). This saving would increase if congestion worsens, or if the average energy consumption of cars was greater than the figures used in the model, and decrease if there was less congestion or cars were more efficient.

Figure 6 shows the calculated fleet energy consumption impact of casual carpooling, combining both the direct and indirect impacts.

FIGURE 6 Comparing daily transportation energy impact of 9,000 San Francisco casual carpoolers with and without casual carpooling



While it stretches the scope of this paper it is worth exploring non-energy benefits of casual carpooling for San Francisco. These include the value of time saved, buses not purchased and operated, bus drivers not paid, and flow-on benefits such as lower emissions and fewer accidents. Alameda County Transit (responsible for moving people from Oakland to San Francisco on the routes where the casual carpooling operates) has publically acknowledged that these bus related savings exist (*19*). If all factors were valued they could amount to more than $US 30.0 million per year, for the morning commute alone, as shown in Table 4.

TABLE 4 Estimate of Annual Savings from Casual Carpooling in San Francisco

Factor	Volume	Value	Total $US million per annum
Energy	900,000 gallons	$3.00	$2.70
Emissions	8,200 tonnes	$15	$0.10
Time Savings for all commuters	900,000 hours	$30	$27.00
Buses not purchased	45 buses	$0.5 million @ 10% pa	$2.20
Bus Operating Costs not Incurred	45 drivers	$50,000 pa	$2.20
Accidents avoided	?	?	?
Total per annum			>$30.0

It seems reasonable to conclude that casual carpooling saves energy and generates other collateral benefits. This appears to be true even if participants would otherwise take the bus, because casual carpooling reduces the number of buses needed, (therefore avoiding deadheading of buses), and increases the energy efficiency of traffic in general use lanes.

The estimated 6,000 daily riders, at 230 days per year, take something in the order of 1.3 million casual carpool trips per year (morning only). The saved bus-driver costs and capital costs alone are estimated at $US 4.4 million, or $3.38 per trip, to which would be added bus fuel, repairs, maintenance and management costs (not listed above) while the total saving per trip could exceed $US 23.00 ($US 30.0 million divided by 1.3 million trips).

If casual carpooling is considered through the lens of transit revenues and costs, it is unlikely that the lost transit revenues would exceed the saved transit costs, and the lost transit revenues would be much lower than the saved total costs, so there would be a net gain to transit from the existence of casual carpooling.

This example of the San Francisco situation, comparing "with" and "without" casual carpooling suggests that there may be potential benefits available from deployment of casual or flexible carpooling to other cities.

4. CONCLUSIONS

The objective of this paper was to compile evidence and estimate the energy consumption impacts of casual carpooling.

Casual carpooling in three US cities moves high volumes of people at very low cost. Using a simple model developed for this paper the benefit to San Francisco is estimated to exceed $US 30.0 million per year, including an estimated 0.9 million US gallons (3.5 million liters) of fuel, at almost no public expenditure.

The success of carpooling (or any other consumer product, including transit) depends on providing a sufficient mix of benefits to attract the desired number of users. Casual carpooling effectively adds schedule flexibility to the usual mix of carpooling benefits, or removes schedule inflexibility from the usual mix of carpooling barriers. Successful adaptation of this system could enable deployment to other cities with benefits of reduced energy consumption for the participants and the rest of the traffic.

To the extent that increased carpooling results in a reduction in SOV travel, there would be an increase in average vehicle occupancy. Raising assumptions about average vehicle occupancy rates could reduce forecast demand for energy.

5. POLICY IMPLICATIONS

The foregoing analysis demonstrates a strong possibility that successful adaptation of casual carpooling will unlock energy savings. The policy implication of this is that research and demonstration projects to establish the scale of these benefits should be an urgent priority. Further research, such as an evaluation of casual carpooling using actual data of daily traffic flows for each route, would validate the calculations offered in this theoretical paper.

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