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Flexible Carpooling: Exploratory Study

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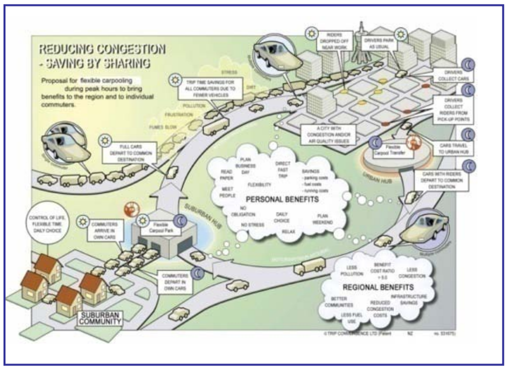

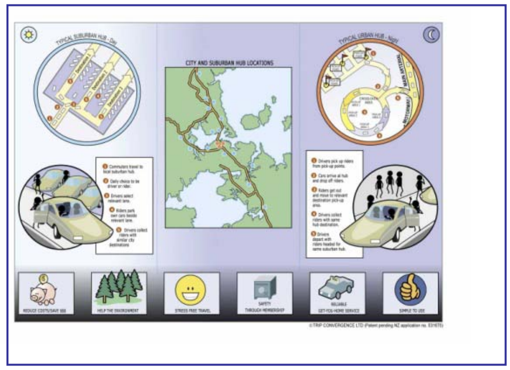

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- Diana Dorinson – Transportation Analytics
- Ben Finkelor – UC Davis Energy Efficiency Center
- Deanna Gay – Law Student, UC Davis
- Paul Minett – Trip Convergence Ltd
- Susan Shaheen – UC Berkeley

The contents of this paper reflect the views of the authors and do not necessarily indicate acceptance by the sponsors.

KEY PERSONNEL AND RESPONSIBILITIES

Susan Shaheen, Honda Distinguished Scholar in Transportation at UC Davis, Co-Director, Transportation Sustainability Research Center at UC Berkeley, and Co-Director of the transportation track of the Energy Efficiency Center, encouraged the initiation of the project, oversaw all phases of the project, and provided feedback to drafts of the chapters.

Ben Finkelor, Executive Director for the UC Davis Energy Efficiency Center, provided project management, engaged the contributors, and coordinated feedback to drafts.

Paul Minett, Co-Founder, President, and CEO of Trip Convergence Ltd, and co-inventor of the flexible carpooling system provided the background for Chapter 2 and conducted the analysis for Chapter 4 the energy efficiency implications of flexible carpooling.

Diana Dorinson, Founder and Principal, Transportation Analytics carried out the analysis that makes up Chapter 3: the factors that would drive individual choice between single occupant vehicle (SOV) driving, public transport, and flexible carpooling.

Deanna Gay, law student at the University of California, Davis, carried out the research for Chapter 5: liability and insurance.

Executive Summary

Energy consumption could be reduced if more people shared rides rather than driving alone, yet carpooling represents a small proportion of all potential carpoolers.

Prior research has found that many who might carpool were concerned about reduced flexibility with carpooling. If flexibility is one of the barriers, how could carpooling be organized to be more flexible?

In Northern Virginia a flexible system has evolved where there are 3,500 single-use carpools per day. In another example, there are 3,000 single-use carpools per day in a system in San Francisco. In both cases riders stand at the equivalent of a taxi stand for carpoolers and there is no requirement for pre-arrangement to create the carpool. Drivers who would typically be driving alone pick up riders and qualify to use the high occupancy vehicle lane (HOV3+, driver plus at least two passengers), thus helping traffic flow a little more freely. These two systems are estimated to save almost three million gallons of gasoline per year because of the impact they have on the rest of the traffic.

The logical flow of this paper is to describe flexible carpooling and 1) explore the economics at a personal level, 2) determine the likely use by individuals (it would), 3) explore the economics at a route level to determine societal benefits (it is), and 4) finally explore the validity of institutional barriers that might be raised.

Key Findings

- When compared with existing modal choices for commuting to work, flexible carpooling would be cost competitive for commuters.
- Given the indicative societal costs and benefits should people use flexible carpooling, it could be a useful additional mode.
- In some circumstances flexible carpooling would most likely draw participants from single occupant vehicle (SOV) driving, while in other circumstances it would draw from SOV driving and public transit, and in still other situations it would be unlikely to succeed. The key factor is the quality of existing mode choices. In circumstances where a transit trip involves multiple providers and poor connectivity, flexible carpooling could be expected to draw from transit. On corridors where there is high congestion with availability of HOV lane capacity flexible carpooling could be expected to draw from SOV drivers.

- Flexible carpooling has the potential to save significant amounts of energy, equivalent to express bus services, but at lower cost. A single flexible carpooling route involving 150 commuters could save up to 6.3 Tera Joules (TJ) of energy per year (the equivalent of 52,000 gallons of gasoline) under certain circumstances of distance and congestion levels and taking into account the savings by both the participants and remaining traffic.
- This review identifies content that should be covered in the participant agreement, and recommends that liability issues be mitigated by establishing the service under a separate entity and purchasing insurance coverage.

Key Recommendations

1. Flexible carpooling should be tested in a field operational test.
2. An optimal field test route would be one where there is congestion and the public transport choices are crowded and incur a significant time penalty compared with car driving; the choice of route should take these into consideration.
3. The feasibility study for and subsequent evaluation of the field test should include analysis of the factors explored in Chapter 3 in order to better understand the motivators of mode choice.
4. Applicants for membership in the field test should show evidence of vehicle insurance.
5. The field test should be operated by an incorporated entity to limit liability.
6. Care should be taken in carrying out and documenting screening procedures before approving members.
7. The incorporated entity should carry appropriate insurance.

Chapter 1: Introduction

1.1. Background

Transportation is a significant user of fossil fuel energy, much of which is wasted due to slow running engines in congested conditions. Reduction of vehicle counts is a key strategy for reducing this energy waste. Other strategies include development of more efficient engines and greater use of alternative fuels.

The prime strategy for reducing vehicle counts is the introduction and expansion of public transportation services: bus, rapid transit, and light/heavy rail. In some jurisdictions commuters are encouraged to carpool/vanpool; cycling, walking, and telework are also promoted. The provision of high occupancy vehicle (HOV) facilities and priorities helps to encourage ridesharing. Community outreach is used to entice single occupant vehicle (SOV) commuters to use alternatives.

Carpooling has been seen as one of the lowest cost alternatives. Carpoolers use their own cars to provide rides often helping to achieve community goals for traffic reduction without the cost of publicly owned or operated vehicles. According to the U.S. Census Bureau, 2005-2007 American Community Survey, 10.6% of workers carpool to work and in some cities carpooling rates exceed 20%. As a mode, carpooling has tended to require a sustained effort on the part of the Transportation Management Agencies (TMAs) and workplace-based Commute Trip Reduction officers (or their equivalent) to keep it working. Some jurisdictions have used cash incentives to encourage greater levels of carpooling, relying on honesty systems for reporting while incurring high administration costs.

In spite of the efforts put into carpooling, the mode has failed to live up to its expectations. SOV rates remain high. A key reason that people give for not carpooling is that they have varying and unpredictable work schedules and could not be tied to the transport schedule of other people.

There are three examples of carpooling that have thrived with almost none of the administrative costs and outreach effort normally associated with carpooling. In San Francisco, CA and Washington, DC, for over 30 years there has been an informal system in which riders and drivers form fuller cars at curbside pick-up points that resemble taxi stands for carpoolers. Called 'casual carpooling' in San Francisco and 'slug-lines' in Washington, DC this phenomenon started in the early 1970s during bus strikes. In the mid-1990s the same concept started in Houston, TX.

In return for providing a free ride to two riders, the driver qualifies to drive in the HOV lane (carpool lane). As many as 3,000 three person 'single use' carpools are formed every morning at about 20 locations in the East Bay of San Francisco avoiding the toll and on-ramp meter as they cross the Bay Bridge into downtown San Francisco. A similar number of informal carpools are formed in 20+ locations in the Washington, DC region each morning. In Houston, the number is below 1,000 from three pick-up points. In these examples the participants are not tied to each others' schedules, but carpool on demand.

Trip Convergence Ltd, a company from Auckland, New Zealand, (co-founded by Paul Minett, an accountant and business strategy advisor and John Pearce, a mechanical engineer and business strategy advisor) devised and patented a flexible carpooling system that has much in common with casual carpooling. They called it HOVER, an acronym for High Occupancy Vehicles in Express Routes. They wanted to avoid calling it 'carpooling' because they perceived a negative association with the term and the concept. Most people, they perceived, believe that carpooling does not work.

The system they devised incorporates a number of enhancements they believe are pre-requisites to enabling high volume carpooling on a route basis as a complement to the existing transport system. In a co-written white paper they estimated that San Francisco gains an annual benefit from casual carpooling in the order of $30 million in saved energy, time, and public transport costs, at almost no cost. They are convinced that a more formalized version, whether exactly the system they devised or a variation of it, could be implemented in new locations and would enable those locations to achieve similar benefits.

Having devised a new way to help commuters they expected a positive response from the transportation planning community. They engaged with transportation agencies in New Zealand and across North America seeking funding and locations for trials and found surprisingly little support. They came up against 'institutional barriers': arguments that if successful the system might take passengers away from public transport, and that offering such a service might expose agencies to liability in the event that a participant got hurt while using the service.

Their efforts led them to the Transportation Sustainability Research Center at UC Berkeley and Energy Efficiency Center at UC Davis. The Centers could see the system potential, but that some sound research would be needed to address the institutional barriers.

1.2. This Project

This project is divided into three parts and the chapters of this report reflect them. The chapters are authored by three different researchers.

Chapter 2, written by Paul Minett of Trip Convergence Ltd, describes a proposed flexible carpooling system including a description of a user experience once the system is operational.

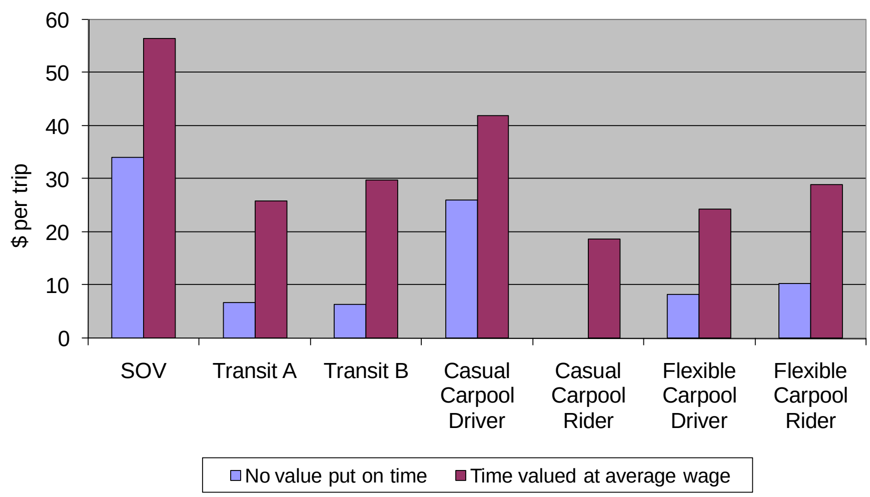
Chapter 3, written by Diana Dorinson of Transportation Analytics, explores the impact that a flexible carpooling system might have on public transportation, by investigating the factors of individual choice. The chapter outlines the potential factors, creates five case study routes around the Bay Area of San Francisco, estimates the cost of using each available mode, and tests the results under a series of different scenarios. The underlying question of this chapter is whether or not people would use flexible carpooling based on economic understanding. The author concludes that in some situations flexible carpooling might draw participants from SOV users, and in other situations from SOV and passenger transport. On a cost-only basis that includes a value for time spent, flexible carpooling looks like a good alternative for individual commuters, especially on longer routes.

The most instructive route explored in this chapter is from Vallejo to downtown San Francisco. This route is interesting because there is an existing casual carpool route operating there. Figure 1 (below) displays the comparison of the existing mode alternatives with the estimated costs for flexible carpool participants. It shows data from two of the scenarios: the 'cash only' costs (as if time has no value) and the costs if time is valued at the average wage rate for the region.

As the author points out, the largest variable in the analysis is the commuters' perceived value of time. There is no broadly accepted method for valuing time and Figure 1 suggests that there is some certainty that 'average wage rate' would not explain the modal split of traffic from Vallejo to downtown. If it did provide such an explanation there would be little single occupant traffic on that route because the Transit A and Transit B examples appear to be economically more attractive.

Figure 1-1

Comparing Identifiable Costs Including Time on Route from Vallejo to Downtown San Francisco (30 Miles)



In Figure 1 the casual carpool driver incurs less cash cost than the SOV driver because the former avoids the bridge toll. The casual carpool rider incurs no cash cost at all.

The flexible carpool driver incurs a net cost that is below one third of the SOV driver by transferring some of that cost to the flexible carpool rider through the ride credit system. If the flexible carpool rider is transferring from being a SOV driver, he/she also saves about two thirds of the cost. If transferring from Transit A or Transit B, the flexible carpool rider would experience about a doubling of cash costs, and no change in estimated cost including time.

On the basis of these route calculations the author suggests that SOV drivers and casual carpool drivers might wish to become flexible carpool drivers, but it is unlikely that transit riders would want to become flexible carpool drivers. Casual carpool riders, on the other hand, if they lose their 'free ride' due to drivers switching, could be expected to prefer transit on a cash only basis, though on a time cost basis they might not have any preference.

Chapter 4, written by Paul Minett, calculates the energy consumption impacts of the system. The underlying question in this chapter is "if Chapter 3 suggests people would use flexible carpooling based on an economic argument, is there a net societal energy consumption benefit to introducing flexible carpooling"? By using a simple model, the author estimates that the energy savings of flexible carpooling are similar to what could be achieved by an express bus service, but without the cost of providing the bus service. Figure 2 shows the key comparison.

For a commuter group of 150 people, the total savings are in the order of 30 Giga Joules (GJ) per day of which almost three quarters is gained by the 'Rest of the Traffic' as it moves more freely, not including the commuter group. The estimated 30 GJ per day converts to approximately 52,000 gallons of gasoline per year.

Figure 1-2

Comparing the daily energy use of 150 commuters as SOV drivers, Flexible Carpool participants, and Express Bus riders

	Scenario	Commuter Group	Rest of Traffic	Bus Operator	Total	Saving vs SOV
1	Commuter Group Drive SOV	10.1 GJ	517.4 GJ	Nil	527.5 GJ	-
2	Commuter Group Flexibly Carpool	3.0 GJ	494.6 GJ	Nil	497.6 GJ	29.9 GJ
3	Commuter Group Take Express Bus	Nil	494.6 GJ	3.2 GJ	497.8 GJ	29.7 GJ

This chapter concludes by calling for a field operational test of the system on the basis of the potential societal energy savings.

Chapter 5, written by Deanna Gay, a business and law student at UC Davis, explores the issues of liability and insurance. This is not intended as an exhaustive review of insurance issues and readers are reminded that the Energy Efficiency Center will not accept any liability for losses resulting from reliance on this information. Organizations considering flexible carpooling might find the content of this chapter to be a useful starting point but in any case should seek their own legal counsel regarding the issues of liability and insurance.

The author explores liability from the viewpoint of product design, negligence, and tort across the different phases of use of the flexible carpooling system. She considers the extent to which governmental agencies could be held liable given their general immunity from liability under the law. Then she looks at insurance—auto insurance for participants and public liability insurance for agencies involved in providing a flexible carpooling service.

The authors' inference from this chapter is that a carefully operated service that carries out the checks it says it will, provides robust products and processes, and carries appropriate product and liability insurance, should be able to operate effectively in the marketplace. Please note that none of the authors are lawyers.

1.3. Conclusions and Recommendations

In the months since this project started there was an unprecedented increase in the price of gasoline, and then a similarly unprecedented fall, and now prices are again rising. At the time of writing this introduction, gas is back around $2.70 per gallon, having risen as high as $4.00 and as low as $2.00 in the recent past. Due to current economic conditions, and the fact that the Transportation Trust Account is running short of money, and other issues associated with funding of services, a reputed 34% of public transit agencies across the country are planning to cut back services in the coming year.

No single system will be a silver bullet to address congestion, fuel use, and emissions. However, this project suggests that flexible carpooling could have a positive impact on the operation of the transport system.

We recommend conducting research trials of flexible carpooling to determine whether this could be a strategy for reducing peak period demand for public transit services (compensating for reduced services), as well as reducing peak SOV demand.

Chapter 2: Meeting Places not Databases

Paul Minett

2.1. Chapter Summary

To the uninitiated there is a bewildering array of alternatives to driving alone. Flexible carpooling has been confused with car sharing (for example FlexCar, a former Seattle based car sharing company in which members rented FlexCar owned cars by the hour), and social network based carpooling (for example, GoLoCo at www.goloco.org, a Facebook Application in which members of the social networking site find others who are going their way for a one-off trip or a regular arrangement). In order to reduce this confusion and help the reader with clarity about the nature of a flexible carpooling system, this chapter describes the background and design of such a system and describes a hypothetical user experience based on the design. At the time of this writing, no formal flexible carpooling system has been made operational, though pilot projects are under consideration for the 2009-2010 financial year.

2.2. Contrast with Traditional Carpooling: The Pre-arrangement Paradigm

There have been attempts to define alternative approaches that achieve the same end as the casual carpools. For example, Kelley (2007) outlined an approach involving technology that would pay participants who organized themselves into carpools as a way of avoiding the cost of building a new high occupancy vehicle (HOV) lane on an existing highway.

The key difference between all other systems defined to date (including that outlined by Kelley), and the concept outlined as flexible carpooling, is the paradigm of pre-arrangement. Most people expect that for carpooling to be effective and safe the people who share rides should know each other in advance and should make very specific arrangements about when and where to meet. This traditional approach suggests that the barrier to forming more carpools is an 'information problem' and that if people just had a way to know who is going their way and when, they would do whatever it took to form carpools. It is expected that these carpools, once formed, would be long lasting.

The reality, as we know, is somewhat different. Much effort goes into forming carpools, but they are anything but resilient. Certainly there are examples of carpooling arrangements that have stood the test of time, but by and large, carpools are fleeting arrangements that might last a season but are easily undone by a change in the schedule of one of the participants.

Nevertheless, we find that the casual carpools (San Francisco) and slug-lines (Washington, DC) have been effective since the early 1970s. Once they started operating they became very resilient, immune to bus strikes, sickness, lateness, and other ailments that befall the rest of the transport system. Taking two riders per car (unless the rider line is backed up in which case they take three), casual carpool drivers provide an incredibly flexible commuter resource. Within their flexibility is the capacity for drivers to opt in and out at will, in the same way as the riders. Neither their attendance nor absence cause the system to fail: the schedule of any one participant becomes irrelevant to the operation of the system. The ongoing effectiveness of these examples suggest the barrier to forming more carpools is not an information problem but an 'assembly problem'. Successful carpooling, perhaps, needs meeting places rather than databases.

John Pearce and the author were not aware of the casual carpools and slug-lines when first defining the basic specification for flexible carpooling. We were not analyzing or evaluating an existing system but defining a new one. We surmised that people would be interested in sharing rides if the value proposition was right and if the process could be made convenient. Over time, we discovered that our design had some features in common with casual carpooling, but many that were much more institutional.

The design includes:

- Dedicated convergence point parking with a special layout to enable formation of fuller cars based on the destination of the commuters with major employment areas as the destinations;
- A membership system with transferable ride credits so that by providing a ride one day, a driver earns the right to a ride at some point in the future;
- Technology that would enable easy tracking of ride activity so that the ride credits could be transferred between participants with minimal effort on their part;
- Pre-screening before being admitted to membership so that the driving record and any other background factors of the applicant could be taken into account and so maximize the safety of the participants;
- A market between members that would enable them to buy and sell ride credits, so that the right to a ride in the future could be transferred to someone else for cash today, with the appropriate mechanisms for people to withdraw the cash; and
- Accounts and record keeping that would enable subsidies or incentives to be channelled directly to the people who are participating, enabling transport agencies to incentivize or subsidize ridesharing activity with confidence that the payments would be for actual activity.

The key components of the system are:

- Convergence point parking (flexible carpooling facility) with a special layout for parking /driving lanes, with a parking area for each destination;
- Membership application on-line;

- Pre-screening for membership based on local rules;
- Infrared membership card that is also biometric (thumb-print to activate);
- Vehicle transceiver that is infrared and radio frequency ID, with diodes that light up to show how many people have activated it (how many are in the car);
- Technology installed at the flexible carpooling facility for capturing trip records and displaying details of who is in the car;
- Signposted pick-up points at the destination end for the return trip;
- On-line member accounts that track money and ride credits and automatic transfer of ride credits from riders to drivers based on the trip record and automatic deduction of the service fee from the financial account each time the system is used;
- On-line trading system that members can use to buy and sell ride credits in a 'bid and ask' environment;
- Feedback system, including 'lost and found';
- Coffee and daily quizzes and occasional prize draws (and potential for other commercial services at the flexible carpooling facility); and
- Facility for local authorities to provide carpool incentives and a system identified so that money go straight into participant accounts.

It is anticipated that pilot projects will help expose how well the above components work together to create a successful flexible carpooling system.

Flexible carpooling therefore envisages providing a convenient transport solution for a large group (150 or more people) who make sufficiently convergent trips (the route from their origins converges at a single point, and their destinations are accessible from a single drop-off point) that they could combine into carpools at the convergence point or designated facility. It would provide a mechanism for forming carpools (driver plus at least two riders) at the convergence point enabling at least two thirds of the commuters to leave their cars behind. The convergence point would be a parking facility.

The key distinction between flexible carpooling and traditional carpooling is that there would be no pre-arrangement of rides and the combinations of riders and driver would be established by the order of arrival at the convergence point.

2.3. User Experience

The following describes the user experience of a hypothetical participant in a flexible carpooling system, as it has been envisioned.

The participant's name is Kate.

Kate is a mid-level manager in an insurance company. Her commute to work (about 20 miles each way) is from an area that has a bus service but the bus is usually very full and stops 10 times between where she would catch it (about 400 yards from her house) and the public transit *station. At the transit station she has to transfer to another bus for the balance of the trip. She has taken the bus in the past but finds it takes about twice as long as driving the car, even in congested traffic. When she drives the car, she is entitled to park at work in a general parking area, at no charge. Kate works regular office hours but sometimes has to stay late for meetings. This is usually predictable, but sometimes not. Also, she occasionally plays a game of tennis in the early morning nearby her office.*

Kate had often thought she would like to share rides but never wanted to be tied to someone else's schedule. She couldn't quite see how carpooling could work for her. Her reasons for being interested in sharing rides included the high cost of gasoline, plus an increasing feeling that energy security and her carbon footprint are important issues that she should address.

Kate heard about this new approach to carpooling and decided it was an interesting idea. It made carpooling look like a realistic choice. She thought she could drive to her early tennis games and give people rides on those days, and the occasional late meeting would not cause a problem. She reasoned that if a meeting went too late, all the riders might already have found rides home, but then the traffic would be lighter anyway. And on the days that she could use it, there is a HOV lane for about three quarters of the distance between the flexible carpooling park and her office. Kate thought it might be good to be a rider on the days that she did not need a car during the day, and the idea of a guaranteed ride home service (a taxi) seemed to solve the problem of unexpected late meetings.

Signing up

Kate visited the website and completed the application. She had to make a statement that she has a good driving record and is not a criminal, and authorize the company to check this with the appropriate authorities.

The application form asked Kate for some information about her auto insurance coverage, existing commute modes, and the flexible carpooling route she wanted to specify as her 'home route.' She also provided her home address, drivers license number, and email address, and accepted the terms of the membership agreement. She was asked if she would be an 'always driver,' 'always rider,' or 'both a rider and driver.' She chose the latter, thinking it would be great to leave the car behind some of the time. She was asked to attach a recent photo that would be lasered onto her membership card.

She completed the application form, paid the application fee online through a secure payment facility, and waited to hear that she would be accepted. Almost immediately she received a security email asking her to confirm that it was she who had completed the application form. She clicked the link, which completed the application process.

Confirmation came through the following day by email. Everything checked out. The email requested that Kate visit the office at the flexible carpooling facility to pick up her membership *card and vehicle transceiver, show her driver's license, and sign the hard copy of the membership agreement. It also invited her to the system launch, a community barbecue, two weeks later.*

Collecting the technology

Kate visited the flexible carpooling facility, which was just nearing completion. She met John, who issued her a vehicle transceiver, and her membership card with her photograph on it, and she signed the membership agreement. Her membership card had a biometric feature. John showed her how to activate it, by using her thumb print, and told her that since she has activated it, no one else would be able to use it. Cool. John helped her to install the vehicle transceiver in her car, low in the center of the windshield, out of the line of vision. He also helped Kate go through the process of loading some money on her online account, so that she could buy ride credits and pay service fees.

The system launch

Kate attended the community barbecue. It was held at the flexible carpool facility. She had to use her membership card to get in, and to get drinks. She recognized a couple of people from her office, and found that some of the other participants worked in buildings near her work. It was an interesting afternoon, and everyone received training on how the system would work when it started the following day. There was a video that demonstrated the service, including how to go online to buy or sell ride credits.

Using the system

When her membership was confirmed, Kate was also issued ten free ride credits into her online account: five for the morning route from the flexible carpooling facility to the destination and five for the evening route from the destination pick-up point back to the facility. Kate had thought she would start as a driver, but since she had ride credits to use, she decided to start out as a rider.

As she got into her car on the first day, she activated her membership card and one light lit up on the vehicle transceiver. She drove to the flexible carpooling facility and was greeted by the display screen, which showed her nickname, 'Skate,' that she used for many of her online accounts. She drove to the parking area for downtown and pulled into the lowest numbered space available. About ten people were standing in front of their cars, waiting for a ride.

It took only a couple of minutes before five cars had come in and picked up the waiting riders, and all of a sudden, it was Kate's turn. A late model Toyota came up the driving lane, and Kate and another rider jumped in. They activated their member cards, and three lights showed on the vehicle transceiver. The car pulled forward. The display screen ahead of them showed that the *people in the car were George, Briana, and Skate. The car pulled out into the traffic, and they were on their way.*

That first morning, the conversation in the car was all about the new system, how easy it was going to be to share rides from then on, and some stories from each of them about their previous experiences with carpooling and commuting. They drove in the HOV lane, and the trip seemed really quick, and pretty soon Briana and Kate were thanking George, and he was thanking them, and Kate was walking the last few yards to her office.

Later that afternoon, Kate walked to the pick-up point. It was on the other side of the road from where she was dropped off in the morning. It was well signposted as a 'Rideshare Stop, No Parking' zone. There was quite a line-up of people, and Kate wondered how long she would have to wait for a ride. She got into a conversation with the guy in front of her (it turned out his name was Michael) and didn't really notice the cars pulling up and picking people up. Each car took three riders that afternoon, and it was only a few minutes before Kate and Michael and the guy in front of him were all climbing into a green Ford. The drive back to the flexible carpool facility seemed to fly by as the four of them (the driver was Mimi) chatted about the new system and how it was going to make life easier and commuting less costly.

The second day, Kate had a tennis game before work. The tennis courts are about a mile from her office, so Kate wanted to take her car. Since the drop-off point was on the way, she decided to pick up some riders, drop them in town, and continue on to her game. It all worked like clockwork, and Kate gave a ride to two people in the morning, and then three in the afternoon. She saw Michael, from the night before, in the parking lot in the morning. He was waiting for a ride but was not at the front of the line when Kate got there. When she got home that evening, Kate reflected on how this new system was working. She had taken two rides so far and used two of her free ride credits. But she had also provided five rides, so she got ride credits from those riders. In total, $4.00 in user fees ($1.00 per trip, as a rider or a driver) had been deducted from her online account. When she thought about the savings in fuel, she felt like she was way ahead in using the system.

Kate continued to use the system regularly, some days as a rider, some days as a driver. So, she knew the system would still be there when she got back from vacation or out of town business trips.

Kate earned enough ride credits, so that she did not have to buy any. She tried to drive and ride in balance. Every once in a while she rode more than she drove and occasionally would get an email from the system telling her she was getting close to running out of ride credits. Those times she would go to the website and bid on some ride credits. That was interesting because she was helping to set the price for everyone. Later, she changed her profile so that it would buy credits for her automatically if her balance got low and sell automatically if her balance got high.

Sometimes Kate would arrive at the flexible carpooling facility intending to be a rider, but after finding many people waiting for rides she would give them a ride rather than wait. It worked really well for Kate because she did not mind whether she was a rider or a driver.

After about a year, her company decided to offer a cash-out for free parking at the office and reduced the number of spaces available. It allowed them to use some of the land for a new building. Kate decided to take the cash incentive from her employer and switch to being an 'always-rider' in the carpooling system. The days she needed to drive to work, she paid for parking in the lot down the street.

Another cool development was when the carpooling company arranged some discount programs. One was with a car sharing company that provided short-term auto use, so that on the days she was a rider, if she needed a car in the middle of the day she could access a car by the hour. Another was with the auto insurance company: they offered a rebate on the auto insurance premiums for anyone who parked their car more than 50 days a year in the flexible carpooling facility because by driving fewer miles these customers represented lower risks for the insurer.

Together, Kate figured she saved over $2,000 a year by using flexible carpooling. And it was really fun because there were award systems, and a daily quiz that the group in the carpool could take together. It was just amazing how much people knew. One time her group won the prize, and they each got a bottle of wine. And then there was the coffee guy at the carpooling facility. He made a really great latte and because she had a standing order he would start making it as soon as she drove in. The coffee would be ready for her as she was driving out, whether as a rider or a driver, and the price was charged to her flexible carpooling account. How cool was that!

Kate used the guaranteed ride home service three times in the first year, twice when meetings unexpectedly went late, and once in the middle of the day when her best friend was in an accident. She had managed to go straight to the hospital, and the carpooling company had been really good about it, also paying for her ride later to pick up her car at the flexible carpooling facility.

She had used the feedback system a couple of times too. One time she had had such a good time talking to everyone in the car that she decided to send them all a 'bouquet' (a feature of the on-line system that enabled members to send positive feedback to the others in the carpool). The other time was when she left her umbrella in someone's car. It was waiting for her at the flexible carpool facility the next morning. It all worked very effectively: she told the system online, and the system automatically told the driver, and her umbrella was returned to the attendant that evening.

She had heard of a couple of people using the feedback system to complain about a scary driver. Members reported that he wove in and out of the traffic at high speeds; everyone had white knuckles. This was reported in the email newsletter, and the carpooling company said they paid *for the guy to take a defensive driving course. Kate's experience with other drivers had always been pretty good. Sometimes she was not that keen on the radio stations they listened to, but at least she had her coffee, and the trips always went quickly.*

All in all, Kate was really pleased with her decision to try flexible carpooling, and now that there were new routes springing up all around, it was starting to make a difference in the traffic.

Chapter 3: Impact on Public Transit

Diana Dorinson

3.1. Chapter Summary

The flexible carpooling system is a set of technology concepts that aims to use excess capacity in single-occupant vehicles by making it easier for drivers and riders to form carpools. Successful implementation of this strategy will increase the person-throughput of the highway network and reduce unnecessary vehicle delay. This chapter uses a case study approach to evaluate how flexible carpooling compares to existing transportation options available to commuters, including driving a single-occupancy vehicle and various transit routings. A spreadsheet model was developed to compute the generalized costs of each travel alternative and to estimate the sensitivity of travelers to changes in key cost drivers, such as cost of fuel, value of travel time, and other quantitative factors. Through a series of scenario tests, it was determined that the largest factor influencing the relative cost—of those factors modelled here—is the commuter's value of travel time. This is not entirely surprising, since the flexible carpooling model offers commuters the most improvement on trips over a long distance or duration.

3.2. Introduction

The flexible carpooling system is a concept that aims to use excess capacity in single-occupant vehicles by making it easier for drivers and riders to form carpools. Successful implementation of this strategy will increase the person-throughput of the highway network and reduce unnecessary vehicle delay. The system depends on serving origin-destination pairs with large passenger volumes, in order to efficiently form the carpools. As a result, some of the corridors where flexible carpooling is likely to be most viable might also tend to be routes where transit agencies have worked hard to develop services and ridership. There is some concern among the transit community that the implementation of flexible carpooling would negatively impact transit operations, principally by reducing transit mode share and the associated fare revenue. This analysis is an effort to better understand the potential impacts on transit—both positive and negative—that could occur in conjunction with the implementation of flexible carpooling.

The discussion that follows is arranged into several sections: Section 3 provides a discussion of the key considerations for any implementation of flexible carpooling, as a framework for the issues raised in this and other studies. The overall methodology for conducting the case study analysis is described in Section 4. Section 5 contains a list of the major assumptions embedded in the methodology. Section 6 is a discussion of the corridors selected for analysis including a description of the available transportation alternatives studied. Numerical results of the baseline analysis are presented in Section 7, and Section 8 contains the results of different scenarios of input variables. Finally, Section 9 provides more general conclusions drawn from this work.

3.3. Analytical Dimensions

The components that make up the flexible carpooling system have been well-defined elsewhere in this and other documents. The basic features of the system are:

- Designated parking areas where carpool passengers may leave their cars, where carpools are spontaneously formed by people bound for a common destination, and where passengers return at the end of their journey;
- Designated pickup and/or transfer areas where participants form carpools for the return journey;
- The exchange of 'ride credits'—market-priced virtual 'tokens' that can be purchased and/or converted to cash—between participants, in order to compensate drivers and encourage participation;
- The use of an identification card and vehicle transponder to verify membership, track program participation, and support financial transactions; and
- Availability of a suite of web-based tools to support user interface and program administration.

One of the chief benefits of the system is that it is designed to be implemented in a variety of different configurations. This variety is a deliberate strategy that permits the system to reasonably accommodate the unique needs of different jurisdictions, travel corridors, and user populations. However, it also adds to the complexity of the analysis. There are many specific dimensions that might vary in any one implementation of flexible carpooling. Generally, these can be divided into three categories:

1) <u>Attributes of the flexible carpooling system itself</u>: the comfort and convenience of the facility, the nature of any co-located services (e.g., coffee, newspaper, dry-cleaning), transfer requirements, and overall scale of the deployment;
2) <u>Characteristics of the potential participants in flexible carpooling</u>: willingness to modify their daily routine, availability of private automobile, etc.; and
3) <u>Features of the other existing transportation options in the area and the degree to which these options represent a comparable travel option to flexible carpooling</u>: reliability, ride quality, schedule, etc.

A detailed listing of attributes in all three categories is given in Appendix A. The implementation of flexible carpooling in one or more locations would involve the combination of one or more options from each of the categories above. This study effort is a theoretical feasibility study of the concept of flexible carpooling, as opposed to a financial feasibility study of actual implementation in a specific corridor. As a result, the analysis does not attempt to quantify specific impacts to transit of any one proposed implementation. Rather, it provides a comparative analysis that gives a sense of the qualitative differences between implementation options.

3.4. Methodology

Given the numerous ways that the many analytical dimensions can be combined, it becomes cumbersome to enumerate and calculate the impacts of every unique possibility. The more manageable approach adopted here is to review actual conditions in several real-life corridors as case studies. Potential study corridors were identified based on several factors:

- High volume of peak-hour trip-making in the corridor.
- Significant peak hour delay for automobiles in the corridor.
- Availability of one or more mainline transit alternatives (i.e., not paratransit or rural service) in the corridor.
- Availability of a high-occupancy vehicle lane during a significant portion of trip.

Using these criteria, five different corridors (also referred to as “cases”) in the San Francisco Bay Area were selected for comparative analysis:

1) San Ramon to San Francisco (34 miles)
2) Vallejo to Downtown San Francisco (30 miles)
3) Vallejo to San Francisco Neighbourhood (35 miles)
4) Hayward to Sunnyvale (26 miles)
5) San Mateo to Mountain View (20 miles)

Multiple transportation alternatives were defined for each corridor:

- Single occupant vehicle driver (SOV)
- Regular transit rider (with frequent-commuter discounts)
- Infrequent transit rider (without commuter discounts)
- Flexible carpool driver (HOV driver)
- Flexible carpool rider (HOV rider)

In most cases, more than one transit option is available in each corridor. Up to three different transit itineraries were defined to demonstrate the variance in existing transit attributes. Taken with and without commuter discounts, this led to a maximum of six transit alternatives in each corridor. In addition, one corridor (Vallejo to Downtown San Francisco) currently has casual carpooling in both directions, so this option—essentially a high-occupancy vehicle scenario without financial incentives—was also modelled.

Regardless of mode, all transportation alternatives were constructed as one-way trips during the morning peak. The specific trip origin points are all centered on transportation hubs in semi-urban residential communities, and the destinations are central business districts or other urban locations with high job concentrations. Once the transportation alternatives were defined, trip attributes were collected for each alternative including components of travel time, and direct and indirect costs.

Travel time data were derived from multiple sources. Driving times were estimated using both the "Predict-A-Trip" ™ feature on http://www.511.org (average drive time for all highway vehicles) and Google Maps Driving Directions ("allow up to x minutes in traffic"). The Google Maps times were used to help adjust timing for single-occupant vehicle drivers, because the travel times on http://www.511.org includes averages for high-occupancy, which might under represent the time faced by a single-occupant vehicle traveller. Also, commuters in the Bay Area know that travel times vary a great deal from day to day; drivers typically allow for a longer trip time than the average travel time in case of incidents or other delays in some cases up to 40% more time (Nelson 2007)! Travel time savings due to the use of high-occupancy vehicle lanes was derived from the MTC's "State of the System 2006" report (MTC 2006). Travel times for transit were based on published schedules on transit operator web sites and itineraries created using the "Take Transit Trip Planner" ™ feature on http://www.511.org (2008). The model also includes a small travel time allowance for each change of vehicle (auto or transit), including a few minutes of wait time at the beginning of transit trips, because users must be sure they arrive before the scheduled departure.

Direct costs were calculated from published transit fares, roadway tolls, and parking fees (calculated as the pro-rated cost of parking assuming a monthly pass is used). Average automobile fuel efficiency for the region was extracted from the California Air Resources Board EMFAC model, and the regional average cost of gasoline ($3.51 per gallon at time of writing) was used to estimate the total cost of fuel for drivers. The computation added or subtracted the appropriate ride credits—the virtual 'tokens' exchanged between participants in flexible carpooling—using a ratio of two riders for each driver. A small service charge was deducted from each transaction to fund system operation. The magnitude of the ride credit was calculated separately for each corridor in the model, but the service charge was the same for all corridors.

Indirect costs were calculated based on estimated expenses for items such as maintenance, repairs, tires, insurance, and accidents. The website www.commutesolutions.org (2008) provides estimates of these expenses on a per mile basis. Other indirect costs of vehicle ownership such as financing and depreciation and residential parking costs are not included in this analysis, as described in more detail in the assumptions section below.

The final input in this analysis is the commuter's individual **value of time** spent travelling. The 'cost' of in-vehicle and waiting time were calculated as a fraction of the average area wage rate, as found in the U.S. Bureau of Labor Statistics December 2007 update for the San Jose-San Francisco-Oakland Combined Statistical Area. All waiting time was penalized at twice the value of in-vehicle time. Further discussion about value of time is included in the assumptions section below.

Once the input values were determined, the last step in the analysis was to compute generalized costs for each alternative through basic formula analysis. These costs were compared to each other to evaluate the potential for mode shift between transit, single-occupant vehicles and high-occupancy vehicles. Input values were varied to test the sensitivity of the model outcomes to different scenarios. A detailed discussion of the results of the computations is included in Section 7.

3.5. Assumptions

To provide consistency between the many alternatives, a number of assumptions were carried throughout the analysis.

1) This study focused primarily on mainline travel. All case study routes begin and end at key transit points, which were selected, in part, for their easy access to the most likely highway routings. It was assumed that a park-and-ride station allowing for easy formation of flexible carpools would be available or constructed at the specified origin and destination points. Also, it was assumed that driving within the flexible carpooling station adds negligible mileage to the total trip, although a small time buffer was added to represent the need to form the carpool inside the station. These assumptions allow for a more equivalent comparison between transportation alternatives in each corridor. Obviously extra travel distance/time necessary to reach the specified origin points would serve to further increase the total costs (but not the relative costs) of choosing any one travel mode.

2) It was assumed that all travelers face an equivalent journey from their home to the origin of the case study route and from the end of the case study route to their final destination, regardless of mode selected. This is not entirely realistic because some travelers who choose transit or high-occupancy vehicles do not have the option of using a private vehicle between home and the transit or carpool origin point. Also, at the morning destination, many drivers have parking available at or near their actual destination, while transit and carpool riders may have to walk a further distance. However, the assumptions permit us to neglect access time and cost for all participants, which vary on an individual basis and would be difficult to estimate on specific corridors within the scope of this study.

3) It was assumed that affected commuters will not change their car ownership status due to availability of particular transit/rideshare options, specifically the introduction of flexible carpooling. The decision to purchase a car is usually made on a longer time-scale than contemplated in this study and may be a fact of life regardless of whether the vehicle owner chooses to use the car for commuting. Therefore the fixed cost to register, finance, and depreciate a vehicle were excluded from the analysis. Similarly, any costs associated with residential parking were not included because they would be incurred regardless of the traveler's mode choice to work. On the other hand, cost of insurance, maintenance, and the occasional accident all increase as the vehicle owner drives more, so these costs were retained in the analysis to show the comparison between driving and riding another mode.

4) In the baseline scenario, it was assumed that single-occupant vehicle and high-occupancy vehicle drivers associate the full cost of any daily parking fees with their morning commute. This treats parking as a cost of the initial morning mode choice, leaving the evening mode choice as a fully independent decision. An alternative treatment is examined during the scenario analysis in which the parking is allocated equally to morning and evening commute, so that the morning commute only bears half of the daily parking fee. This second approach assumes that drivers spread trip costs out over all travel that uses the private vehicle, in line with the fact that monthly parkers typically consider the overall benefit derived from having a parking space available at work when choosing their regular travel mode.

5) This model does not capture the feedback effects of road congestion on travel costs. As road congestion continues to increase on a given corridor, drivers may be forced to operate at lower speeds. This means their travel time is longer. And, depending on vehicle speed, their fuel consumption may increase or decrease from the regional average fuel efficiency used in this model. If speeds were previously very high, a small decrease in speeds can raise fuel efficiency, so that the increased time costs might be offset by reduced costs of fuel. However, at lower and lower speeds, fuel consumption increases at the same time as travel time is increasing, leading to much higher costs on a given corridor. These effects can happen in a single commute, as peak travel intensifies and then abates; they can also occur on a longer timescale, as ongoing residential development and job creation change commuting patterns in a region. However, although the effects are very real, the model does not calculate the individual or cumulative impact of changing traffic conditions in each corridor. These feedback effects are considered in Chapter 4.

6) To calculate the transit costs borne by frequent commuters, the model used the cheapest average trip cost available for each leg, for example by dividing the cost of a monthly unlimited pass for each transit operator by a typical number of monthly trips. It was also assumed that frequent travelers use all possible transfer discounts and cooperative fare policies among various transit agencies. However, the use of Commuter Checks, which can further reduce the out-of-pocket cost of transit by allowing commuters to use pre-tax dollars, was not explicitly considered here because the individual tax savings would vary across the user population.

7) The magnitude of the ride credit exchanged between riders and drivers was varied by corridor because it is envisioned that the value of ride credits would be allowed to fluctuate and settle at a market-clearing price for each origin-destination pair. There are several theoretical methods for estimating the price that users might ultimately agree on so far in advance of the availability of the service in question. However, most methods require a more careful study of potential participants than is possible within the scope of this analysis. The simplifying assumption used here is that all flexible carpooling users would drive the carpool one third of the time to recover their long-run rider costs by sometimes being a driver. (Recall that the flexible carpooling system assumes each driver picks up two riders, for safety, and so each driver collects two ride credits per trip.) If this is the case, presumably each rider would be willing to pay at most one

third the cost of single-occupant vehicle driving to receive a flexible carpool ride. A high-occupancy vehicle ride is faster than a single-occupant vehicle ride, which means users actually gain intangible value from participating, and so the single-occupant vehicle cost represents an upper bound on the value of the ride credit.

Related to the above, it must be acknowledged that current users of casual carpooling do not typically exhibit the “drive one third of the time” pattern. A 1998 study of casual carpools in the San Francisco Bay Area reported that 67% of participants are "normally a passenger," while only 11% are a combination of driver and passenger (Beroldo 1999). However, the existing casual carpool system does not involve any exchange of payment between participants, so riders have no reason to try to recover their costs by driving some of the time. Also, the survey did not directly ask whether passengers had a car available for the commute, so it is not known whether it is even possible for these numbers to shift under a different financial equation. Another consideration from the same study is that the bulk of casual carpool passengers (89%) stated they would choose transit modes if casual carpooling was not available. But again, the survey instrument did not quantify whether casual carpoolers would be choice riders or captive on their fallback mode, and so it is difficult to determine whether riders would be able to become drivers if there were greater financial incentives for participation.

8) The computations for the cost of commuting time rest on the assumption that travel time is valued at one half the prevailing wage rate, consistent with transportation modelling best practices. However, all travelers in a given region—or even a given commute corridor—do not face the same opportunity cost of travel time, since they may have different levels of employment and compensation. In the absence of fine-grained data from which to calculate the magnitude and shape of the income distribution for the corridors in this analysis, a regional average wage rate was used, together with a “wage sensitivity factor,” which helps to demonstrate how the baseline results vary with different wage levels.

9) There are numerous qualitative costs and benefits of travel by different modes that have <u>not</u> been quantified in this analysis. Some examples of these intangible factors include:

- Physical discomfort or annoyance from having to share a (potentially crowded) transit vehicle with other riders who play loud music, talk on mobile phones, or create other distractions;
- The “good person” feeling some commuters receive when they take transit instead of driving, thereby reducing their carbon footprint;
- The psychological stress of stop-and-go driving;
- The benefit of having a private vehicle available at a place of work in case of emergency, such as a sick child who needs to be picked up from school;
- Potential for greater exposure to weather/the elements when using transit or ride share as compared to a door-to-door vehicle;

- Convenience of being able to carry or have available personal items needed for work or recreational activities (e.g., construction tools, change of clothes for gym workout, or sales collateral/product samples/inventory);
- Varying (and rapidly evolving) levels of sophistication of user information about travel time, delays, and travel options (e.g., transition from historical to real-time information on driving times, provision of automatic vehicle location information to transit riders, or trip planning tools now available for download to PDAs);
- Varying ability to use travel time productively and/or enjoyably (e.g., making phone calls, reading, knitting, using a music or video player, or using a computer and/or internet);
- Varying ability to eat or drink in the vehicle and/or waiting area;
- Varying ability to trip-chain to conduct errands as part of journey to/from work (e.g., dry cleaning, shoe repair, grocery/pharmacy, or purchase of newspaper/coffee/breakfast); and
- Varying ability to pick-up/drop-off other family members at school/work as part of journey to/from work.

This list is by no means exhaustive. And while these qualitative factors clearly influence an individual's mode choice decision, it is extremely difficult to quantify the trade-offs each traveler makes among these elements, in part because each individual values each element differently. Existing academic studies and practice handbooks offer guidance for evaluating changes in transit service levels (e.g., schedule frequency or vehicle capacity), but these do not adequately address the less tangible attributes of personal comfort and convenience. Some researchers advocate the development of a "Level of Service" (LOS) concept, similar to that of roadway evaluation (for example: Kittleson 2003 and Littman 2007). However, there has not been sufficient agreement among theorists and practitioners about how to classify quality and thus how different travelers react to varying levels of quality. As a result, the elements described above have not been incorporated into the analytical model at the present time. This gap in the methodology is a significant one, but incorporating every possible factor would require a major analytical effort. A more appropriate place to examine these trade-offs would be during a feasibility study of an individual deployment and/or corridor, where a discrete commuter population can be directly surveyed as to their preferences.

3.6. Corridor Attributes

Recall that there are five commute corridor "cases," as defined in the methodology section. These corridors vary in length, as shown in Table 3-1, below.

Table 3-1

One-Way Travel Distance for Five Commute Corridors

	Description	Distance (mi)
Case (1)	San Ramon to San Francisco	34
Case (2)	Vallejo to Downtown San Francisco	30
Case (3)	Vallejo to San Francisco Neighborhood	35
Case (4)	Hayward to Sunnyvale	26
Case (5)	San Mateo to Mountain View	20

In addition to varying by distance, the corridors have different types of alternative transit available (i.e., bus, ferry, heavy rail, and light rail). Recall that up to three different transit routings were modelled in each corridor, and these were analyzed both with and without commuter discounts. Thus, for all calculations performed with this model, single-occupant vehicle driving (SOV) is compared with up to six different combinations of transit routing and payment scheme together with two flexible carpooling (HOV) options, and existing casual carpooling, where applicable. The model results are presented in a matrix format where the rows represent different commute corridors, and the columns represent different mode choices. A brief description of the various combinations is provided in Table 3-2, below. Additional detail on travel routings is available in Appendix B.

As seen below, the transit routings are generalized across all corridors as 'Transit A' through 'Transit F'. The routings **with** discounts available to frequent riders appear as Transit A through Transit C, and routings **without** utilizing discounts are Transit D through Transit F. The three pairs of transit routings are shown with different colors of text for additional clarity. The casual carpool option—valid for Case (2) only—is placed into empty spaces in the transit columns for more compact presentation, where Transit E represents the casual carpool driver and Transit F represents the casual carpool rider. This layout and format is repeated for all scenario results presented in this analysis, although text colors are only applied to the headings in the numerical tables. An example with numerical results is given in Table 3-3, below, which shows travel time in minutes for each corridor and mode, according to the baseline assumptions in the model.

Table 3-2

Travel Alternatives for Five Commute Corridors

			with regular rider discounts			**without** regular rider discounts				
	Corridor	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
Case (1)	San Ramon to San Francisco	I-680 to Hwy 24 to I-80 to Bay Bridge (toll + parking)	CCCTA + BART	CCCTA + BART	Drive + CCCTA + BART	CCCTA + BART	CCCTA + BART	Drive + CCCTA + BART	I-680 to Hwy 24 to I-80 to Bay Bridge: HOV (parking only)	I-680 to Hwy 24 to I-80 to Bay Bridge: HOV (parking only)
Case (2)	Vallejo to Downtown SF	I-80 to Bay Bridge (toll + parking)	Vallejo ferry/express bus to SF Ferry Bldg	n/a	n/a	Vallejo ferry/express bus to SF Ferry Bldg	I-80 to Bay Bridge: Casual Carpool (parking only)	I-80 to Bay Bridge: Casual Carpool (parking only)	I-80 to Bay Bridge: HOV (parking only)	I-80 to Bay Bridge: HOV (parking only)
Case (3)	Vallejo to SF Neighborhood	I-80 to Bay Bridge to Fell/Lincoln (toll only)	Vallejo ferry/express bus then MUNI Metro	Vallejo transit bus then MUNI Metro	n/a	Vallejo ferry/express bus then MUNI Metro	Vallejo transit bus then MUNI Metro	n/a	I-80 to Bay Bridge to Fell/Lincoln: HOV	I-80 to Bay Bridge to Fell/Lincoln: HOV
Case (4)	Hayward to Sunnyvale	I-880 to US-237	BART + VTA (bus & train)	BART + VTA (bus & train)	BART + VTA (bus only)	BART + VTA (bus & train)	BART + VTA (bus & train)	BART + VTA (bus only)	I-880 to US-237: HOV	I-880 to US-237: HOV
Case (5)	San Mateo to Mountain View	US-101	Caltrain	samTrans + VTA	samTrans + VTA	Caltrain	samTrans + VTA	samTrans + VTA	US-101: HOV	US-101: HOV

same transit routings

NOTES ON TABLE 3-2: 1.) BART = Bay Area Rapid Transit; CCCTA = Contra Costa County Transit Authority; MUNI = San Francisco Municipal Transportation Authority; VTA = Santa Clara Valley Transportation Authority
2.) All bridges have $4 toll, unless automobile qualifies as a High-Occupancy Vehicle (HOV)
3.) Cases (1) and (2) include cost of downtown parking; all other Cases have free parking at morning destination.

Table 3-3

Total Minutes of Travel Time by Mode for Five Commute Corridors

Baseline model assumptions

		with regular rider discounts			**without** regular rider discounts			casual carpool **driver**	casual carpool **rider**
	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
Case (1)	90	105	79	46	105	79	46	72	72
Case (2)	100	75	n/a	n/a	85	68	68	68	68
Case (3)	116	103	103	n/a	113	103	n/a	84	84
Case (4)	60	97	109	88	97	109	88	38	38
Case (5)	40	51	138	95	51	138	95	31	31

same transit routings

It should be acknowledged that most of the travel times shown above are considerably longer than the 2000 Census Bay Area average of 29.4 minutes (for all commuters, regardless of mode) (Hoge 2006). This is partly by design: only longer commutes stand to benefit from travel time savings, and so the case study routes were deliberately selected in corridors that are longer and slower than others in the region.

Also, in the first transit routing shown for Case (2) and Case (3), a commuter travels by ferry or bus from the Vallejo terminal to San Francisco as part of their journey. The operators of the bus and ferry recommend arriving a full 20 minutes prior to boarding for parking and ticket purchase. It was assumed that a regular commuter (Transit A) would know the routine and be able to manage these activities within half the time, so they were assigned only 10 minutes of pre-travel wait time. The infrequent rider (Transit D) has been assigned the full 20 minutes, leading to a difference in travel time even though the vehicle routing is identical.

3.7. Baseline Results

Based on the scenarios, assumptions, and computations that have been described above, the model can demonstrate the relative cost that commuters experience when making their journey to work. This model is a scenario planning tool, rather than a full-scale travel demand model; the computed value of commute cost is explicitly derived from the key inputs selected for analysis, most of which have not been specifically calibrated to the individual corridors. For example, there is no adjustment for wage rates and household incomes of the commuters in the different corridors; a monetized cost of $50.00 per trip might represent a huge burden to a low-income commuter, but it would be more easily absorbed by a high-net-worth commuter. Without additional information about income distributions, it is difficult to estimate the sensitivity of commuters to cost differences, and so the impacts to mode-share cannot be accurately calculated.

Because the model is not finely tuned to a specific population of commuters, it is most useful for testing relative sensitivity to the various input variables, and not for predicting absolute outcomes. All scenarios modelled in this study will be compared to the baseline assumptions.

Further, the available transit options vary considerably in their nature, and are not directly comparable across corridors. Thus, most analysis and conclusions should be made in reference to comparisons along the horizontal axis of the matrix, although it can be instructive to note where and how the choice set faced by commuters varies across the same region. The generalized cost results for the baseline scenario are presented in Table 3-4, below.

Table 3-4

Generalized Commute Costs

Baseline model assumptions

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
Case (1)	$ 51.62	$ 33.46	$ 28.67	$ 24.35	$ 34.59	$ 28.95	$ 22.48	$ 28.80	$ 28.76
Case (2)	$ 56.41	$ 25.83	n/a	n/a	$ 29.82	$ 41.90	$ 18.63	$ 24.22	$ 28.97
Case (3)	$ 46.82	$ 38.18	$ 42.17	n/a	$ 42.55	$ 42.55	n/a	$ 24.08	$ 27.84
Case (4)	$ 22.97	$ 37.62	$ 36.95	$ 29.99	$ 45.27	$ 41.10	$ 32.39	$ 16.80	$ 14.35
Case (5)	$ 16.28	$ 15.77	$ 43.59	$ 35.96	$ 18.12	$ 44.11	$ 37.23	$ 13.71	$ 12.44

The results for the baseline assumptions show one slightly counter-intuitive result that should be explained before proceeding with more general comments. In Case (1), the cost for Transit C (<u>with</u> frequent rider discounts) is actually <u>higher</u> than Transit F (the same routing <u>without</u> discounts). This is because the cost for daily parking at the BART station is <u>less</u> than the pro-rated amount paid by holders of monthly parking passes. The monthly parking is reserved (guaranteed), so presumably a regular commuter would opt for the higher priced parking, whereas an occasional commuter might not. A similar parking discrepancy also exists for Case (2) and Case (3) at the Vallejo bus/ferry terminal; however, the savings from other frequent-rider discounts makes up for the higher cost of parking, so it is not immediately obvious in the total cost results above.

Comparing across all modes, the model yields costs whose relative magnitude are consistent with expectations. For example, all high-occupancy vehicle options—including casual carpool in Case (2)—represent a lower cost travel option than driving a single-occupant vehicle in the same corridor, due to time savings and reduced bridge tolls. In some corridors, the transit options cost less than driving, while in other corridors, the costs of riding transit are higher. This is reasonable, because some transit service is more closely comparable to driving (e.g., non-stop BART trip), while other transit service is not (e.g., a 3-seat ride on multiple providers). The relative costs of each mode choice in a given corridor are compared to each other in the following two tables. Table 3-5a focuses on how other modes compare to single-occupant vehicle driving, and Table 3-5b compares the options to the lowest cost transit option in each corridor.

Table 3-5a

Relative Commute Costs

Baseline model assumption

Each travel option compared to <u>single-occupant vehicle</u> in same corridor

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
Case (1)	100%	65%	56%	47%	67%	56%	44%	56%	56%
Case (2)	100%	46%	n/a	n/a	53%	74%	33%	43%	51%
Case (3)	100%	82%	90%	n/a	91%	91%	n/a	51%	59%
Case (4)	100%	164%	161%	131%	197%	179%	141%	73%	62%
Case (5)	100%	97%	268%	221%	111%	271%	229%	84%	76%

Table 3-5b

Relative Commute Costs

Baseline model assumptions

Each travel option compared to <u>lowest cost transit</u> in same corridor

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
Case (1)	230%	149%	128%	108%	154%	129%	**100%**	128%	128%
Case (2)	303%	139%	n/a	n/a	160%	225%	**100%**	130%	156%
Case (3)	123%	**100%**	110%	n/a	111%	111%	n/a	63%	73%
Case (4)	77%	125%	123%	**100%**	151%	137%	108%	56%	48%
Case (5)	103%	**100%**	276%	228%	115%	280%	236%	87%	79%

All else being equal, the results above suggest that the significant cost savings possible from the use of some existing transit options would have already led to striking differences in mode share by corridor. For example, we would expect that the majority of commuters in Cases (1) or (2) would choose transit, while most riders in Cases (4) or (5) would probably choose to drive as a single-occupant vehicle. However, recent estimates show that the highest transit share in the Bay Area (from the East Bay to/from San Francisco—similar to Case (1)), is only 37% (Sacramento Bee 2007). Clearly there are other factors besides the generalized costs that drive travel choice behavior.

Recall from the assumptions section that there are numerous intangible costs and benefits that have not been captured here. The values of cost reported by the model may not reflect the true monetized costs felt by commuters, either as individuals or in the aggregate. The variety of possible intangibles—and the differences in how commuters value these considerations—helps to explain much of the difference between the numerical results generated by the model and observed conditions in the field. Still, the model does permit a quantitative evaluation of how a new mode choice compares to existing choices within a corridor. The remainder of this section contains a discussion of the implications of the baseline scenario for each corridor.

<u>Case (1): San Ramon to Downtown SF (34 miles)</u> In this corridor, the transit options represent different combinations of CCCTA and BART service, all of which are considerably lower cost than driving alone. The lowest cost transit option (Transit F) includes driving up to Walnut Creek BART station, rather than taking CCCTA, and may only be available to a sub-set of commuters. Still, it is clear that, all else being equal, most commuters would be expected to prefer transit. Although transit mode share in this corridor is very high compared to regional averages, a large number of people still choose to drive, so there are clearly some qualitative factors which must be influencing the decision. If flexible carpooling were introduced, its costs would be almost exactly the same as Transit B/E, but its qualitative factors may be closer to driving. It is possible that some transit riders who previously chose the higher priced transit options would shift to flexible carpooling to become riders, since they could lower or maintain their quantitative costs while potentially improving the quality of their ride. However, those with a car who were already choosing Transit C/F might decide to bypass flexible carpooling and still drive to Walnut Creek BART, since the cost of that option would still be lower.

Case (2): Vallejo to Downtown SF (30 miles) This corridor is the only one in the study that has casual carpooling currently operating. Being a casual carpool rider is clearly the least cost option, because riders pay nothing and still have a very fast trip. Casual carpool drivers pay a good deal more, in part because they absorb all of the direct costs of the automobile use. However, there is still a reasonable savings when compared to driving alone. The fact that some drivers choose casual carpooling compared to the very direct transit service provided by the Vallejo bus and ferry indicates that again, there are some key qualitative differences between transit and driving options. In this scenario, the introduction of flexible carpooling is likely to have more mixed effects. The cost to participate as a driver of a flexible carpool is certainly less than driving a casual carpool, so some existing drivers of casual carpool may shift over to the new flexible carpooling option to reduce their quantitative costs. Driving a flexible carpool represents a much more substantial savings compared to driving alone, and so some drivers of single-occupant vehicles are likely to shift to flexible carpooling. However, from the rider point of view, things are very different. Those people currently taking transit or riding in casual carpool would experience a cost increase if they shifted to flexible carpooling, so it is unlikely that many transit riders would shift—as evidenced by the fact that transit riders already have the opportunity to be riders in the very low cost casual carpool and have not chosen to do so. If the qualitative preferences are strong enough, there could be a short-term mismatch between 'too many' drivers and 'not enough riders', although participants would be able to adjust their behavior in real-time, depending on how many waiting cars or riders were at the origin point. Overall, flexible carpooling may help to encourage new participation in carpooling, but it is not likely to draw its participants from existing transit ridership.

Case (3): Vallejo to SF Neighborhood (35 miles) This corridor is similar to Case (2), where drivers of single-occupancy vehicles have to pay a bridge toll, but the morning destination is not located in the downtown area, so it has been assumed that there would not be a parking fee assessed to drivers. The transit options from Vallejo are similar to Case (2) as well, with riders completing their journey via a final segment on SF Muni's light rail. The addition of the extra transit segment means that total travel times—and also the overall costs of commuting—are very similar between solo driving and taking transit. However, the transit option requires a change of provider as well as a walk between stations, so the qualitative experience is definitely superior in the private vehicle. As a result, flexible carpooling compares very favorably to all of the existing alternatives in the corridor. It seems clear that a number of commuters would probably shift to the new option, some from transit and some from driving alone. The exact proportions would depend on the degree to which their qualitative preferences control their current mode choice decision.

Case (4): Hayward to Sunnyvale (26 miles) This corridor represents the only case in the study where the quantified costs of commuting via single-occupancy vehicle are definitively lower than every transit option available in the corridor. This would imply that virtually all travelers who have an automobile available would choose to drive, and in fact the corridor is one of the most congested in the region. One of the major reasons for the discrepancy is that the available transit options are somewhat complex, requiring multiple connections between different modes and providers, with little coordination in schedule and fares. The resulting travel times on transit are 47% to 82% longer than driving alone. Flexible carpooling represents a further improvement in both travel time and costs, and would be a very attractive option for those commuters currently captive on transit, as well as any solo driver who is interested in reducing their costs and speeding their trip. The positive gap between the costs of driving a single-occupancy vehicle and riding transit creates room for the market-clearing price of the ride credit in the corridor to settle at a value somewhat higher than the baseline calculation. This could help to overcome any qualitative preferences of current drivers who would otherwise prefer to be alone in their cars.

Case (5): San Mateo to Mountain View (20 miles) In this corridor, the available transit options are quite varied, with the direct rail trip on transit being almost the same cost as driving a single-occupancy vehicle, while the various bus options are comparatively much more expensive, in large part due to the much slower travel time. Riding the best transit option takes 25% longer than driving alone, but the direct cash outlays for the transit option is slightly higher, making the two options nearly identical from a quantitative perspective. Caltrain has developed a strong reputation for providing a fairly comfortable and reliable service, so it is unlikely that flexible carpooling would offer these riders a markedly improved qualitative experience. Still, flexible carpooling does represent a meaningful savings of between 13% (flexible carpooling driver vs. transit rider) to 30% (flexible carpooling rider vs. single-occupancy vehicle driver). It is likely that participants in flexible carpooling would be drawn from both the driving and transit groups, in number dictated primarily by their qualitative preferences.

3.8. Scenario Results

Based on the scenarios, assumptions, and computations that have been described above, the model has demonstrated the relative costs that commuters experience when making their journey to work, in terms of selected quantifiable variables. The model can also be used to understand the impact of changes to the input variables. Because the model is focused on a subset of all possible costs and decision factors, it is more helpful for evaluating sensitivity, rather than absolute outcomes. By adjusting the values of key input parameters and measuring the change in values *against the baseline*, it is possible to learn which of the factors considered within the model are the most significant. This can help us understand which real world future scenarios might lead to a more or less effective deployment of a system like flexible carpooling.

For example, if the model shows a high sensitivity to wages, then that might suggest a focused deployment only in low-income or high-income areas. (Note that the choice of whether the focus should be low-income or high-income would depend on policy goals, such as provision of transportation alternatives to dependent populations, or promoting efficient use of highway assets.) Alternatively, the model may be much more sensitive to cost of driving, and thus a region-wide deployment should be closely coordinated with the relevant economic, environmental, and road pricing policies. Wherever possible, these sorts of policy suggestions are contained in the discussion below. These should not be taken as prescriptive or exhaustive; they are merely suggestions for policymakers to consider as they evaluate whether flexible carpooling would be an appropriate strategy in their community.

Scenario #1: Parking Cost Allocation

The first scenario studied was the alternative method for allocating parking costs to the trip. Recall that the baseline scenario allocated 100% of the cost to the morning commute being modelled; this approach treats the parking as a 'sunk cost' of using a private car for travel to work. The alternative examined in Scenario 1 allocated only half of the parking cost to the morning trip, consistent with the idea of 'one-way' costs. The alternative generalized costs are shown in Table 3-6, together with a comparison to the baseline scenario.

Table 3-6

Generalized Commute Costs

Alternative parking cost: 50% allocation to reflect 'one-way cost' rather than 'sunk cost'

N.B. -- Does not affect Case 3 or Case 4

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value...								
Case (1)	$ 44.12	$ 33.46	$ 28.67	$ 22.78	$ 34.59	$ 28.95	$ 21.98	$ 26.30	$ 26.26
Case (2)	$ 48.91	$ 25.83	n/a	n/a	$ 29.82	$ 34.40	$ 18.63	$ 21.72	$ 26.47
Case (3)	$ 46.82	$ 38.18	$ 42.17	n/a	$ 42.55	$ 42.55	n/a	$ 24.08	$ 27.84
Case (4)	$ 22.97	$ 37.62	$ 36.95	$ 29.99	$ 45.27	$ 41.10	$ 32.39	$ 16.80	$ 14.35
Case (5)	$ 16.28	$ 15.27	$ 43.59	$ 35.96	$ 17.12	$ 44.11	$ 37.23	$ 13.71	$ 12.44
	Percent Increase (Decrease) from Baseline...								
Case (1)	(15%)	0%	0%	(6%)	0%	0%	(2%)	(9%)	(9%)
Case (2)	(13%)	0%	n/a	n/a	0%	(18%)	0%	(10%)	(9%)
Case (3)	0%	0%	0%	n/a	0%	0%	n/a	0%	0%
Case (4)	0%	0%	0%	0%	0%	0%	0%	0%	0%
Case (5)	0%	(3%)	0%	0%	(6%)	0%	0%	0%	0%

A re-allocation of parking costs reduces the effective cost of travel for all users who park, which includes the single-occupant vehicle and high-occupancy vehicle drivers traveling to downtown San Francisco in Case (1) and Case (2) and the transit riders who need to pay for station-area parking in Case (1)—Transit C/F—and Case (5)—Transit A/D. It is interesting to note the ways that the same variation in downtown parking cost (50% of the $300/month fee) affects different types of drivers differently. The smallest reduction in cost happens with the flexible carpooling scenario because the system uses ride credits to help high-occupancy vehicle drivers recover their travel costs. The total generalized costs of using flexible carpooling are lower, so it might seem like the reduction in effective cost should have a larger percentage impact. However, just as costs are shared among participants, any savings are also distributed. Compare this to the casual carpool driver (under Transit E, Case (2)), who received all of the benefit of the cost themselves (+18%), while the rider (Transit F) has no change.

One factor to consider with this scenario is that the choice of allocation scheme is not dependent on regulatory or policy choices; the two options represent two different ways that individual commuters might choose to 'value' the convenience of parking as part of their personal mode choice decision. The variance in impact across different commuting groups shown above suggests that it may be difficult to find a parking policy that uniformly encourages individual travelers to choose an option like flexible carpooling. (Recalling that this model does not include consideration for the qualitative value that parking represents, the variance is likely to be even wider than shown here.) As a result, the recommendation from this scenario is for a careful and selective coordination of parking policies, depending on mode shift that is desired and/or required to satisfy specific policy goals.

Scenario #2: Increased Fuel Cost

In this scenario, the cost of automobile fuel was increased from its baseline value of $3.51 per gallon up to $4.38 per gallon (a 25% increase) and $5.26 per gallon (a 50% increase). There has been a recent run-up in Bay Area fuel prices since the initial model runs were performed, with regular unleaded gasoline selling well above $4.00 per gallon as of this writing. There is some debate among industry analysts as to whether there is anything that government regulators can (or should) be doing to try to mitigate the price increases. Even so, the relative impact of the increases modelled in Tables 3-7 and 3-8 is instructive regardless of whether actual costs will be unstable in the near term.

Table 3-7

Generalized Commute Costs
Fuel cost increased by 25%

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value…								
Case (1)	$ 53.04	$ 33.46	$ 28.67	$ 24.73	$ 34.59	$ 28.95	$ 22.86	$ 29.27	$ 29.23
Case (2)	$ 57.66	$ 25.83	n/a	n/a	$ 29.82	$ 43.15	$ 18.63	$ 24.64	$ 29.39
Case (3)	$ 48.29	$ 38.18	$ 42.17	n/a	$ 42.55	$ 42.55	n/a	$ 24.57	$ 28.33
Case (4)	$ 24.05	$ 37.62	$ 36.95	$ 29.99	$ 45.27	$ 41.10	$ 32.39	$ 17.16	$ 14.71
Case (5)	$ 17.12	$ 15.77	$ 43.59	$ 35.96	$ 18.12	$ 44.11	$ 37.23	$ 13.99	$ 12.72
	Percent Increase (Decrease) from Baseline…								
Case (1)	3%	0%	0%	2%	0%	0%	2%	2%	2%
Case (2)	2%	0%	n/a	n/a	0%	3%	0%	2%	1%
Case (3)	3%	0%	0%	n/a	0%	0%	n/a	2%	2%
Case (4)	5%	0%	0%	0%	0%	0%	0%	2%	3%
Case (5)	5%	0%	0%	0%	0%	0%	0%	2%	2%

Table 3-8

Generalized Commute Costs
Fuel cost increased by 50%

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value…								
Case (1)	$ 54.47	$ 33.46	$ 28.67	$ 25.10	$ 34.59	$ 28.95	$ 23.23	$ 29.75	$ 29.71
Case (2)	$ 58.92	$ 25.83	n/a	n/a	$ 29.82	$ 44.40	$ 18.63	$ 25.05	$ 29.81
Case (3)	$ 49.75	$ 38.18	$ 42.17	n/a	$ 42.55	$ 42.55	n/a	$ 25.05	$ 28.82
Case (4)	$ 25.14	$ 37.62	$ 36.95	$ 29.99	$ 45.27	$ 41.10	$ 32.39	$ 17.53	$ 15.07
Case (5)	$ 17.96	$ 15.77	$ 43.59	$ 35.96	$ 18.12	$ 44.11	$ 37.23	$ 14.27	$ 13.00
	Percent Increase (Decrease) from Baseline…								
Case (1)	6%	0%	0%	3%	0%	0%	3%	3%	3%
Case (2)	4%	0%	n/a	n/a	0%	6%	0%	3%	3%
Case (3)	6%	0%	0%	n/a	0%	0%	n/a	4%	4%
Case (4)	9%	0%	0%	0%	0%	0%	0%	4%	5%
Case (5)	10%	0%	0%	0%	0%	0%	0%	4%	5%

In this scenario, we see that a 25% increase in fuel costs has relatively little impact on the generalized travel costs for drivers—perhaps a few percentage points change. A 50% increase doubles the impact across the board, but it is still relatively small except for the fastest commutes. This is because the cost of travel time remains a larger component of the total than the cost of fuel for most of the scenarios—at least under present driving conditions.

It should be noted that many transit providers are also subject to rising fuel costs and may try to recover those costs through fare increases. This would increase the costs of the transit options, but every agency will be affected differently, so it is difficult to model the fare increases here. However, the relative impact of a small fare increase would be quite small compared to the long travel and wait times experienced by transit commuters, so the net impact would still be expected to be minor.

The overall conclusion is that fuel cost alone is not a significant driver of mode selection under this choice set. This is consistent with recent research conducted at the Institute of

Transportation Studies at UC Davis indicating that contemporary consumers are less sensitive to price increases than during past fuel price spikes (Sperling 2008).

Scenario #3: Increase in Flexible Carpooling Service Charge

At the present time, it is not known exactly how much it will cost to operate a given deployment of a flexible carpooling system. The current operating model envisions a fixed service charge paid by every participant to recover those costs. For the baseline scenario, the per-ride service charge was estimated at $1.00, but if capital and other start-up costs are large, the value might have to be more than $1.00 to finance and develop the service, depending on how these costs are funded. This scenario examined how an increase of 100% in the service charge (from $1.00 to $2.00 per trip) might affect results.

Table 3-9

Generalized Commute Costs

Increased flexible carpooling service charge

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value...								
Case (1)	$ 51.62	$ 33.46	$ 28.67	$ 24.35	$ 34.59	$ 28.95	$ 22.48	$ 29.80	$ 29.76
Case (2)	$ 56.41	$ 25.83	n/a	n/a	$ 29.82	$ 41.90	$ 18.63	$ 25.22	$ 29.97
Case (3)	$ 46.82	$ 38.18	$ 42.17	n/a	$ 42.55	$ 42.55	n/a	$ 25.08	$ 28.84
Case (4)	$ 22.97	$ 37.62	$ 36.95	$ 29.99	$ 45.27	$ 41.10	$ 32.39	$ 17.80	$ 15.35
Case (5)	$ 16.28	$ 15.77	$ 43.59	$ 35.96	$ 18.12	$ 44.11	$ 37.23	$ 14.71	$ 13.44
	Percent Increase (Decrease) from Baseline...								
Case (1)	0%	0%	0%	0%	0%	0%	0%	3%	3%
Case (2)	0%	0%	n/a	n/a	0%	0%	0%	4%	3%
Case (3)	0%	0%	0%	n/a	0%	0%	n/a	4%	4%
Case (4)	0%	0%	0%	0%	0%	0%	0%	6%	7%
Case (5)	0%	0%	0%	0%	0%	0%	0%	7%	8%

In Table 3-9 we see that the cost increases are roughly similar for all participants, with a smaller increase in the case of higher priced trips like Cases (1), (2), and (3), and a higher impact in the lower priced trips like Cases (4) and (5). The small discrepancy between the flexible carpool driver and rider is due to the fact that the riders' costs are slightly higher to begin with because they experience a transfer penalty cost that the high-occupancy vehicle driver does not.

Note that the impact of doubling the fee (adding only a dollar to the cost of each flexible carpool trip) has an impact on flexible carpooling participants that is equal to or greater than a 50% increase in the cost of fuel! This would seem to suggest that one of the most critical variables in developing flexible carpooling is the sizing, planning, and financing of the deployment. However, though the increased service charge does have a meaningful impact, the relative price of using flexible carpooling remains less than or equal to transit alternatives. This suggests that some commuters would still use flexible carpooling—even with the larger service charge—if the qualitative attributes available in flexible carpooling are more desirable than those available in existing transit.

Scenario #4: Change in Value of Ride Credit

In this scenario, the service charge paid to the operator of flexible carpooling was returned to its baseline value of $1.00, but the value of the ride credit—the market-clearing price for offering or taking a ride on a given corridor—was allowed to fluctuate. Recall that the specific value of the ride credit in each corridor is based on one third the costs of single-occupant vehicle driving. A multiplier was used to test increases and decreases of 25% and 50% on all corridors at the same time, regardless of the corridor-specific ride credit value. This approach permits consideration of the possible outcomes regardless of whether our simplified method has over- or under-estimated the market valuation of the ride credit. The baseline and scenario values for the ride credit are shown below in Table 3-10. The ride credit in the first three cases is large, because drivers must pay the cost of gasoline, bridge tolls, and parking, while driving a single-occupant vehicle in Case (4) and Case (5) only incurs the cost of gasoline. Total costs for these scenario results are given in Tables 3-11, 3-12, and 3-13, below.

Table 3-10

Comparison of Ride Credit Values

	-50%	-25%	Baseline	+25%	+50%
Case (1)	$ 4.12	$ 6.17	$ 8.23	$ 10.29	$ 12.35
Case (2)	$ 4.67	$ 7.01	$ 9.34	$ 11.68	$ 14.01
Case (3)	$ 2.31	$ 3.47	$ 4.62	$ 5.78	$ 6.93
Case (4)	$ 0.73	$ 1.09	$ 1.45	$ 1.81	$ 2.18
Case (5)	$ 0.56	$ 0.83	$ 1.11	$ 1.39	$ 1.67

Table 3-11

Generalized Commute Costs

Ride Credit decreased by 25%

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value...								
Case (1)	$ 51.62	$ 33.46	$ 28.67	$ 24.35	$ 34.59	$ 28.95	$ 22.48	$ 32.91	$ 26.70
Case (2)	$ 56.41	$ 25.83	n/a	n/a	$ 29.82	$ 41.90	$ 18.63	$ 28.89	$ 26.64
Case (3)	$ 46.82	$ 38.18	$ 42.17	n/a	$ 42.55	$ 42.55	n/a	$ 26.39	$ 26.69
Case (4)	$ 22.97	$ 37.62	$ 36.95	$ 29.99	$ 45.27	$ 41.10	$ 32.39	$ 17.53	$ 13.99
Case (5)	$ 16.28	$ 15.77	$ 43.59	$ 35.96	$ 18.12	$ 44.11	$ 37.23	$ 14.27	$ 12.16
	Percent Increase (Decrease) from Baseline...								
Case (1)	0%	0%	0%	0%	0%	0%	0%	14%	(7%)
Case (2)	0%	0%	n/a	n/a	0%	0%	0%	19%	(8%)
Case (3)	0%	0%	0%	n/a	0%	0%	n/a	10%	(4%)
Case (4)	0%	0%	0%	0%	0%	0%	0%	4%	(3%)
Case (5)	0%	0%	0%	0%	0%	0%	0%	4%	(2%)

Table 3-12

Generalized Commute Costs

Ride Credit increased by 25%

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value...								
Case (1)	$ 51.62	$ 33.46	$ 28.67	$ 24.35	$ 34.59	$ 28.95	$ 22.48	$ 24.68	$ 30.82
Case (2)	$ 56.41	$ 25.83	n/a	n/a	$ 29.82	$ 41.90	$ 18.63	$ 19.55	$ 31.31
Case (3)	$ 46.82	$ 38.18	$ 42.17	n/a	$ 42.55	$ 42.55	n/a	$ 21.77	$ 29.00
Case (4)	$ 22.97	$ 37.62	$ 36.95	$ 29.99	$ 45.27	$ 41.10	$ 32.39	$ 16.08	$ 14.71
Case (5)	$ 16.28	$ 15.77	$ 43.59	$ 35.96	$ 18.12	$ 44.11	$ 37.23	$ 13.15	$ 12.72
	Percent Increase (Decrease) from Baseline...								
Case (1)	0%	0%	0%	0%	0%	0%	0%	(14%)	7%
Case (2)	0%	0%	n/a	n/a	0%	0%	0%	(19%)	8%
Case (3)	0%	0%	0%	n/a	0%	0%	n/a	(10%)	4%
Case (4)	0%	0%	0%	0%	0%	0%	0%	(4%)	3%
Case (5)	0%	0%	0%	0%	0%	0%	0%	(4%)	2%

Table 3-13

Generalized Commute Costs

Ride Credit increased by 50%

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value...								
Case (1)	$ 51.62	$ 33.46	$ 28.67	$ 24.35	$ 34.59	$ 28.95	$ 22.48	$ 20.57	$ 32.87
Case (2)	$ 56.41	$ 25.83	n/a	n/a	$ 29.82	$ 41.90	$ 18.63	$ 14.88	$ 33.64
Case (3)	$ 46.82	$ 38.18	$ 42.17	n/a	$ 42.55	$ 42.55	n/a	$ 19.46	$ 30.15
Case (4)	$ 22.97	$ 37.62	$ 36.95	$ 29.99	$ 45.27	$ 41.10	$ 32.39	$ 15.35	$ 15.07
Case (5)	$ 16.28	$ 15.77	$ 43.59	$ 35.96	$ 18.12	$ 44.11	$ 37.23	$ 12.59	$ 13.00
	Percent Increase (Decrease) from Baseline...								
Case (1)	0%	0%	0%	0%	0%	0%	0%	(29%)	14%
Case (2)	0%	0%	n/a	n/a	0%	0%	0%	(39%)	16%
Case (3)	0%	0%	0%	n/a	0%	0%	n/a	(19%)	8%
Case (4)	0%	0%	0%	0%	0%	0%	0%	(9%)	5%
Case (5)	0%	0%	0%	0%	0%	0%	0%	(8%)	5%

Recall that in the proposed model of flexible carpooling, two riders each pay their ride credit to one driver. We can see that the negative impact of an increase in the value of ride credit for the riders becomes a positive savings (or reduction in cost) for the driver. This is in contrast to an increase in the *service charge* in the previous scenario, which all participants experience as a net cost.

Note the wide variation in how the same percentage change impacts results. For low-cost corridors like Case (4) and Case (5), the impacts to both driver and rider are relatively small. But, for the corridors where the costs are higher, the increasing ride credit cost creates a big disparity between the driver and any riders in a high-occupancy vehicle. It is unclear whether there is a breaking point at which such a disparity would influence the participants' choices about how often they drive or ride.

However, we can say something about the relative cost of flexible carpooling as compared to other modes of travel. If the difference between choosing a high-occupancy vehicle versus other modes becomes large, the other modes begin to look more attractive. For example, in Case (2), the high-occupancy vehicle rider would experience an effective cost of almost $35.00 per trip, but the effective cost of the Transit A option is less than $27.00 per trip. If qualitative factors did not outweigh the cost discrepancy, more high-occupancy vehicle riders would shift to transit, resulting in less system demand for flexible carpooling, and a likely reduction in the market-based ride credit value. On the other hand, for Case (4), the cost to participate in flexible carpooling is still well below the costs of any other mode. As more travelers choose a lower-cost option like flexible carpooling, the value of the ride credit would rise; all else being equal, this should attract more high-occupancy vehicle drivers to the system until a stable equilibrium is reached.

Scenario #5: Increase in Schedule Buffering Time

The next area examined was the way in which added wait times at the beginning of the journey can affect traveller results. If a transit service is unreliable, the user must arrive early—or may be forced to wait longer—at the initial point, to guarantee they will catch the right vehicle for an on-time arrival at their destination. Similarly, if a flexible carpooling origin is lightly used, the flexible carpooling participant may have to wait longer before enough participants arrive to fill the car. For the purposes of this scenario, both the time to form a carpool at the flexible carpooling origin and the buffer that the transit rider allows at their transit origin were increased from 3 minutes to 5 minutes (+67%).

Table 3-14

Generalized Commute Costs

Origin travel buffers increased by 67%

	Absolute Value...								
Case (1)	$ 51.62	$ 34.35	$ 29.57	$ 25.25	$ 35.49	$ 29.85	$ 23.38	$ 29.70	$ 29.66
Case (2)	$ 56.41	$ 25.83	n/a	n/a	$ 29.82	$ 42.79	$ 19.53	$ 25.12	$ 29.87
Case (3)	$ 46.82	$ 38.18	$ 43.07	n/a	$ 42.55	$ 42.55	n/a	$ 24.98	$ 28.74
Case (4)	$ 22.97	$ 38.52	$ 37.85	$ 30.89	$ 46.17	$ 42.00	$ 33.29	$ 17.70	$ 15.25
Case (5)	$ 16.28	$ 16.67	$ 44.49	$ 36.86	$ 19.02	$ 45.01	$ 38.12	$ 14.61	$ 13.34
	Percent Increase (Decrease) from Baseline...								
Case (1)	0%	3%	3%	4%	3%	3%	4%	3%	3%
Case (2)	0%	0%	n/a	n/a	0%	2%	5%	4%	3%
Case (3)	0%	0%	2%	n/a	0%	0%	n/a	4%	3%
Case (4)	0%	2%	2%	3%	2%	2%	3%	5%	6%
Case (5)	0%	6%	2%	3%	5%	2%	2%	7%	7%

Even though the increase in buffer time was significant compared to the baseline value, Table 3-14 shows that the overall travel times for these corridors are large enough that it does not represent a large impact on overall results. The implication is that a significant increase in reliability of transit arrival time and/or carpool formation time might not have a very big effect on mode choice. However, the combination of an increase in one type of reliability and a decrease in the other could be more meaningful. For example, if the service improves on a transit mode (thereby decreasing the required schedule buffer) at the same time as usage of flexible carpooling decreases (thereby increasing the required time to form carpools), the net effect becomes much more significant, potentially inducing a shift between modes.

Scenario #6: Change in Transfer Penalty

Another key area where assumptions can influence results is in the choice of penalty to assign to transfers between vehicles. The time spent waiting between moving portions of a journey is already weighted at twice the cost of in-vehicle time. However, some analysts also add a penalty value of a certain number of minutes to the trip (that carries the associated travel time cost) to account for the inconvenience and uncertainty of changing vehicles: the rider must collect personal belongings as they exit, possibly change platforms, levels, or even stations, and deal with additional stress in the case of any service disruptions. The baseline value of this transfer penalty was 12 additional minutes of in-vehicle time. However, this scenario examined the impact of a 25% reduction to 9 minutes. The results are shown in Table 3-15.

Table 3-15

Generalized Commute Costs

Transfer penalty reduced by 25%

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value…								
Case (1)	$ 51.62	$ 32.78	$ 28.00	$ 23.68	$ 33.91	$ 28.28	$ 21.81	$ 28.80	$ 28.09
Case (2)	$ 56.41	$ 25.83	n/a	n/a	$ 29.82	$ 41.90	$ 17.96	$ 24.22	$ 28.30
Case (3)	$ 46.82	$ 37.51	$ 40.82	n/a	$ 41.87	$ 41.87	n/a	$ 24.08	$ 27.17
Case (4)	$ 22.97	$ 35.60	$ 35.60	$ 29.32	$ 43.25	$ 39.75	$ 31.72	$ 16.80	$ 13.67
Case (5)	$ 16.28	$ 15.77	$ 42.92	$ 34.61	$ 18.12	$ 43.44	$ 35.88	$ 13.71	$ 11.77
	Percent Increase (Decrease) from Baseline…								
Case (1)	0%	(2%)	(2%)	(3%)	(2%)	(2%)	(3%)	0%	(2%)
Case (2)	0%	0%	n/a	n/a	0%	0%	(4%)	0%	(2%)
Case (3)	0%	(2%)	(3%)	n/a	(2%)	(2%)	n/a	0%	(2%)
Case (4)	0%	(5%)	(4%)	(2%)	(4%)	(3%)	(2%)	0%	(5%)
Case (5)	0%	0%	(2%)	(4%)	0%	(2%)	(4%)	0%	(5%)

As with other scenarios that evaluate time-based impacts, a relatively large change in one portion of the journey had a small impact on the total costs because it does not outweigh the much larger elements of the trip. However, we can see how cost impacts do depend on the number of transfers, since Case (4) shows three different transit options, each with a different number of transfers: Transit A/D has three transfers; Transit B/E has two; and Transit C/F has one. Naturally the reduced penalty has a more beneficial impact when more transfers are required for the journey, so Transit A/D shows the most improvement. The high-occupancy vehicle rider also experiences bigger gains in Cases (4) and (5) because the overall trip time is shorter, and the relative impact of the savings is higher.

This is another scenario that shows sensitivity to *personal* valuations of trip attributes, rather than a policy choice or market-wide effect such as the level of service charge or fuel price. This model cannot account for the distribution in how individual commuters feel about making transfers. However, it does show that the variance in how commuters value the penalty does not have much impact on results except in the most complex transit journeys. If transit options in a flexible carpooling corridor are direct and well-served, flexible carpooling represents a reasonably comparable option to transit regardless of the value of penalty; for those corridors with poor transit service, flexible carpooling *may* represent a small improvement over current transit choices.

Scenario #7: Wage Sensitivity

One of the most difficult items to evaluate in a high-level modeling exercise is the overall economic sensitivity of participants to the travel costs they incur. A regional average wage rate was used as a proxy for value of time, but clearly this metric will not be the same for all travelers. As a result the model can be used to learn more about the sensitivity of the results to the precise value of the wage rate, to weigh its relative effect on overall viability. Multiple scenarios are presented in Tables 3-16, 3-17, 3-18, and 3-119, including both increases and decreases in the wage rate relative to the baseline.

Table 3-16

Generalized Commute Costs

Wage multiplier at 75% of baseline

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value…								
Case (1)	$ 46.57	$ 26.38	$ 23.06	$ 20.93	$ 27.52	$ 23.34	$ 19.06	$ 24.59	$ 23.88
Case (2)	$ 50.79	$ 21.06	n/a	n/a	$ 23.93	$ 37.91	$ 13.98	$ 20.23	$ 24.31
Case (3)	$ 40.31	$ 30.61	$ 33.41	n/a	$ 33.85	$ 33.85	n/a	$ 19.20	$ 22.29
Case (4)	$ 19.60	$ 28.87	$ 28.36	$ 23.14	$ 36.52	$ 32.51	$ 25.54	$ 14.50	$ 11.37
Case (5)	$ 14.04	$ 12.74	$ 33.38	$ 27.65	$ 15.09	$ 33.89	$ 28.92	$ 11.80	$ 9.86
	Percent Increase (Decrease) from Baseline…								
Case (1)	(10%)	(21%)	(20%)	(14%)	(20%)	(19%)	(15%)	(15%)	(17%)
Case (2)	(10%)	(18%)	n/a	n/a	(20%)	(10%)	(25%)	(16%)	(16%)
Case (3)	(14%)	(20%)	(21%)	n/a	(20%)	(20%)	n/a	(20%)	(20%)
Case (4)	(15%)	(23%)	(23%)	(23%)	(19%)	(21%)	(21%)	(14%)	(21%)
Case (5)	(14%)	(19%)	(23%)	(23%)	(17%)	(23%)	(22%)	(14%)	(21%)

Table 3-17

Generalized Commute Costs

Wage multiplier at 90% of baseline

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value…								
Case (1)	$ 49.60	$ 30.63	$ 26.42	$ 22.98	$ 31.76	$ 26.71	$ 21.11	$ 27.11	$ 26.81
Case (2)	$ 54.16	$ 23.92	n/a	n/a	$ 27.47	$ 40.30	$ 16.77	$ 22.62	$ 27.11
Case (3)	$ 44.22	$ 35.15	$ 38.67	n/a	$ 39.07	$ 39.07	n/a	$ 22.13	$ 25.62
Case (4)	$ 21.62	$ 34.12	$ 33.51	$ 27.25	$ 41.77	$ 37.66	$ 29.65	$ 15.88	$ 13.16
Case (5)	$ 15.39	$ 14.56	$ 39.50	$ 32.63	$ 16.91	$ 40.02	$ 33.90	$ 12.94	$ 11.41
	Percent Increase (Decrease) from Baseline…								
Case (1)	(4%)	(8%)	(8%)	(6%)	(8%)	(8%)	(6%)	(6%)	(7%)
Case (2)	(4%)	(7%)	n/a	n/a	(8%)	(4%)	(10%)	(7%)	(6%)
Case (3)	(6%)	(8%)	(8%)	n/a	(8%)	(8%)	n/a	(8%)	(8%)
Case (4)	(6%)	(9%)	(9%)	(9%)	(8%)	(8%)	(8%)	(5%)	(8%)
Case (5)	(5%)	(8%)	(9%)	(9%)	(7%)	(9%)	(9%)	(6%)	(8%)

Table 3-18

Generalized Commute Costs

Wage multiplier at 105% of baseline

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value...								
Case (1)	$ 52.63	$ 34.87	$ 29.79	$ 25.03	$ 36.00	$ 30.07	$ 23.17	$ 29.64	$ 29.74
Case (2)	$ 57.53	$ 26.79	n/a	n/a	$ 31.00	$ 42.69	$ 19.57	$ 25.02	$ 29.90
Case (3)	$ 48.13	$ 39.70	$ 43.92	n/a	$ 44.29	$ 44.29	n/a	$ 25.06	$ 28.95
Case (4)	$ 23.64	$ 39.37	$ 38.67	$ 31.36	$ 47.02	$ 42.82	$ 33.76	$ 17.26	$ 14.94
Case (5)	$ 16.73	$ 16.38	$ 45.63	$ 37.62	$ 18.73	$ 46.15	$ 38.89	$ 14.09	$ 12.96
	Percent Increase (Decrease) from Baseline...								
Case (1)	2%	4%	4%	3%	4%	4%	3%	3%	3%
Case (2)	2%	4%	n/a	n/a	4%	2%	5%	3%	3%
Case (3)	3%	4%	4%	n/a	4%	4%	n/a	4%	4%
Case (4)	3%	5%	5%	5%	4%	4%	4%	3%	4%
Case (5)	3%	4%	5%	5%	3%	5%	4%	3%	4%

Table 3-19

Generalized Commute Costs

Wage multiplier at 115% of baseline

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value...								
Case (1)	$ 54.65	$ 37.70	$ 32.04	$ 26.40	$ 38.83	$ 32.32	$ 24.54	$ 31.32	$ 31.69
Case (2)	$ 59.77	$ 28.69	n/a	n/a	$ 33.36	$ 44.29	$ 21.43	$ 26.61	$ 31.77
Case (3)	$ 50.73	$ 42.73	$ 47.42	n/a	$ 47.77	$ 47.77	n/a	$ 27.01	$ 31.18
Case (4)	$ 24.99	$ 42.88	$ 42.10	$ 34.10	$ 50.53	$ 46.25	$ 36.50	$ 18.18	$ 16.13
Case (5)	$ 17.63	$ 17.59	$ 49.72	$ 40.94	$ 19.94	$ 50.24	$ 42.21	$ 14.85	$ 13.99
	Percent Increase (Decrease) from Baseline...								
Case (1)	6%	13%	12%	8%	12%	12%	9%	9%	10%
Case (2)	6%	11%	n/a	n/a	12%	6%	15%	10%	10%
Case (3)	8%	12%	12%	n/a	12%	12%	n/a	12%	12%
Case (4)	9%	14%	14%	14%	12%	13%	13%	8%	12%
Case (5)	8%	12%	14%	14%	10%	14%	13%	8%	12%

As expected, the wage rate used in the model has a significant impact on results. This is because in almost every case, the cost of the time spent traveling far exceeded any direct or indirect costs of making the trip. The fact that travel time is the biggest cost element in the model supports the observed commuter preference for driving over transit; trips on transit often take longer because of intermediate stops or they are perceived to take longer because of unreliability or less direct routings. Thus, a commuter trying to minimize the personal cost of their journey might choose to drive, even if they could achieve a monetary cost reduction from making a different choice. The one exception to the observation that travel time is the largest cost component occurs when the traveller must pay downtown parking charges, in the case where these are allocated 100% to the morning trip. In this case, the direct costs slightly exceed the travel time costs for single-occupant vehicle and casual carpool drivers only.

Another observation is that the magnitude of the cost impacts due to wages tends to vary more significantly across modes more than across corridors. Thus, policymakers and operators in a given corridor should be sensitive to income distributions within different mode choice segments, in addition to the distribution in the commuting population as a whole. This type of data must be obtained empirically through survey methodologies and could be a significant driver of the success of flexible carpooling within a given corridor.

Scenario #8: Travel Time Valued at Zero

One way to better understand the significant impact of the cost of travel time on the model results is to set its value to zero. The results are shown below in Table 20. The values of percent change versus the baseline vary from 39% (solo driving in Case (1)) up to 100% (the casual carpool rider in Case (2)). The average of the percent change values in these cases is 74%--in effect, nearly three quarters of the total cost is the value of the time spent making the journey. See Table 3-20.

The costs that remain after excluding time vary a great deal across the choice set. Some transit options only cost a few dollars, while the options that include bridge tolls and downtown parking are ten times as much. Driving in several corridors is actually cheaper than transit in other corridors! In some cases, flexible carpooling is almost equivalent to driving; in other corridors it represents only a fraction of the costs. The fact that the numerical results are so different when the value of time is not included points out just how onerous congestion delay and slow-moving transit can be on our daily commute. Once the value of travel time is removed, transit appears to be a far superior option. Transit is virtually always cheaper than driving alone and in many cases cheaper than driving the flexible carpool. We can also see how much of an improvement flexible carpooling would represent over casual carpooling in Case (2).

Table 3-20

Generalized Commute Costs

Value of Hourly Wage Set to Zero

	SOV	Transit A	Transit B	Transit C	Transit D	Transit E	Transit F	HOV - driver	HOV - rider
	Absolute Value...								
Case (1)	$ 31.42	$ 5.17	$ 6.22	$ 10.66	$ 6.30	$ 6.50	$ 8.79	$ 11.96	$ 9.23
Case (2)	$ 33.96	$ 6.75	n/a	n/a	$ 6.25	$ 25.96	$ -	$ 8.28	$ 10.34
Case (3)	$ 20.78	$ 7.88	$ 7.15	n/a	$ 7.75	$ 7.75	n/a	$ 4.55	$ 5.62
Case (4)	$ 9.50	$ 2.60	$ 2.60	$ 2.60	$ 10.25	$ 6.75	$ 5.00	$ 7.60	$ 2.45
Case (5)	$ 7.30	$ 3.65	$ 2.73	$ 2.73	$ 6.00	$ 3.25	$ 4.00	$ 6.07	$ 2.11
	Percent Increase (Decrease) from Baseline...								
Case (1)	(39%)	(85%)	(78%)	(56%)	(82%)	(78%)	(61%)	(58%)	(68%)
Case (2)	(40%)	(74%)	n/a	n/a	(79%)	(38%)	(100%)	(66%)	(64%)
Case (3)	(56%)	(79%)	(83%)	n/a	(82%)	(82%)	n/a	(81%)	(80%)
Case (4)	(59%)	(93%)	(93%)	(91%)	(77%)	(84%)	(85%)	(55%)	(83%)
Case (5)	(55%)	(77%)	(94%)	(92%)	(67%)	(93%)	(89%)	(56%)	(83%)

3.9. Conclusions

In the scenarios modelled above, the major modelling variables were adjusted, with contrasting impacts on the results. In some cases, the variable in question represented a feature that could be designed into the system, such as the level of the service charge. In other cases, the variable was a market attribute that is difficult to control at the local level, such as fuel price. Still others represented personal valuations of key service variables that are likely to have wide distributions over regional and local areas as well as among the commuting population in a corridor. The results also varied in their level of impact: certain variables showed strong influence on results (e.g., wage sensitivity), while others were mixed or minimally significant (e.g., fuel costs). When brought together, there is no clear correlation between the type of variable and the level of impact on results, as shown in Table 3-21.

Table 3-21

Scenario Summary

Variable Modelled	Variable Type	Cost Impact
Parking cost allocation	Personal valuation	Mixed
Fuel Cost	Market attribute	Low
Service Charge	System design attribute	Medium
Ride Credit	Market attribute	High
Schedule buffer time	Combination[1]	Medium
Transfer penalty	Personal valuation	Low
Wage sensitivity	Market attribute	High

[1]A change in the schedule buffer time relates differently to the different modes, e.g., the schedule reliability of transit is a system design issue as well as an individual valuation of the need for on-time arrival; the schedule buffer required for flexible carpooling depends both on the system design of where and how to build a flexible carpooling facility as well as the market demand for the service at the origin node.

The table above only shows how each variable modelled compares to the baseline. It does not indicate how significantly the variables perform against each other. It would be tempting to say that policymakers and system designers should focus only on what they can control or only on variables with high impacts to costs. However, a much more significant consideration is whether a change in variable values can impact the costs—and the qualitative experience—enough to shift mode share from its current levels. This is more likely to happen from a coordinated effort to influence the full combination of variables, rather than from focusing on any one or two attributes alone. Moreover, the high impact of some features beyond the immediate control of the implementers (e.g., wage sensitivity) indicate that a necessary first step in deployment is a more complete understanding of the demographic characteristics and travel preferences of the local population in the corridor(s) to be served. Once these are well understood, policymakers can evaluate whether flexible carpooling is likely to be a feasible and sustainable transportation alternative for the region they serve.

3.10. References

Beroldo, S., 1999. Casual Carpooling 1998 Update (January, 1999). RIDES for Bay Area Commuters, Inc.

Hoge, P., 2006. "YOUR COMMUTE IS SHRINKING: Bay Area workers drive less as more jobs move to suburbs", published February 28, 2006, in the San Francisco Chronicle.

Kittleson, 2003. Kittleson & Associates, Transit Capacity and Quality of Service Manual, TCRP Report 100, Transportation Research Board, 2003

Littman, T., 2007. "Valuing Transit Service Quality Improvements--Considering Comfort and Convenience In Transport Project Evaluation", Victoria Transport Policy Institute, May, 2007

MTC, 2006. State of the System 2006. MTC.

Nelson, E. N., 2007. "I-880 commute least reliable, study finds; Commission report compares driving times in seven major Bay Area Corridors," Oakland Tribune, June 1, 2007

Sacramento Bee, 2007. "RT chief dismayed at funds plan," from Back-Seat Driver column, published Monday, April 2, 2007, in the Sacramento Bee

Sperling, D., 2008. "Consumer Response to Fuel Price Changes: Implications for Policy," presented at 87th Annual Meeting of the Transportation Research Board, January 16, 2008

US Bureau of Labour, 2007. Statistics Update.

www.511.org, 2008. "Take Transit Trip Planner" feature on the 511 website which allowed travel times for transit to be calculated.

www.commutesolutions.org, 2008. Website used to extract estimates of car operating costs on a per mile basis.

Chapter 4: The Energy Consumption Impacts of Flexible Carpooling

Paul Minett

4.1. Chapter Summary

This chapter is concerned with the energy consumption impacts of flexible carpooling. The previous chapter explored the decision factors that would influence individual behaviour. This chapter considers the energy implications of the system once the individual decisions have joined. It assesses whether the system is a good idea from a societal perspective on the basis of energy savings. A spreadsheet model was developed to calculate the energy consumption of a commuter group under different scenarios, and a discussion is presented to consider variations in the key assumptions. The analysis suggests that energy savings exist, while recognising that the magnitude of the savings is situation dependent.

4.2. Introduction

The alternative modes available to a commuter include 'drive alone' (SOV), 'carpool/vanpool' (HOV), and 'bus/train'. They also include cycling, walking, and telecommuting, but for the purpose of this chapter, the analysis is restricted to motorized travel.

Flexible carpooling envisages providing a convenient transport solution for a large group (150 or more people) who make sufficiently convergent trips (the route from their origins converges at a single point, and their destinations are accessible from a single drop-off point) that they could combine into carpools at the convergence point or designated facility. It would provide a mechanism for forming carpools (driver plus at least two riders) at the convergence point enabling at least two thirds of the commuters to leave their cars behind. The convergence point would be a parking facility. (There would be provision for people to walk or cycle or get dropped off at the convergence point; however, the use of these facilities is not included in this analysis.)

The key distinction between flexible carpooling and traditional carpooling is that there would be no pre-arrangement of rides, and the combinations of riders and driver would be established by the order of arrival at the convergence point each day.

On some routes, as many as 80% of the commuters drive alone. A key reason they give for not carpooling is that they have a variable schedule and would not want to be tied to someone else's schedule. The notion of carpooling in order of arrival potentially removes this schedule synchronicity barrier.

In many cases on such routes commuters continue to drive alone even though there is a bus service that they could use. They would give a variety of reasons for not using the bus service. A reason that is often given is that a public transport commute can take up to twice as long, door-to-door, as a car-based commute. An express bus service could reduce this margin by not stopping 'en route' to pick up additional passengers.

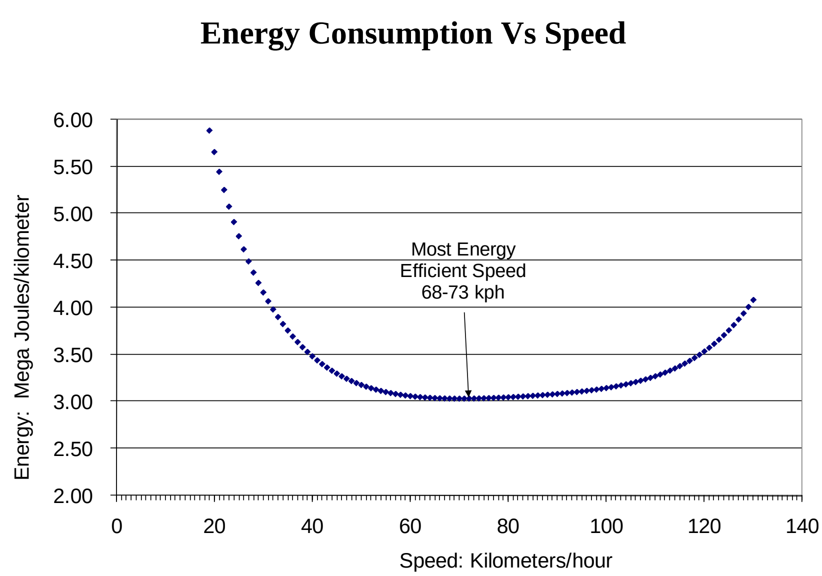
This analysis will compare the energy consumption impacts of a group of commuters under three different scenarios as follows, if they were to: 1) drive alone, 2) carpool using a flexible carpooling service from a single convergence point with adequate parking, or 3) use an express bus service from the same convergence point.

In estimating the energy consumption impacts, the author distinguishes between three constituencies:

- The group of commuters,
- The wider traveling community on the same route, and
- The operators of the express bus service.

A key input to the analysis is the relationship between traffic speed and energy consumption: very slow traffic and very fast traffic consume energy at rates above that of medium speed traffic. The energy consumption for average traffic at different speeds is shown in Figure 4-1 based on work carried out by Barth and Boriboonsomsin 2007.

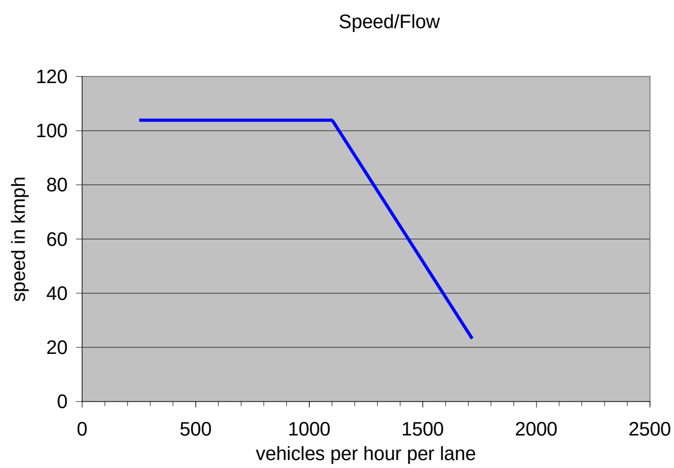
Figure 4-1



A second key input is the relationship between speed and flow. As flow (vehicle count or demand) rises above a certain level, average speed is reduced. This is not a purely linear effect, and very high flows have been observed at high speeds (for example 2,500 vehicles per lane hour at 60 miles per hour (mph) (PeMS Database 2008). However, road design and the incidence of merging traffic impedes speed, and there is a greater probability that traffic flows will ‘break down’ with more traffic. Figure 4-2 is based on actual data from San Francisco region HOV lanes (Caltrans 2004).

Figure 4-2

Vehicle Speed vs. Vehicle Flow



It can be seen that the energy consumption impacts of the different modal choices will vary depending on the prevailing traffic conditions on the route. At vehicle counts below 1,100 vehicles per lane hour (v/lh) initiatives to reduce traffic would save only the energy that would have been consumed by the vehicles removed. At vehicle counts above about 1,300 v/lh, initiatives to reduce traffic would help the traffic speed up, therefore saving energy for the rest of the traffic as well as saving energy that would have been consumed by the vehicles removed. Interestingly, there is a level (between 1,100 and 1,300 v/lh) at which decreasing the level of traffic could result in a less efficient operating speed for all the traffic (because it allows the traffic to operate at less efficient highway speeds).

Flexible carpooling has been designed for situations where there is traffic congestion. Therefore, the analysis that follows is based on a situation where demand per lane hour exceeds 1,300 vehicles.

4.3. Approach

The author’s approach is to calculate the energy consumption under a consistent set of assumptions and then discuss the potential for different results if the assumptions are varied.

Assumptions:

- The route is 12 miles (20 km) from convergence point to destination area;
- There are two lanes of general traffic and one HOV3+ lane (driver plus at least two passengers) for the whole distance;
- There is demand on the route over the peak period of 7,845 vehicles in the general purpose lanes. This is an average of 1,569 per lane hour for the 2.5 hour peak travel period. HOV lane use is negligible;
- The average speed in the general purpose lanes is 25 mph (40.25 kilometers per hour; kmph);
- The average speed in the HOV lane is 55 mph (88.6 kmph);
- The traffic consumes energy at the rates shown in Figure 1, given the speed that it is travelling (the table underlying Figure 1 will be used to determine energy use at different speeds);
- Changes to the volume of traffic will change the average speed of the traffic according to the relationship shown in Figure 2; and
- The commuter group is 150 people, who when they drive alone are part of the total demand of 7,845 vehicles.

The measures of energy used in this chapter are either megajoule (MJ) (10^6 joules) or gigajoule (GJ) (10^9 joules), or terajoule (TJ) (10^{12} joules). One U.S. gallon of gasoline contains approximately 121 MJ or 0.121 GJ of energy. At 26 mpg a car would use 4.65 MJ per mile (2.9 MJ per kilometer). One GJ of energy (8.264 gallons of gasoline) would propel that car 215 miles. One TJ of energy (8,264 gallons of gasoline) would propel it 215,000 miles.

4.4. Scenario 1: Energy Use if Commuter Group all Drive Alone (SOV)

In this scenario, the commuter group drives alone in the general purpose lanes. There is no express bus service. The commuter group experiences energy consumption patterns consistent with the rest of the traffic. Figure 4-3 shows the calculations, and Table 4-1 shows that the one-way energy consumption per day is 527.5 GJ.

Figure 4-3: Calculation for Scenario 1

Starting Volume	7845						
Traffic Change							
% Change	0						
Starting Flow per lane hour	1569	Consumption					
Starting Speed (kmph)	40.2663	3.48	MJ/Km/Vehicle				
Starting consumption		27,303	MJ/Km		Allocated to User Group		
Traffic Change	0						
Ending Flow per lane hour	1569				Commuter Group	Rest of Traffic	Total
Ending Speed (kmph)	40.2663	3.48	MJ/Km/Vehicle	Vehicles	150	7,695	7,845
Ending consumption		27,303	MJ/Km	MJ/Km	522	26,781	27,303
Impact of Change (MJ per Km)		-					
Distance (km)		19.32	weighted avg distance for the whole traffic,				
Total Change per Day		-	MJ per day				
					Commuter Group	Rest of Traffic	Total
Start Consumption per day		527,502	MJ	MJ Start	10,086	517,416	527,502
End Consumption per day		527,502	MJ	MJ End	10,086	517,416	527,502
Change as % of Start		0%					

Table 4-1: Total Energy Consumption When Commuter Group Drive Alone

Scenario 1	Commuter Group	Rest of Traffic	Bus Operator	Total
Commuter Group Drive SOV	10.1 GJ	517.4 GJ	Nil	527.5 GJ

4.5. Scenario 2: Energy Use if Commuter Group Uses Flexible Carpooling

In this scenario, the 150 members of the commuter group use flexible carpooling to get to work each day. They use 100 spaces of a parking facility at the convergence point, leave 100 cars behind and carry on with 50 cars each carrying the driver and two passengers. Because the vehicles are now HOVs they travel in the HOV lane. There is, therefore, a reduction to the traffic in the general purpose lane of 150 vehicles and an increase in the traffic in the HOV lane of 50 vehicles (see Figures 4-4 & 4-5 and Table 4-2 for the total energy use). Energy use in this scenario is 497.6 GJ, being 3.0 GJ for the commuter group and 494.6 GJ for the rest of the traffic. This represents a reduction of 29.9 GJ per day compared with the SOV scenario.

Figure 4-4: Calculation 1 for Scenario 2, Impact on Rest of Traffic

Starting Volume	7845						
Traffic Change	-150						
% Change	-1.9%						
Starting Flow per lane hour	1569	Consumption					
Starting Speed (kmph)	40.2663	3.48	MJ/Km/Vehicle				
Starting consumption		27,303	MJ/Km		Allocated to User Group		
Traffic Change	-30						
Ending Flow per lane hour	1539				Commuter Group	Rest of Traffic	Total
Ending Speed (kmph)	44.0853	3.33	MJ/Km/Vehicle	Vehicles		7,845	7,845
Ending consumption		25,602	MJ/Km	MJ/Km	0	25,602	25,602
Impact of Change (MJ per Km)		- 1,702					
Distance (km)		19.32	weighted avg distance for the whole traffic,				
Total Change per Day		- 32,879	MJ per day				
					Commuter Group	Rest of Traffic	Total
Start Consumption per day		527,502	MJ	MJ Start	0	527,502	527,502
End Consumption per day		494,623	MJ	MJ End	0	494,623	494,623
Change as % of Start		-6%					

Figure 4-5: Calculation 2 for Scenario 2: Fuel Used By Commuter Group in HOV Lane

Starting Volume	50						
Traffic Change							
% Change	0.0%						
Starting Flow per lane hour	50	Consumption					
Starting Speed (kmph)	90	3.08	MJ/Km/Vehicle				
Starting consumption		154	MJ/Km		Allocated to User Group		
Traffic Change	0						
Ending Flow per lane hour	50				Commuter Group	Rest of Traffic	Total
Ending Speed (kmph)	90	3.08	MJ/Km/Vehicle	Vehicles	50	0	50
Ending consumption		154	MJ/Km	MJ/Km	154	0	154
Impact of Change (MJ per Km)		-					
Distance (km)		19.32	weighted avg distance for the whole traffic,				
Total Change per Day		-	MJ per day				
					Commuter Group	Rest of Traffic	Total
Start Consumption per day		2,975	MJ	MJ Start	2,975	0	2,975
End Consumption per day		2,975	MJ	MJ End	2,975	0	2,975
Change as % of Start		0%					

Table 4-2: Total Energy Consumption When Commuter Group Uses Flexible Carpooling

Scenario 2	Commuter Group	Rest of Traffic	Bus Operator	Total
Commuter Group Carpool Flexibly in HOV Lane	3.0 GJ		Nil	3.0 GJ
Rest of Traffic with 150 Fewer Vehicles		494.6 GJ	Nil	494.6 GJ
Total	3.0 GJ	494.6 GJ	Nil	497.6 GJ

4.6. Scenario 3: Energy Consumption if Commuter Group Uses Express Bus

In this scenario, an express bus service is provided from the parking facility and the 150 members of the commuter group park in the parking facility and use the express bus to get to work. Because it is an express bus it does not stop at any intervening stops, but uses the HOV lane and goes straight to the destination drop-off point, which is the same as would be used for flexible carpooling. The 'time in bus' is therefore the same as the 'time in carpool.' The 'rest of traffic' energy consumption is the same as for Scenario 2.

To estimate the energy consumption by the bus, it is necessary to predict the number of trips the bus will be required to make. The 150 members of the commuter group will seek trips spread over the 2.5 hours of the peak period and experience shows that this will itself have a 'peak' flow. The following additional assumptions are relevant to this scenario:

- Allowing an average speed of 55 MPH, the 24-mile roundtrip for a bus will take 26.2 minutes. A single bus could therefore provide a half-hourly service with 1.9 minutes at each end for embarking and disembarking.
- The service that is offered therefore provides half hourly pick-ups through the peak period, commencing at 6:30 am.

- The passengers arrive in a distribution pattern through the morning peak period as follows:

Trip	Time	Passengers
1	Up to 6:30 am	12
2	6:30 to 7:00 am	24
3	7:00 to 7:30 am	39
4	7:30 to 8:00 am	39
5	8:00 to 8:30 am	24
6	8:30 to 9:00 am	12
	Total	150

- A 54 seat bus is used to allow for it to be used for the afternoon as well, with capacity for a sharper peak in the afternoon.
- The bus consumes energy at the rate of 24.1 MJ/Mile (15 MJ/km) (Strickland 2007).
- The bus overnights in the parking lot and after trip six it parks up in the destination area to await afternoon trips. The morning trips therefore involve 5.5 roundtrips or 132 miles (212.5 km).
- The bus consumes 3,181 MJ of energy in the morning peak.

The energy consumed when the commuter group takes the express bus is shown in Table 4-3. The total energy used is 497.8 GJ or 0.2 GJ more than the flexible carpooling scenario.

Table 4-3: Total Energy Consumption When Commuter Group Takes Express Bus

Scenario 3	Commuter Group	Rest of Traffic	Bus Operator	Total
Commuter Group take Bus in HOV Lane	Nil		3.2 GJ	3.2 GJ
Rest of Traffic with 150 Fewer Vehicles	Nil	494.6 GJ		494.6 GJ
Total	Nil	494.6 GJ	3.2 GJ	497.8 GJ

4.7. Summary of Scenarios

Total energy consumption in this simplified example is lowest for the flexible carpooling scenario, very similar for the express bus scenario, and highest for the drive alone scenario. See Table 4-4.

Table 4-4: Summary of Total Energy Consumption Under Different Scenarios

	Scenario	Commuter Group	Rest of Traffic	Bus Operator	Total	Saving vs SOV
1	Commuter Group Drive SOV	10.1 GJ	517.4 GJ	Nil	527.5 GJ	-
2	Commuter Group Flexibly Carpool	3.0 GJ	494.6 GJ	Nil	497.6 GJ	29.9 GJ
3	Commuter Group Take Express Bus	Nil	494.6 GJ	3.2 GJ	497.8 GJ	29.7 GJ

Assuming that 'drive alone' is the status quo, successfully introducing flexible carpooling or an express bus service on the route would reduce energy consumption by about 5.7 percentage points or almost 30 GJ per day for the given set of assumptions.

About 25% (7.1 GJ) of the reduction would be achieved by the commuter group if they use flexible carpooling, and the other 75% would be achieved by the remaining traffic. If the commuter group instead takes an express bus, the energy they would have used as flexible carpoolers would instead be used by the bus operator.

In energy efficiency terms, the savings day by day for flexible carpooling and express bus are about the same, so a decision as to which service to offer should be made based on additional criteria.

4.8. Discussion: Potential for Different Results if Assumptions are Varied

Table 5 outlines the potential variations and discusses the likely energy consumption impact of each variation.

The variation that would have the greatest impact on the calculated savings is where there is currently free flowing traffic (see assumption 3 in Table 5). In this case, the rest of the traffic would achieve no gain from the commuter group switching to flexible carpooling or the express bus, and the savings would be limited to the energy that would have been used by the vehicles left behind, 6 GJ, or about 20% of the total benefits outlined above. The other variations would have less impact than this.

In most of the variations discussed in Table 5, the energy consumption impact is similar for flexible carpooling and the express bus, on an average daily basis. However, as discussed in assumption 13, the energy usage pattern of a scheduled bus service that would continue to run regardless of passenger volumes (for example on a school holiday) would be different to the energy usage pattern of a flexible carpooling service that expanded and contracted according to the flow of passengers. Taken across the whole year, the flexible carpooling alternative would be responsive to demand changes, while the energy consumed by the express bus would most likely be more constant.

A variation where the express bus alternative provides greater energy savings than flexible carpooling is assumption 12, where the variation assumes the express bus is an existing service.

Table 4-5: Considering Variations to the Baseline Assumptions

Baseline Assumption	Variation	Energy Consumption Impact
1. The route is 12 miles (20 km) from convergence point to destination area.	Shorter or greater distance.	The energy savings per route mile would be about the same for any distance, as long as the conditions were equivalent. A different level of congestion on a feeder route from further away would suggest a different result. The uptake of the alternatives could be expected to be subject to some sort of ratio of the time involved in taking the alternative compared with the savings achieved from taking the alternative.
2. There are two lanes of general traffic and one HOV 3 lane for the whole distance.	No HOV lane, or HOV 2, or HOV 4 or greater.	The absence of an HOV lane would reduce the overall savings in two ways. First, the energy saving for the commuter group would be lower because they would travel in the slow general purpose traffic rather than the faster HOV lane. Second, the general purpose traffic would be reduced only by the number of vehicles left behind. Because the express bus reduces total vehicle count by a greater amount, the energy savings from express bus (24.3 GJ) would be greater than for flexible carpooling (19.1 GJ). An HOV2+ (driver plus at least one passenger) lane would likely already be more utilized. The rules of flexible carpooling would call for HOV3+ (driver plus at least two passengers) regardless of whether the local rules allowed HOV2+. An HOV4+ lane (or greater) would increase the energy savings from flexible carpooling. The existence of flexible carpooling would make it easier for people to use the HOV4+ lane, and deliver energy savings. The amount of the gain would be based on fewer cars in the HOV lane for a given size of commuter group: 37 cars rather than 50 cars for the same number of riders.

Baseline Assumption	Variation	Energy Consumption Impact
3. There is demand on the route over the peak period of 7,845 vehicles in the general purpose lanes. This is an average of 1,569 per lane hour for the 2.5 hour peak travel period. HOV lane use is negligible.	Lower demand. Higher demand. HOV lane is already well used.	If demand is lower and the traffic on the route is currently free flowing throughout the morning peak, then there will be no energy savings to the rest of the traffic, and the savings for the commuter group would be only the fuel not used by the vehicles left behind (about 6 GJ). Both flexible carpooling and express bus alternatives would show lower impacts (both about 24 GJ lower). If demand is higher, then the slower the current speed of the traffic, the greater the impact of reducing the traffic. Both flexible carpooling and express bus would show a similar gain. If the HOV lane is already well used, the impact will depend on how well used it is. If it is over about 1,100 vehicles per lane hour, then adding vehicles will raise the potential for its flow to break down. In such a case, adding an express bus would have less negative impact than adding flexible carpooling because the number of inbound vehicle trips would be five for the bus, compared with fifty for the flexible carpools. Note that a flexible carpool system could make easier the conversion of a heavily used HOV2+ lane into an HOV3+ lane.
4. The average speed in the general purpose lanes is 25 mph (40.25 km/h).	The average speed is faster or slower.	The impact is the same as the impact of lower or higher demand, above.
5. The average speed in the HOV lane is 55 mph (88.6 km/h).	The average speed is slower.	The impact is the same as the impact of HOV already well used, above.

Baseline Assumption	Variation	Energy Consumption Impact
6. The traffic consumes energy at the rates shown in Figure 1, for the speed that it is traveling. The table underlying Figure 1 is used to determine energy use at different speeds.	The vehicles use energy at a greater or lesser rate than shown in Figure 1.	Individual vehicles will use energy at different rates. There will be highly efficient cars and highly efficient buses. Carpoolers might share the ride in their most efficient or least efficient vehicle. The use of Figure 1 provides an order of magnitude result. The benefits of flexible carpooling or taking an express bus would be proportionately greater or smaller if the average energy use was higher or lower than shown in Figure 1. The magnitude of the savings in percentage terms would not change.
7. Changes to the volume of traffic will change the average speed of the traffic according to the relationship shown in Figure 2.	The traffic flows at higher speeds than shown in Figure 2 for a given volume.	The design of the roads can have a big impact on the speed/flow relationship. The number of lanes in a single direction, the width of the lanes, the slope of the road, the incidence of merging traffic, and the weather conditions are all known to have an impact on speed and flow. On a facility that has the optimum combination of conditions, the line shown in Figure 2 could be expected to move to the right, and a change in traffic volume would only make a difference to energy consumption by the rest of the traffic if the actual volumes are within the area of the sloping part of the graph in its new position. At higher throughput and higher speed levels both the probability and the impact of an incident of the sort that could cause the traffic to be interrupted would likely be greater.
8. The commuter group is 150 people, who when they drive alone are part of the total demand of 7,845 vehicles.	The commuter group is larger or smaller.	Impact on flexible carpooling: The logic of a commuter group of 150 for the flexible carpooling alternative is that through a 2.5 hour (150 minute) peak period, there is an average arrival of a rider every minute and an average departure every three minutes. The waiting times for riders or drivers on a normal distribution would never be more than a few minutes, and in designing such a service, it is presumed that experienced waiting times will have an impact on ongoing participation. A larger commuter group will enable either more focused destinations (splitting into multiple routes) or more frequent and reliable service to a single destination and proportional increase in the energy savings. A smaller commuter group will increase waiting times and reduce the viability of the flexible carpooling alternative, and reduce energy savings. Testing is required to determine the threshold values for this dimension.

Baseline Assumption	Variation	Energy Consumption Impact
		Impact on the express bus service: The discussion thus far has not explored whether the commuter group would be prepared to use a bus service with a half hour headway. Good practice for public transit services is a ten-minute headway. Increasing the commuter group could enable more frequent bus services, so making the uptake more likely. Alternatively, it could enable use of larger buses and a higher average occupancy, leading to greater energy savings for the bus alternative. Reducing the commuter group would make the bus service less viable, and in time it might be closed down. With fewer users it would save less energy and could even cause a net increase in total energy use on the route.
10. The service that is offered provides half hourly pick-ups through the peak period, commencing at 6:30 am.	Longer or shorter headway between services.	Longer headways make the bus service less attractive to users. Shorter headways make it more attractive. Providing greater frequency will use more energy if the bus size is the same. To provide shorter headways, additional buses would be required, including drivers and other incidental costs.
11. The passengers arrive in a bell shaped distribution pattern through the morning peak period.	Passengers arrive in a different pattern: more of a peak or less of a peak.	The potential benefit of a different pattern is that it better matches the seating profile of an available bus. A flatter pattern would allow a smaller bus, with greater energy savings. A higher peak would demand a larger bus. Running the larger bus on the time slots that carry fewer passengers results in less energy savings and increases the likelihood that managers would decide to divert the express bus to pick up passengers at other stops, reducing the attractiveness of the service to the commuter group.

Baseline Assumption	Variation	Energy Consumption Impact
12. The bus overnights in the parking lot, and after trip 6 it parks in the destination area to await afternoon trips. The morning trips therefore involve 5.5 roundtrips, or 132 miles (212.5 km).	The bus is used to provide social services throughout the day or an existing bus is used to provide the express service.	The use of the bus for other services should be a separate decision and whether it saves energy on those other routes should not influence the decision for this route. It certainly makes comparative evaluation more difficult. Adding the commuter group as riders on an existing service also makes the comparative evaluation more difficult. If the capacity exists, one feels that it should be utilized. This would be a component of a route by route analysis. Clearly, the energy savings will be greater if the commuter group can be convinced to start using an existing service, such that there is no incremental energy consumption on the buses for a large energy saving in the cars.
13. The energy impacts of a single day can be used to influence decision making.	Weekly, monthly or annual impacts are different.	There are variations in commuter and traffic flows on a daily, weekly, and monthly basis. Depending on the extent of these variations the daily averages might be more or less useful. Some days of the year, there is free flowing traffic regardless of how bad it gets on other days. School holidays are an example because parents often take time off work and withdraw from the daily commute. Comparing between flexible carpooling and express bus services, the express bus service tends to be a scheduled event that consumes energy whether the passengers show up or not. Flexible carpooling on the other hand is likely to shrink proportionately (fewer drivers and fewer riders) such that on a per passenger mile basis it would have a more consistent record throughout most of the year.

Baseline Assumption	Variation	Energy Consumption Impact
14. The commuter group would equally willingly take up either non-SOV alternative.	Less or more willing uptake of flexible carpooling. Less or more willing uptake of express bus.	Flexible carpooling: If the service is offered but uptake is lower than assumed, the energy savings would be proportionately lower than calculated. If the uptake is greater than assumed, as long as there is adequate parking at the convergence point, the system can expand and the energy savings would increase proportionately. Express bus: If the service is provided but uptake is lower than assumed, the energy savings could turn into energy costs. For example, if there were no passengers at all the bus would consume energy in addition to the existing level being consumed by the traffic. (However, net energy savings would be achieved from as low as six passengers per bus trip). If the uptake is greater than assumed, as long as there is adequate parking at the convergence point, the passenger count could expand until the bus is full and the energy savings would increase to the point of adding a larger or an additional bus.

4.9. Conclusions

Both flexible carpooling and express bus services have a similar impact on total energy consumption when compared with drive alone commuting on a somewhat congested route with an uncongested HOV lane available. The energy consumption reduction calculated for the specific situation outlined is in the order of six percent.

The situation outlined assumes automatic uptake by a commuter group of 150 members who would use either:

- Flexible carpooling if it was offered, with an average headway of three minutes, using 100 parking spaces at the convergence point, reducing demand for parking at the destination by 100 spaces; or
- An express bus service if it was offered, with an average headway of 30 minutes, using 150 parking spaces at the convergence point, reducing demand for parking at the destination by 150 spaces.

The purpose of this chapter is to provide the energy consumption impacts to help in an assessment of whether flexible carpooling would be a good idea from an institutional point of view.

A key variable not explored so far in this section is the relative likelihood of uptake of the alternatives. If uptake of both alternatives is considered to be certain, then given a choice between continued single occupant driving in congested traffic, and offering either flexible carpooling or an express bus service, the energy savings suggest that there should be considerable interest from institutions to support both alternatives.

Further, given a choice between offering flexible carpooling or an express bus service, the energy savings would favor flexible carpooling in most circumstances and the express bus service in others.

The establishment and operating costs of flexible carpooling are expected to offer substantial cost savings when compared with providing an express bus service. Flexible carpooling requires no purchase of buses nor payment of drivers or other ongoing bus operating costs.

This would suggest that an institution that had responsibility for funding transportation alternatives might prefer flexible carpooling over an express bus.

There remains therefore the question of the rate of uptake of flexible carpooling. The usage of casual carpooling in San Francisco in which 8-10,000 people participate each day from 23 pick-up locations in the East Bays and carpool into downtown San Francisco can be taken as an indicator that commuters will use a carpooling system without pre-arranged rides. Whether such a system could be implemented on a new route, how quickly it would develop, and what challenges would be faced, should properly be determined by a feasibility study and field operational test.

A field test that served 150 flexible carpoolers on a route that is consistent with the assumptions made in this section could save up to 30 GJ of energy per day or approximately 6.3 TJ of energy in a year (assuming 210 days at 100% usage or 230 days at 90% usage). A saving of 6.3 TJ of energy is the equivalent of 52,000 gallons of gasoline.

A citywide implementation that attracted 15,000 flexible carpoolers could save up to 630 TJ of energy or 5.2 million gallons of gasoline per year, if the conditions across the city were consistent with the assumptions outlined in this chapter.

On the basis that the energy savings justify further investigation, the next chapter explores whether there are any liability or insurance constraints associated with offering a flexible carpooling solution.

4.10. References

Barth, M., Boriboonsomsin, K., 2007. Real-World CO_2 Impacts of Traffic Congestion. Prepared for the 87th Annual Meeting of the Transportation Research Board. TRB 2008 Annual Meeting CD-ROM

Caltrans, 2004. 2004 Bay Area HOV Lanes. District 4, Year 2004 Annual HOV Lane Report, California Department of Transport

PeMS Database, 2008. Personal research on the Freeway Performance Measurement System (PeMS), a cooperative effort between UC Berkeley, PATH and Caltrans.

Strickland, J., 2007. Energy Efficiency of different modes of transportation. Downloaded from http://www.strickland.ca/efficiency.html, March 2008

Chapter 5: Liability and Insurance

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5.1. Chapter Summary

The purpose of this Chapter is to explore whether there are liability or insurance constraints to establishing a flexible carpooling service. Here, we attempt to answer the question, "if people would use flexible carpooling (Chapter 3), and if it is a good idea from an energy saving perspective (Chapter 4), are there any liability or insurance barriers to creating such a service and how would they be overcome". The chapter explores liability from the viewpoint of common carrier liability, negligence and product design, and considers the extent to which governmental agencies could be held liable, especially given their general immunity from liability under law. Finally, it looks at insurance, both auto insurance for participants and public liability insurance, for agencies involved in providing a flexible carpooling service.

5.2. Liability

This section on liability will address various areas of concern that may arise at any point in the flexible carpooling process. For the purpose of this analysis, this process begins at the doorstep of the traveler's home and ends at the door of the traveler's workplace.

5.2.1 Identifying Vulnerabilities in the Flexible Carpooling Process

Flexible Carpooling Process

The flexible carpooling process accounts for door-to-door delivery of the individual ride-sharer. Although flexible carpooling technology and representatives may not be involved in the early or late phases of the process, these portions of the trip are included in this analysis because: (1) these portions of the trip are required for any commuter to use flexible carpooling, and (2) California Air Resources Board (CARB) uses a door-to-door model in calculating the cost effectiveness of air quality projects. The various phases of the flexible carpooling process are outlined below:

Phase 1 - Travel to flexible carpooling facility (convergence point parking)

a) The participant drives directly to the convergence point, or

b) The participant catches a ride with a fellow flexible carpooler to the convergence point, or

c) The participant walks or cycles to the convergence point, or

d) The participant walks to a bus stop and catches a bus or shuttle to the convergence point.

Phase 2 - Carpools form at the convergence point

Phase 3 - Travel within the flexible carpool to the destination

a) Convergence point to designated drop off point

b) Drop off point to workplace

<u>Potential Liabilities in the Flexible Carpooling Process</u>

The company may be subject to a heightened standard of care if it is considered a common carrier (Dolan 2004). This legal classification in California includes a variety of conveyances for people and items, including: streetcar, stage coach, wagon, airlines, elevators, escalators, muletrains, ski lifts, taxicabs, and amusement park rides. California imposes the duty of use the utmost care and diligence for the safe carriage of passengers. The carrier must provide everything necessary for that purpose, and must exercise a reasonable degree of skill to meet this duty (Civil Code § 2100).

If the company is not considered a common carrier, then it may be considered a private carrier, which provides carriage for hire but will not incur liability if he refuses service for a reasonable price. Common examples of a private carrier include: school buses under contract for a single school, corporate shuttles, and incidental transportation. Private carriers remain subject to negligence standard.

Phase 1 (claims for injuries sustains en route to the flexible carpooling facility):

The liability of a carrier only begins at the start of the relationship. Therefore, no heightened duty should be imposed during Phase 1, unless the following occurs:

1) The rider intended to be a passenger,

2) The carrier accepted the passenger, and

3) The rider placed his or herself under the control of the carrier.

However, if the company does not exercise standard reasonableness, if it plays a hand in establishing this phase, then the company may remain liable under the negligence standard.

Thus, the company should require that any person transporting another to the flexible carpooling facility is insured. There is no feasible way for the company to enforce this rule, but this language should be included in the client contract. As an additional measure of protection, the company should be incorporated to minimize liability on the part of the shareholder in the event of a successful liability claim.

The company may encourage public transportation to transport passengers to the flexible carpooling facility. The public entity may be liable but will likely have insurance to cover such expenses. If the entity has insurance, then any remedy is limited to the amount of the insurance coverage.

Private drivers will likely be the first to be found liable in the event of an accident causing property or personal damage. For this reason, all drivers to the flexible carpooling facility should have the minimum required insurance available in California and should preferably have a greater level of insurance. In particular, the drivers may want to consider additional insurance coverage for uninsured drivers, in the event that an uninsured driver causes the accident, yet a passenger in the insured driver's car is injured. The company should include advisory language such as this in the client contract, to limit the risk of a negligence claim.

Please find further discussion of private insurance below in section 5.3 Insurance.

Phase 2 (claims based on the failure of electronic systems)

Liabilities may arise against the company, and if this is a public-private venture, then against the governmental entity.

The flexible carpooling system has four components ensuring efficiency and driver safety: (1) the physical structure of the transport, (2) the databank of registered drivers, (3) the electronic device attached to the vehicle, and (4) the electronic identification badge attached to the driver and riders.

The company will run the risk of product liability and negligence claims resulting from design flaws in the surveillance and tracking techniques creating a false sense of security.

A product liability suit would claim that the company has violated a duty of care to the client. The company should limit liability by ensuring that the electronics systems are in proper working order and schedule regular examinations of the system. Additionally, to the extent this product is marketed, in part, for its security features, a great deal of attention should be focused on closely monitoring individuals who pass through the flexible carpooling facility, including the following surveillance techniques: background checks, insurance checks, manned checks, electronic ID checks, camera checks, and an electronic record of all individuals who pass though the system, including individuals who bring unregistered passengers**.**

Phase 3(claims for injuries sustains during a flexible carpooling ride)

The final phase focuses on the liability of the company and individual drivers.

A claim against the company will again rely on the argument that the company violated the heightened duty of care as a common carrier, or at a minimum, acted with negligence. As part of that duty, carriers are bound to provide vehicles safe and fit for the purposes to which they are put, and are not excused for default in this respect by any degree of care (Civil Code § 2101). Likewise, in providing services a common carrier must give to passengers all such accommodations as are usual and reasonable, and must treat them with civility, and give them a reasonable degree of attention (Civil Code § 2103).

Mere negligence issues may arise over improper driver screening and background checks. It is very important to carry out and document the results of the member screening process with great care. Other issues that are likely to be raised in this phase include the possibility of being abandoned, dropped off at the wrong location, or a generally unpleasant driving experience. Approaches to address bad driver behavior may include providing a panic button or a responsive "in case of emergency" hotline. Additionally, a merit system could penalize people with poor merit through probation from the system.

Individual liability claims will resemble those issues that occur in Phase 1. Again, the company should ensure that every driver has proof of at least the minimum required drivers insurance mandated by state law on a regular basis (e.g., quarterly).

5.2.2 Liability of Government

This section explores the liabilities of a government agency, assuming that ride sharing is incorporated as a project of the agency. In general, a public entity must agree by statute to have a claim of liability raised against it. However, in California the Tort Claims Act, imposes statutes that impose liability. Exceptions and affirmative defences are available. The Tort Claims Act, in the California Government Code imposes the statutory liability on public entities for negligent government action, which usually ends in settlement instead of expensive litigation for meritorious claims (Snipes v. City of Bakersfield 1983 5th Dist). Although the Governor budgets around $1,300,000 for liability judgments, the state of California in reality pays a far greater number in judgments. For the fiscal year of 2001-2002, the Department of Transportation alone paid out $60.5 million in Torts awards.

<u>Employment of Private Drivers</u>

In the context of vicarious liability, a public entity will be held liable of the wrongful actions of an employee, as if the agency committed those actions itself.

The provisions of this Act hold the state liable for the actions of a private contractor acting in the capacity of their contract. A private contractor will sign a "Personal Services Contract" (PSC) (California Code of Regulations § 279.1). Any contract, requisition, purchase orders, etc. will be considered a Personnel Services Contract. The conditions for entering a PSC could apply to the conditions of flexible carpooling. Those elements include:

(a) Services incidental to a contract,

(b) For the purchase or lease of real or personal property, and

(c) These services include but are not limited to office equipment (Government Code §19130).

Thus, if a contract is established to "purchase" time or "lease' the services of the individual private vehicles, then under this section, an agency would be required to draft a PSC, which by definition, identifies the contractor as a private contractor, subjecting the agency to liability. Thus, to limit liability, the agency should not draft any contract with a private party for the lease of their vehicle. Efforts not to enter into a service contract will not subject the agency to the liability for actions of independent contractors.

Vehicle Code and Government Liability

Section 17000 of the Vehicle Code provides that an agency will be liable for death or caused by the operation of a motor vehicle, by an employee in the scope of his employment. Thus, the agency must clearly state in the contract that those who enlist to drive with this program are not employees.

Filing a Claim Against an Agency

In the event that an agency is subjected to liability, the party bringing a claim must properly file a written claim with the appropriate officer, to:

(a) The entity should be able to promptly investigate the claim, and

(b) The entity should have the opportunity to resolve meritorious claims without litigation.

Thus, this claims provision allows the governmental entity the opportunity to: settle claims before they are brought, permit an early investigation of facts, facilitate fiscal planning for potential liabilities, and to help avoid similar liabilities (CaJur VovLia § 4). Persons liable as employees include: Judicial officer […] employee, or servant, whether or not compensated, but does not include an independent contractor (Cal Gov Code § 810.2).

Summary

In summary, an agency may be subject to liability for any injury resulting from their own employees, but private drivers should not be included in this class.

5.3. Insurance

This section addresses the concept of insurance for the drivers, the business, and governmental entities.

5.3.1 Personal Automobile Insurance

Despite state law, California shows that 14.3% of vehicles on the road in California being uninsured, out of 23,987,027 registered vehicles in 2003; leaving only 20,557,275 automobiles insured. The current economic downturn is expected to trigger a rise in this rate (Insurance

Research Council 2008). Below is a partial list by counties of importance to this study, for the statistics of uninsured vehicles in 2003.

Table 5-1 Insured Motorists in Select Regions

County	Number of Vehicles	Number of Insured	Rate of Uninsured
San Diego	2,051,016	1,883,313	6.69%
San Francisco	412,009	322,727	15.07%
Alameda	1,025,720	884,115	9.6%
Marin	202,265	187,184	2.52%
Contra Costa	733,891	669,907	5.85%
San Mateo	569,075	487,511	9.83%
Santa Clara	1,268,021	1,141,347	3.74%
Napa	91,623	83,201	5.98%
State			
California	23,987,027	20,557,275	14.3%

Most counties of concern to this study are well below the state average for uninsured drivers, with the exception of San Francisco motorists. This information may be used as an indicator for flexible carpooling to estimate what percentages of commuters today are uninsured. These statistics also provide evidence to show that a large enough percentage of commuters in the target market areas are uninsured, roughly 10% of motorists. Thus proof of insurance should be required to participate in the flexible carpooling process.

What is Automobile Insurance?

The Department of Insurance defines automobile insurance as “a contract for certain types of financial losses or obligations from the use or ownership of an automobile.” The Department further states that the most accepted and common way to meet the financial responsibilities of automobile ownership in California is to purchase automobile liability insurance, as outlined in § 16451 of the Vehicle Code.

By statute, Californians are required to have the minimum coverage:

(a) Related to bodily injury, $15,000 for death or injury for any one accident and if two or more are injured, $30,000 for all persons in any one accident; and

(b) Related to property damage, other than for the property of the at fault driver, $5,000 for any one accident.

The state recognizes four methods for meeting the above stated minimum liability coverage:

(a) To receive coverage from an automobile insurance provider (the most common);

(b) The automobile owner may make a cash deposit of $35,000 with the DMV;

(c) DMV issued certificate of self insurance available only to owners of fleets with at least 25 vehicles; and

(d) A surety bond of $35,000 issued by a California licensed insurance provider.

Additionally, auto insurance providers are required to provide insurance against uninsured or underinsured motorists. Therefore, when a party is injured by an uninsured or by an underinsured driver, then the insurance of the injured party will cover the costs of bodily injury or property damage.

Other common, although not mandatory coverage options include:

(a) Medical payment coverage, regardless of fault;

(b) Collision (despite fault) and comprehensive coverage (including fire, theft, windstorm, flood, vandalism, etc.) and most damage not related to mechanical breakdown or normal wear and tear; and finally; and

(c) Endorsements and riders, including after-market additions, towing, and rental reimbursement.

5.3.2 Government Insurance

Government entities require insurance coverage, especially in anticipation of claims against property or casualty.

<u>General Background on Immunity and Insurance</u>

The article, *Liability Insurance and the Tort Immunity of State and Local Government*, by Gerold Gibbons, published in the 1959 Duke Law Review, provides insight into the generalities and incentives of public entity insurance. If a governmental entity feels that it may not have immunity from liability claims, then it may wish to purchase insurance coverage. In some jurisdictions, where the purchase of insurance is authorized by statute, this purchase of insurance may protect the entity from a tort liability (ATLA-tort § 66:43). However, this purchase of insurance, may amount to a waiver of government immunity, if stated by the plaintiff (Napier v. Town of Windham, 187 F 3.d 177 1st Cir. 1999). This waiver hinges on whether the purchase of insurance complies with the statute and necessarily requires the waiver of immunity. An example of when sovereign immunity is not waived is when an entity purchases motor vehicle insurance. This insurance is specifically targeted to cover the negligent actions of agents or employees while driving and does not strip the entity of its immunity (Harry v. Glynn County, 269 Ga. 503). Government officials may purchase liability insurance to cover immune activities to defend the against tort liability with partial coverage when immunity is uncertain, thus placing the risk on the insurer by purchasing partial insurance coverage (Gibbons 1959). Full insurance coverage will protect members of the public that may be injured by government employees and protect the agency if it remains liable for their own tortuous actions.

Further, although the purchase of insurance coverage may set new limits for liability coverage, even beyond those limits imposed by statute, but no greater than the insurance plan, the purchase of an insurance plan does not limit the availability of defences and exceptions available to it through the Tort Claims Act. In other words, although the purchase of an insurance policy may waive an entity's immunity that stems from its condition as a sovereign state, the state Tort Claims Act has already subjected the state to general liability, subject to certain exceptions, that an insurance policy cannot effect.

5.4. Conclusions

Following some best practices guidelines will minimize exposure to liability. The following is a summary of the key findings of this chapter:

(a) Follow appropriate corporate or company formation requirements or purchase appropriate insurance to limit liability on the part of the shareholder in the event of a successful liability claim.

(b) Ensure that the electronics systems are in proper working order and schedule regular examinations of the system. Additionally, to the extent this product is marketed, in part, for its security features, a great deal of attention should be focused on closely monitoring individuals who pass through the flexible carpooling facility, including the following surveillance techniques: background checks, insurance checks, manned checks, electronic ID checks, camera checks, and an electronic record of all individuals who pass though the system, including individuals who bring unregistered passengers.

(c) Carry out and document the results of the member screening process with great care to avoid negligence.

(d) Enforce member insurance to avoid negligence:

(1) Ensure that every driver has proof of at least the minimum required drivers insurance mandated by state law on a regular basis (e.g., quarterly).

(2) Include advisory language in the client contract encouraging carrying uninsured driver insurance.

(e) Consider Liability Insurance if this becomes a government project.

5.5. References

ATLA-tort § 66:43

CaJur VovLia § 4, Application of the Act

Cal. App. 2d Dist. 2007

California Civil Code § 2100, et seq.

California Code of Regulations, § 279.1

California Vehicle Code § 16451

California Vehicle Code §17000

California Government Code § 810.2.

California Government Code § 19130

Dolan, Christopher, "Common Carrier Liability", retrieved 22 June 2009 from cbdlaw.com/CM/Articles/CommonCarrier.pdf.

Gibbons, Jerald R. Liability Insurance and the Tort Immunity of State and Local Government, Duke Law Journal (1959).

Harry v. Glynn County, 269 Ga. 503

insurance.ca.gov/

insurance.cch.com/RUPPS/public-entity-insurance.htm

Insurance Research Council, 2008. "Uninsured Motorists", 2008 Edition, retrieved 22 June 2009 from http://ircweb.org

Napier v. Town of Windham, 187 F 3.d 177 (1st Cir. 1999) [If the plaintiff does not state that the insurance coverage waives immunity in his complaint, then immunity is presumed, and the plaintiff has no actionable claim.]

Snipes v. City of Bakersfield (1983, 5th Dist) 145 Cal App 3d 861

West's Ann.Cal. § 815 Liability for Injuries Generally

Appendix A: Relevant Transportation Attributes (Chapter 3)

DETAILED LISTING OF TRANSPORTATION ATTRIBUTES RELEVANT TO FLEXIBLE CARPOOLING

There are a variety of characteristics that might vary in the environment where flexible carpooling in being considered. These characteristics can be grouped into three primary categories: (A) attributes of the flexible carpooling system itself, (B) attributes of the potential participants in flexible carpooling, and (C) attributes of the other existing transportation options in the area. The following list describes the numerous alternatives and options that can impact the success and viability of flexible carpooling in the field.

<u>A. Details of flexible carpooling System</u>
This section describes the routing and amenity considerations in any rollout of flexible carpooling

1. **Physical characteristics of morning origin / evening destination**
    a. Existing park & ride used for carpools only
    b. Existing park & ride with transit available
    c. New park & ride facility
    d. Designated on-street loading area (e.g., existing "casual carpool" style)
    e. Neighborhood pick-up as link to flexible carpooling park
    f. Spoke transit station
    g. Major transit hub or other existing transfer point
2. **Physical characteristics of morning destination / evening origin**
    a. Downtown business district
    b. University or medical center
    c. Office park / suburban employment center
    d. Spoke transit station
    e. Major transit hub or other existing transfer point
3. **Physical characteristics of transfer points**
    a. No transfer points implemented
    b. Transfers at park & ride facilities (i.e., no transit available nearby)
    c. Transfers at facilities with transit as an available alternative

4. **Features of flexible carpooling facilities**
    a. Charging stations for plug-in vehicles available? (Y/N)
    b. Commute-related amenities available, such as coffee service or newspapers? (Y/N)
    c. On-site neighborhood services available, such as shoe- repair, laundry/dry cleaning, car detailing/minor servicing, child care? (Y/N)
    d. Close to commercial areas, for trip linking with errands e.g., groceries, bank, post office? (Y/N)
    e. Close to other trip generators, e.g., schools, medical centers? (Y/N)
5. **Relationship with regional transit providers**
    a. Cooperative
    b. Adversarial
6. **Scale of implementation**
    a. Single location trial, e.g., 100 parking spaces
    b. Single corridor
    c. Multiple corridors
    d. Flexible carpooling is "everywhere"
    e. *NOTE: Assume that the idea of "short trips" (i.e., neighborhood pickups that help move riders to/from organized pickup and drop-off points) would only be viable when system penetration reaches stage d above, because high level of public acceptance required for broad implementation.*

IMPORTANT: Item 6 (above) necessarily has an implicit time scale – it will take multiple years to reach the end state where flexible carpooling is pervasive in an urban area. During system development, there will also be developments in the regional transportation network that will affect the success of flexible carpooling and the associated transit interactions. As an example, in the S.F. Bay Area, there may be new transit links such as BART to San Jose, the Dumbarton rail link, BRT in the East Bay or San Francisco, and SMART rail in Marin; new highway investments could come online including HOT lanes, 4th Caldecott tunnel bore, and major widening efforts; there will be programs that increase the use of electronic toll/fare collection media; trends in car ownership/driving may be affected by the price of gas, availability of alternative fuels, and government programs that influence fuel efficiency; and of course, the improvements mentioned above would each be implemented in stages, so that there could be different interactions at different points in time. Predicting the various combinations as the years pass could be extremely complicated.

B. Characteristics of Potential Participants

This section describes the various features that define the potential population of flexible carpooling users.

7. **Prior transportation status participants**
    a. Captive single-occupant vehicle (no transit available between origin and destination)
    b. Single-occupant vehicle by choice
    c. Private high-occupancy vehicle
    d. "Casual carpool" / "slug lines"
    e. Regular, scheduled rideshare
    f. Public high-occupancy vehicle (e.g., vanpool, corporate shuttle)
    g. Transit by choice
    h. Captive transit (no auto available)
    i. Captive high-occupancy vehicle (no private auto available and no transit available)
    j. PLUS – all reasonable combinations of the above in a single trip
8. **Flexibility to transportation alternatives**
    a. Must make same journey every day; once committed, no variation
    b. Willing to vary routine, but rarely, or only for special scheduling
    c. Willing to vary routine, but current options unacceptable
    d. Different schedule every day, must have variety of options in 'toolkit'
9. **Flexibility of trip-making generally**
    a. Fixed schedule, no flexibility
    b. Flex hours okay
    c. Flex days and/or part-time
    d. No fixed commute, e.g., salesman, consultant
    e. Regular traveler, variety of trip types, e.g., travel for errands, doctor visits
    f. Occasional traveler only

C. Existing Regional Travel Alternatives

This section describes the degree to which drivers or riders in the flexible carpooling system have choices between different transportation alternatives available.

10. **Definition of "availability" of transportation options**
    a. Two components required for an option to be available to an individual participant
        i. Physical existence of modal infrastructure between origin and destination
        ii. Costs of system (monetary and otherwise) within willingness and ability to pay.

b. Implicit in (a) above is the fact that participants already have knowledge of—and trust in—their available transportation options, otherwise they would not have considered them as viable before making their choices. This study does not address large-scale changes in the level of knowledge of or trust in transportation systems among the general public.
c. There may be multiple options "available" to any one individual according to this definition; however, assume that individuals have made their choice among existing options so that the only choice they make in this analysis is between their current mode and the new flexible carpooling option.

11. Transportation mode(s) in the corridor

a. For this study, the physical mode or type of vehicle used for traveling on transit systems (e.g., bus, light rail, ferry, etc.) will be neglected in favor of distinguishing between the styles of travel the passenger experiences, as described below.

12. Transit system design features

a. Frequency
    i. On demand – i.e., private auto, taxi, limo
    ii. High – headways less than or equal to 5 minutes
    iii. Medium – headways greater than 5 minutes, but less than or equal to 15 minutes
    iv. Low – headways greater than 15 minutes but less than or equal to 30 minutes
    v. Infrequent – headways greater than 30 minutes
    vi. *NOTE: Assume that the frequency that dictates passenger experience is the largest headway / smallest frequency of any one segment of the trip.*
b. Service type
    i. Express service – no stops to pick-up/drop-off for majority of route
    ii. Limited stop – stops to pick-up/drop-off for entire route but spaced far apart to speed travel time
    iii. Regular service – closely-spaced stops, typical of urban travel
    iv. Neighborhood collector services.
c. Routing
    i. Dedicated right-of-way – exclusive transit use, e.g., BART
    ii. Mixed right-of-way – few interactions, e.g., transit operating on rail with scheduled freight train service
    iii. Shared right-of-way – many interactions, e.g., highway that includes private trucks and autos
    iv. Combination of dedicated and shared – e.g., express bus that makes several local stops before switching to the dedicated facility

    v. *NOTE: For the purposes of this study, all water transit (ferry, water taxi, etc.) is assumed to have limited or no interactions with other sailing vessels; therefore, it is equivalent to dedicated right-of-way.*

13. Transit system reliability features

a. Capacity
    i. Seats available on a regular basis
    ii. Seats may or may not be available
    iii. Standing room only
    iv. Crush loading
b. On-time performance
    i. Routinely on time – delays rare
    ii. Mostly on-time – delays uncommon and/or quickly resolved
    iii. Routine minor delays (magnitude and/or duration)
    iv. Routine major delays (magnitude and/or duration)
    v. Limited reliability – system highly variable day to day
c. System control
    i. Synchronized, scheduled transport (e.g., train network, potentially with centralized train control system)
    ii. Independent vehicle operators (e.g., buses or taxis dispatched from yard, with radio communications, but limited control over outcomes)

14. Passenger's trip complexity

a. Segments
    i. Single-seat ride
    ii. Same system, with transfers
    iii. Multi-system ride
b. Transfer schedule coordination
    i. None required (single-seat ride)
    ii. Frequent service; transfer time negligible
    iii. Infrequent service with short wait time; connection is riskier
    iv. Infrequent service with long wait time at connection; slow but reliable
c. Fare media
    i. Cash-only
    ii. Multi-trip pass, with or without fare discount
    iii. Single agency rechargeable card (e.g., BART EZRider)
    iv. Integrated payment media (e.g., TransLink)
d. Fare integration
    i. None required (single-seat ride)
    ii. Separate media, separate costs
    iii. Separate media, with discounted transfers

15. Transportation system access

a. Walking distances
   i. Short or no walk required
   ii. Walk less than one quarter mile
   iii. Walk between one quarter and one half mile
   iv. Walk between one half and one mile
   v. Walk more than one mile
   vi. NOTE: Assume that the walking distance that dictates passenger experience is the longest distance at the beginning, end, or transfer between modes and/or lines at any point during the trip

b. Availability of parking (at transit)
   i. Preferred parking
   ii. Reserved spaces
   iii. Controlled access, therefore availability assured
   iv. General access, availability expected
   v. General access, but capacity constrained

c. Cost of parking (at transit)
   i. Free
   ii. Fixed charge, monthly or yearly
   iii. Fixed charge, daily
   iv. Variable pricing (e.g., based on demand, time of day, etc.)

d. Need for parking
   i. At destination? (Y/N)
   ii. When connecting between auto and alternative mode? (Y/N)

16. Cost / Pricing relative to alternatives

a. Riders – Out-of-pocket costs for flexible carpooling are ___________ current travel alternative
   i. Greater than
   ii. Equal to
   iii. Less than

b. Drivers – Net payments received for flexible carpooling are ___________ costs to drive alone (e.g., fuel, tolls, and other road pricing)
   i. Greater than
   ii. Equal to
   iii. Less than

NOTES: (a) Cost of parking is considered in Item 15 (above); (b) Many drivers do not evaluate the fully burdened cost of car ownership and operation when contemplating their daily commute choices, so the cost of driving a single-occupant vehicle above is limited to direct costs like fuel, bridge tolls, road pricing, etc.; if the 'fixed' costs of choosing to own a vehicle (e.g., financing *and depreciation) were included in this analysis, cost to drivers—and the incentive to participate in flexible carpooling—would obviously be greater than assumed here; (c) This analysis assumes that no change in car ownership is induced based on the availability of flexible carpooling.*

Appendix B: Case Study Routings (Chapter 3)

DETAILED TRANSPORTATION ROUTINGS BY CASE-STUDY CORRIDOR AND TRAVEL MODE

	Description	SOV	HOV - driver	HOV - rider
Case (1)	San Ramon to San Francisco	Drive I-680 to SR-24 to I-80 across Bay Bridge (TOLL) to Fremont St. exit; surface streets to Market & Fremont.	Drive I-680 to SR-24 to I-80 (HOV) across Bay Bridge (HOV) to Fremont St. exit; surface streets to Market & Fremont.	Drive I-680 to SR-24 to I-80 (HOV) across Bay Bridge (HOV) to Fremont St. exit; surface streets to Market & Fremont.
Case (2)	Vallejo to Downtown San Francisco	Drive I-80 across 2 bridges (TOLL) to Fremont St. exit; surface streets to Market & Fremont.	Drive I-80 (HOV) across Bay Bridge (HOV) to Fremont St. exit; surface streets to Market & Fremont.	Drive I-80 (HOV) across Bay Bridge (HOV) to Fremont St. exit; surface streets to Market & Fremont.
Case (3)	Vallejo to San Francisco Neighborhood	Drive I-80 across Bay Bridge (TOLL) to Octavia exit to Fell Street to Lincoln/GG Park	Drive I-80 (HOV) across Bay Bridge (HOV) to Octavia exit to Fell Street to Lincoln/GG Park	Drive I-80 (HOV) across Bay Bridge (HOV) to Octavia exit to Fell Street to Lincoln/GG Park
Case (4)	Hayward to Sunnyvale	Drive I-880 to SR-237 to Mathilda Ave. Exit	Drive I-880 (HOV) to HOV FLYOVER to SR-237 (HOV) to Mathilda Ave. Exit	Drive I-880 (HOV) to HOV FLYOVER to SR-237 (HOV) to Mathilda Ave. Exit
Case (5)	San Mateo to Mountain View	Drive U.S. 101	Drive US 101 (HOV)	Drive US 101 (HOV)

	Description	Transit A	Transit B	Transit C
Case (1)	San Ramon to San Francisco	Ride CCCTA Route 121 from Bollinger Canyon Rd. to Walnut Creek BART (TRANSFER) then ride BART to Embarcadero Station	Ride CCCTA Route 960B (EXPRESS) from Bishop Ranch to Walnut Creek BART (TRANSFER) then ride BART to Embarcadero Station	Drive from Crow Canyon Rd. to Walnut Creek BART (TRANSFER) then ride BART to Embarcadero Station
Case (2)	Vallejo to Downtown San Francisco	Vallejo Ferry or Baylink Express Bus to SF Ferry Building at foot of Market Street		
Case (3)	Vallejo to San Francisco Neighborhood	Vallejo Ferry or Baylink Express Bus (TRANSFER) then ride MUNI Metro N-Judah line to UCSF stop	Vallejo Transit Bus #80 (TRANSFER) to BART (TRANSFER) to ride MUNI Metro N-Judah line to UCSF stop	
Case (4)	Hayward to Sunnyvale	BART from Hayward to Fremont station (TRANSFER) then ride VTA bus (EXPRESS) #180 (TRANSFER) then ride VTA bus (EXPRESS) #140 (TRANSFER) then ride VTA train #902	BART from Hayward to Fremont station (TRANSFER) then ride VTA bus (EXPRESS) #180 (TRANSFER) then ride VTA train #902	BART from Hayward to Fremont station (TRANSFER) then ride VTA bus (EXPRESS) #120
Case (5)	San Mateo to Mountain View	Ride Caltrain from San Mateo Station to Mountain View Station	Ride samTrans bus #390 to Stanford Shopping Center (TRANSFER) then ride VTA bus #35 to Castro & Villa	Ride samTrans bus #390 to Stanford Shopping Center (TRANSFER) then ride VTA bus #522 to El Camino & Castro (TRANSFER) then ride VTA bus #52 to Castro & Villa

	Description	Transit D	Transit E	Transit F
Case (1)	San Ramon to San Francisco	Ride CCCTA Route 121 from Bollinger Canyon Rd. to Walnut Creek BART (TRANSFER) then ride BART to Embarcadero Station -- without commuter discounts	Ride CCCTA Route 960B (EXPRESS) from Bishop Ranch to Walnut Creek BART (TRANSFER) then ride BART to Embarcadero Station -- without commuter discounts	Drive from Crow Canyon Rd. to Walnut Creek BART (TRANSFER) then ride BART to Embarcadero Station -- without commuter discounts
Case (2)	Vallejo to Downtown San Francisco	Vallejo Ferry or Baylink Express Bus to SF Ferry Building at foot of Market Street -- without commuter discounts	[Casual carpool driver] - Drive I-80 (HOV) across Bay Bridge (HOV) to Fremont St. exit; surface streets to Market & Fremont.	[Casual carpool rider] - Drive I-80 (HOV) across Bay Bridge (HOV) to Fremont St. exit; surface streets to Market & Fremont.
Case (3)	Vallejo to San Francisco Neighborhood	Vallejo Ferry or Baylink Express Bus (TRANSFER) then ride MUNI Metro N-Judah line to UCSF stop -- without commuter discounts	Vallejo Transit Bus #80 (TRANSFER) to BART (TRANSFER) to ride MUNI Metro N-Judah line to UCSF stop -- without commuter discounts	
Case (4)	Hayward to Sunnyvale	BART from Hayward to Fremont station (TRANSFER) then ride VTA bus (EXPRESS) #180 (TRANSFER) then ride VTA bus (EXPRESS) #140 (TRANSFER) then ride VTA train #902 -- without commuter discounts	BART from Hayward to Fremont station (TRANSFER) then ride VTA bus (EXPRESS) #180 (TRANSFER) then ride VTA train #902 -- without commuter discounts	BART from Hayward to Fremont station (TRANSFER) then ride VTA bus (EXPRESS) #120 -- without commuter discounts
Case (5)	San Mateo to Mountain View	Ride Caltrain from San Mateo Station to Mountain View Station -- without commuter discounts	Ride samTrans bus #390 to Stanford Shopping Center (TRANSFER) then ride VTA bus #35 to Castro & Villa -- without commuter discounts	Ride samTrans bus #390 to Stanford Shopping Center (TRANSFER) then ride VTA bus #522 to El Camino & Castro (TRANSFER) then ride VTA bus #52 to Castro & Villa -- without commuter discounts