SafeRide: Reducing Single Occupancy Vehicles

Jim Morris[*]

Two people in an SUV use the same amount of gas as an SOV. Let's increase the occupancy rate to reduce congestion, pollution, and loneliness.

Vision

SafeRide is a combination of ideas from 511.org, Google Transit, Mapquest maps, Zipcar, SmartBike, Facebook, MySpace, eBay, and eHarmony that exploits GPS and cell phones as well as the web. It is the central nervous system of the entire surface transportation system for the San Francisco Bay Area. It lives on the web and communicates to public transit services, vehicle-based radios, personal computers, and cell phones. It links drivers and riders in an attempt to match the convenience of personal vehicles. It can be a profit-making service that helps the environment, improves the quality of lives, and supports community.

If this project were wildly successful it might reduce one-person cars by 50% in some places. While this would be helpful for pollution and CO_2 reduction, it is not a solution to the climate change problem. Getting China, India, and other aspiring countries to change their energy production methods is essential. They are not going to change until they can approximate our way of life; and Carlotta Perez observed,

> *The old 'American Way of Life' is still seen as the model of well-being to imitate because it has not been replaced in America.*

So this project is as much about changing attitudes and behavior as it is about reducing traffic. How do we make communal driving something people everywhere prefer?

Reality

This kind of idea has been tried many times and failed because a robust market of drivers and riders never formed. (I even tried it at U.C. Berkeley in 1973!) To achieve a system that attracts riders, there will have to be many drivers available. The drivers will emerge only when it appears profitable or otherwise desirable, and that depends on there being many riders. Thus we have a market-formation problem.

Several pilots of this idea have failed to find a market, so venture capitalists are not interested, unless you count Ben Rosen. Someone must discover a winning formula before anyone will invest. *If* a service succeeds, it will have an early mover's advantage. Not only will the service with the most subscribers have gravity working for it, it will also have useful data exhaust that informs it where there is unmet supply or demand.

On the other hand, improvements in computing infrastructure and deterioration of our transportation system suggest it may work someday. The current atmosphere has given rise to several companies that

---

[*] with contributions from Harvey Appelbe, Shumeet Baluja, Ray Bareiss, Peter Boatwright, Jon Cagan, Patricia Collins, Martin Griss, Dan Kirshner, Paul Resnick, Steve Raney, Scott Russell, Ted Selker, and Anup Yanamandra. A few of us have started a wiki to expand the discussion. I receive partial support from Carnegie Mellon's CyLab and Google.

are claiming some traction.

GoLoco.com was started in Boston by Robin Chase, the founder of Zipcar. It emphasizes social networking and attracts users through Facebook.

NuRide.com claims 25,000 subscribers and 1.25M rides arranged in six metropolitan locations in the East and Midwest. They sign up companies (presumably claiming all their employees as subscribers) and award ride sharers points that are redeemable for discounts from local merchants. Somebody pays them a small amount for arranging a ride.

Zimride.com works primarily through Facebook and claims about 3,000 subscribers, mostly from Cornell and the University of Wisconsin at LaCrosse.

ReadySetGoose.com started out getting 150 Microsoft HQ employees to sign up and ran a simulation showing that most of them could get matched. Apparently they made no further headway with Microsoft, but did get a little government funding, so "[t]he service is now available to all commuters in Washington state through a partnership between Goose Networks, WSDOT, and King County Metro." It makes heavy use of SMS messaging and seems remarkably frictionless. No subscriber numbers are available.

MapFlow.com is a serious, funded startup in Dublin, Ireland.

PickUpPal.com started in Canada in 2008. Drivers post prices they charge riders and are expected to pay PickUpPal 7% of what they collect. They also transport cargo and have a Facebook presence.

CraigsList.org always has many requests and offers for ridesharing and probably links up many pairs.

See dynamicridesharing.org for a more complete list of activities.

Theories

For an anecdotal estimate of the value of ride sharing, look around you while traveling on any road. The occupancy rate is about 25%, based on the number you can fit in a car. Any airline with a 25% occupancy rate would fail. The 102M Americans who drive to work solo pay 21 cents per mile or $131B per year in gas and maintenance. The savings from their sharing might fund a business.

Why do we prefer our own cars?

- Plan-free travel: We have our car with us all the time, can start a trip any time, start back any time, and change plans any time. We need to be aware of the transaction costs of arranging trips. Many successful services are providing long, one-time trips that people are willing to plan for. Short trips, decided on impulse, are the natural province of the personal automobile. Even cities with great subway and taxi service still extract a small cognitive load for each move. One wonders how much of the stress of living in big cities is caused by the need to think about every trip, at least a little bit.
- Reliability: If you maintain your car it is always available. Depending on car pools, taxis, or other services may be a problem if the system is not highly robust.
- Safety: If you are a good driver, you might be safer in your own car than in someone else's.

Hitchhiking or car-pooling can be uncomfortable or even dangerous inside a car with unfamiliar people.

- Coolness: Driving around in a Porsche cannot be beat; cars are like jewelry for guys.
- Marginal Economy: Once you have paid for a car, it seems cheap compared to services with a driver.
- Avoidance of others. There are many simple complaints a person may have about fellow travelers: reliability, hygiene, smoking, come-ons, radio choices, politics, gender, cell phones. In short, all the things that can annoy us in any close encounter. There is also a general desire to be with "people like me."

Most of these factors are especially powerful in California, which was designed around the automobile. Only San Francisco was developed before the car. Everywhere else, public transit was added after sprawl had taken over. If the movie *Roger Rabbit* had any truth, the auto establishment worked to destroy public transit in LA.

In the affluent SF Bay Area environmental impact, safety, and cost are minor factors. They motivate a few, but to get the essential critical mass we must focus on convenience. For most individuals personal time is precious. They will buy a hybrid, but most won't ride share, bicycle, or take public transportation if it adds significantly to their commute. Even if they can tolerate the time lost on the basic commute, they believe they need their car for *ad hoc* trips during the day.

Why might we change?

- Driving at rush hour is boring.
- Parking is expensive or a hassle.
- Gas is more expensive.
- Younger people want to be green.
- Cities might start charging admission, following London's lead.
- Highways may start charging tolls, using sensing technology, if only to raise revenue for maintenance.
- Communal vehicles can be cool if equipped with space, WiFi, Cappuccino, and twenty-somethings. It's sort of a latter-day Connecticut-Manhattan commuter.

No amount of social networking or advertising will build a market if the fundamental advantages are not real. For the riders, how good a service has to be to get people to use it in preference to their cars? There are at least five factors

- Speed: How much longer can a door-to-door trip be: 30%?
- Lead Time: How far in advance must a trip be booked: 3 hours?
- Hit rate: How often must a proposal be accepted for a person to continue trying: 80%?
- Reliability: How often must the participants perform as promised: 95%?
- Cost: How expensive can the service be relative to the marginal car operating costs: 70%? The IRS calculates amortized operating costs at about $0.50/mile. A charge of $0.25 /mile might be reasonable. SafeRide's fixing the cost may reduce the anxiety associated with

negotiating.

Cost may trade off against the first three which seem mutually orthogonal.

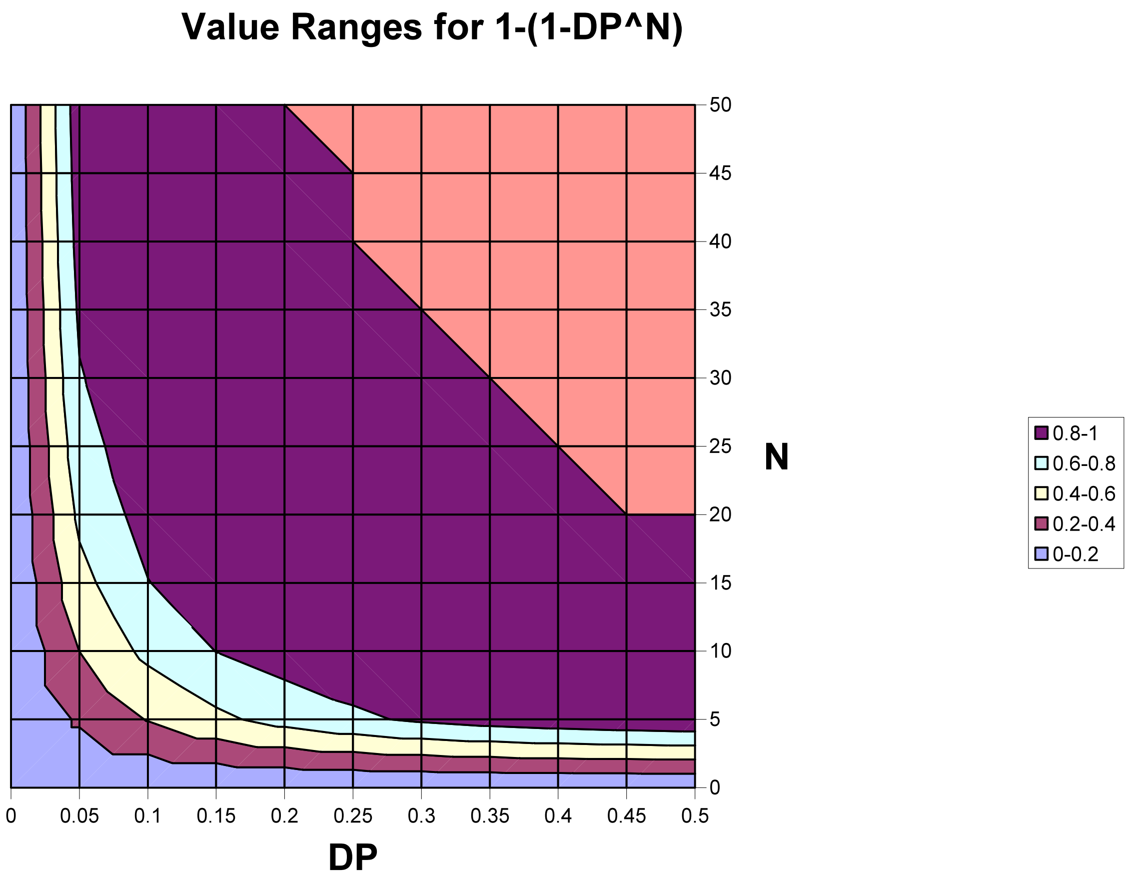

Figure 1. Effect of DP and N on Success Rate

An Analytic Model

There is a *tipping point* based on the size of the pool of potential partners. As the pool gets larger, the probability of someone finding a match goes up, increasing the probability that they continue in the pool and encourage others by word-of-mouth. The tipping point occurs when more people are joining than dropping out. Given the sensitivity of success to the number of potential partners, increasing that number is important.

Determining the tipping point for a given market is crucial. Initially, the growth of a service must be started by a marketing campaign. Obviously, an intense, short campaign is preferred since it promises to reach the tipping point while suffering fewer drop-outs. Having a model might bolster the courage to spend heavily on marketing. We need a model that estimates where the tipping point is, thereby predicting the cost of the marketing campaign.

First, consider the likelihood of a given driver and rider successfully engaging. One question is how much the driver needs to deviate from his route to serve the rider. There are three times, r_1 = the deviation on pick-up, r_2 = the deviation on drop-off, w = the waiting time at the pick-up spot, and l= the lateness at the destination. These times must be compared to the total length of the driver's trip, L. The delay factor D is defined by

$$D = \frac{L}{L + r_1 + r_2 + w + l}$$

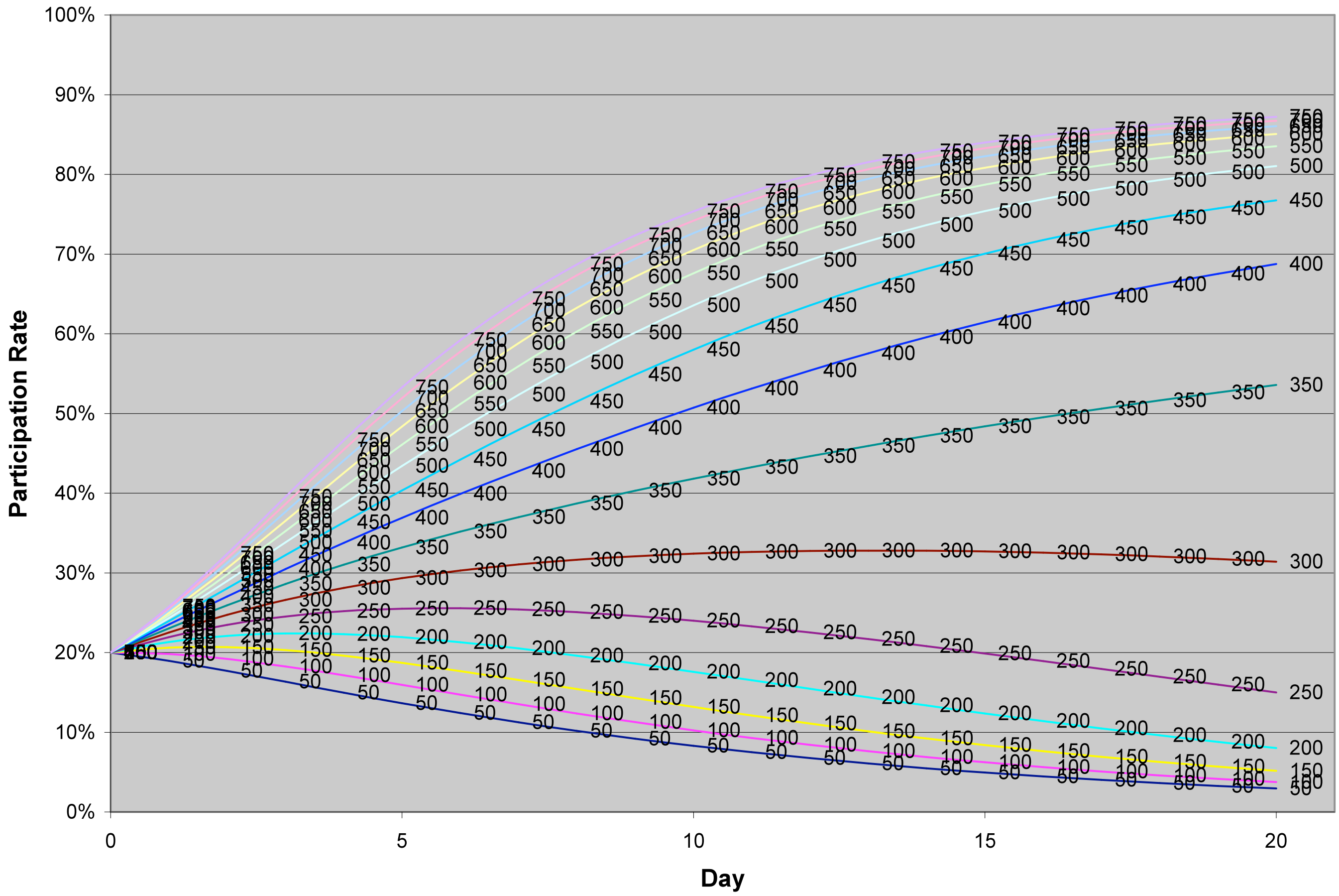

Figure 2. Effect of Population Size on Participation Rate over 20 Days

Steve Raney's studies suggest that a D of 0.75 or more is acceptable, but we can simply use D as an approximate probability that the driver and rider are feasible partners.

Then there is a catch-all, imponderable probability P that a rider and driver are otherwise compatible yielding probability DP that a proposed arrangement between the two will fly.

Suppose there are N drivers for some fixed D. Then the chance of a rider securing a ride is

$$1-(1-DP)^N$$

i.e. one minus the probability of all of the drivers refusing a proposal. As Figure 1 shows, to get the chances over 80% one needs either $DP>0.25$ or $N>30$, and there is a large range of values for which a match is virtually certain. If the tipping point is 50%—the success rate needed to increase the probability of repeat requests—then $N>20$ might be good enough. As the chart shows, success is relatively insensitive to DP in that region.

For simulation purposes, where the routes of individual drivers and riders are known, the more exact formula is

$$1-\prod_{i=1}^{N}(1-D_i P)$$

Note that the set can be truncated for computational purposes when D_i gets below a threshold, e.g. 0.75.

Figure 2 illustrates the effect population size on participation rates. Consider a range of population from 50 to 750. Each person starts with a 20% probability of participating. If a request succeeds she increases her probability by moving half the distance to 1.0. If the request fails, she halves the probability. As the population increases, the probability of a request succeeding increases; causing the subsequent rate of participation to increase—a virtuous (or vicious) cycle. Apparently, a population of 350 is sufficient to cause continuing growth in this example, shown more dramatically in the Figure 3 below. Again, it seems population size is more important than other parameters. If ever there was a principled argument for "Get big fast!" this is it.

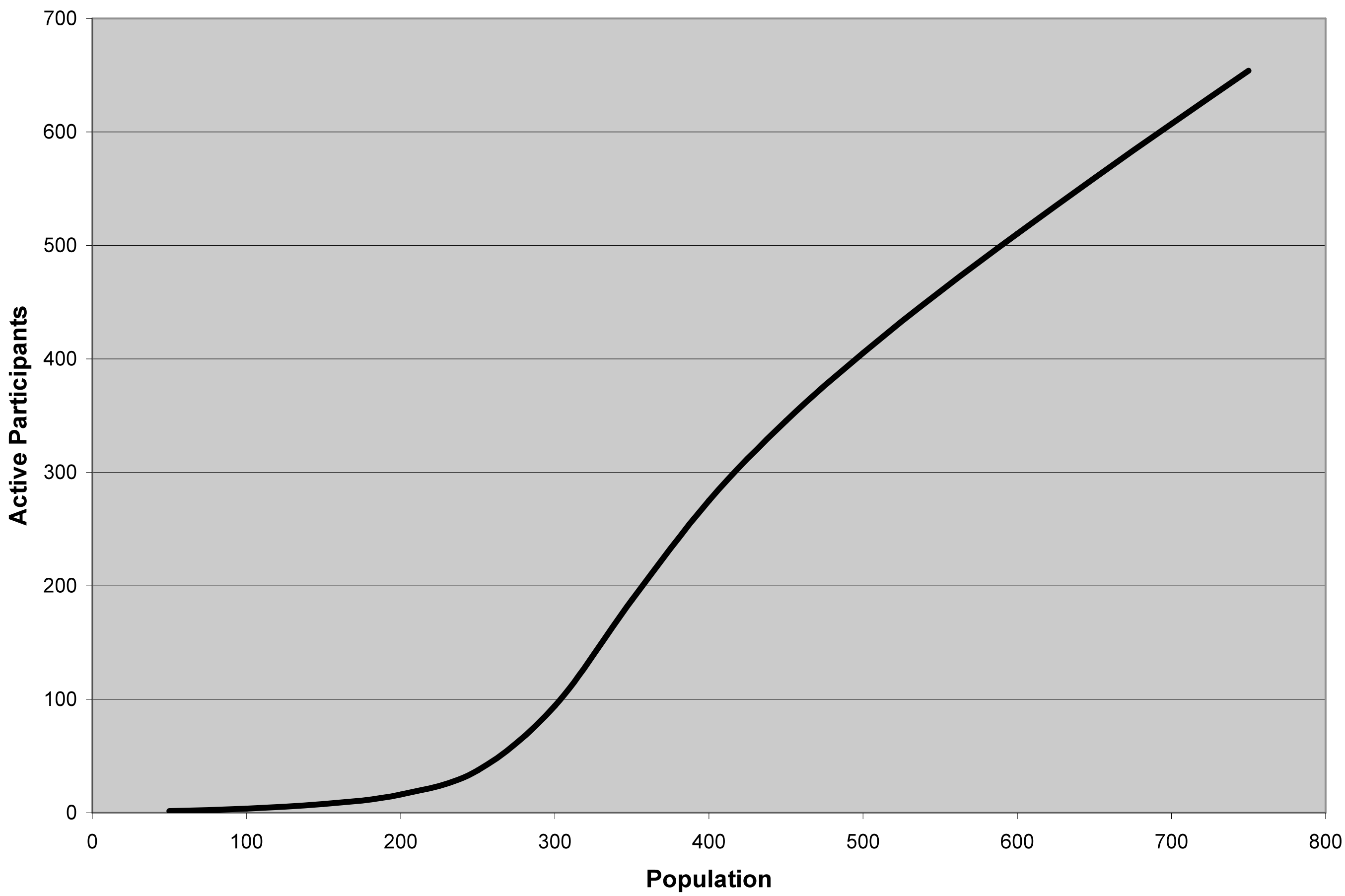

Figure 3. Participants at Day 20 vs. Population

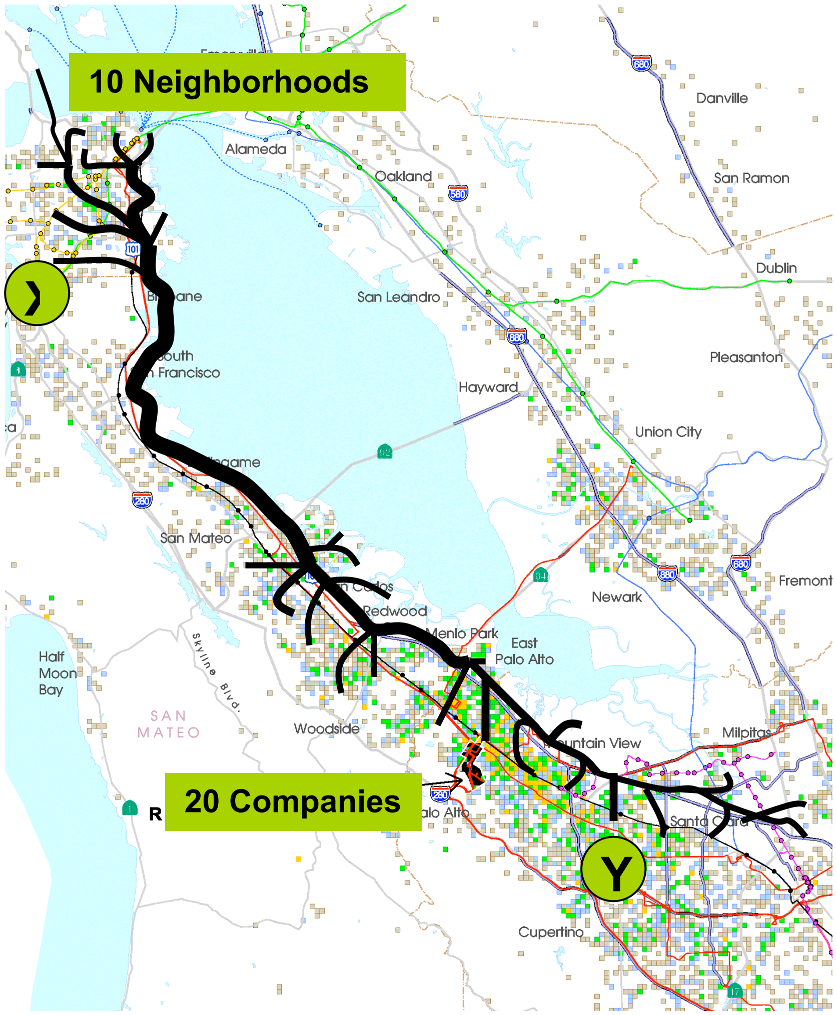

Figure 4. The Dispersal of Sources and Destinations for 101 Travelers

Creating Virtual Hubs with Cell Phones

Hubs can also increase the possible matches, as a toy example, depicted in Figure 4, suggests. Suppose there are 1,000 drivers starting from ten different home neighborhoods and going to twenty different companies. For simplicity, assume they are equally distributed among neighborhoods and companies, i.e. 100 in each. Then, continuing the assumption of uniform distributions, there are about 5 people in neighborhood X who are also driving to company Y. So there are about 5 possible partners for someone seeking a ride. If the basic probability of an agreement between rider and driver is 0.1, then the chance of a match is about 0.4.

On the other hand, suppose we have an intermediate hub that all 1,000 commuters pass through at about the same time, allowing passengers to switch from someone from their neighborhood to someone going to their company. In this case there are about 100 people the rider can start with and about 50 he can continue with. The population of potential drivers has increased by almost a factor of 10 and the probability of a match goes up to 1 (=0.995)! Generally, if there is are D drivers, N neighborhoods, and

C companies, the potential number of drivers for a given rider is about D/min(N,C) if transfers are allowed and D/NC if they are not. So a hub has a dramatic effect.

In most regions there are few large hubs *per se*, but major highways and bridges constitute virtual hubs. For example, the Bay Area's US 101 is a sort of 40 mile hub running from San Francisco to Silicon Valley; it is fed by hundreds of neighborhoods and drained by hundreds of companies. Suppose I can find someone passing through my neighborhood and commuting on 101 during the same time frame that someone else who passes my company is traveling on 101. Assuming there is some common stretch of 101 they both traverse, I can arrange to switch anywhere along it.

This is where GPS-equipped cell phones become useful. Arranging the rendezvous without them would be risky, but as long as the two drivers can be in communication, a convenient transfer location can be found and adjustments for traffic and mishaps can be made. The vision of hundreds of commuters stopping on the shoulder is worrisome, so a series of waiting kiosks could be established, probably at interchanges, to reduce danger.

Extending Neighborhoods

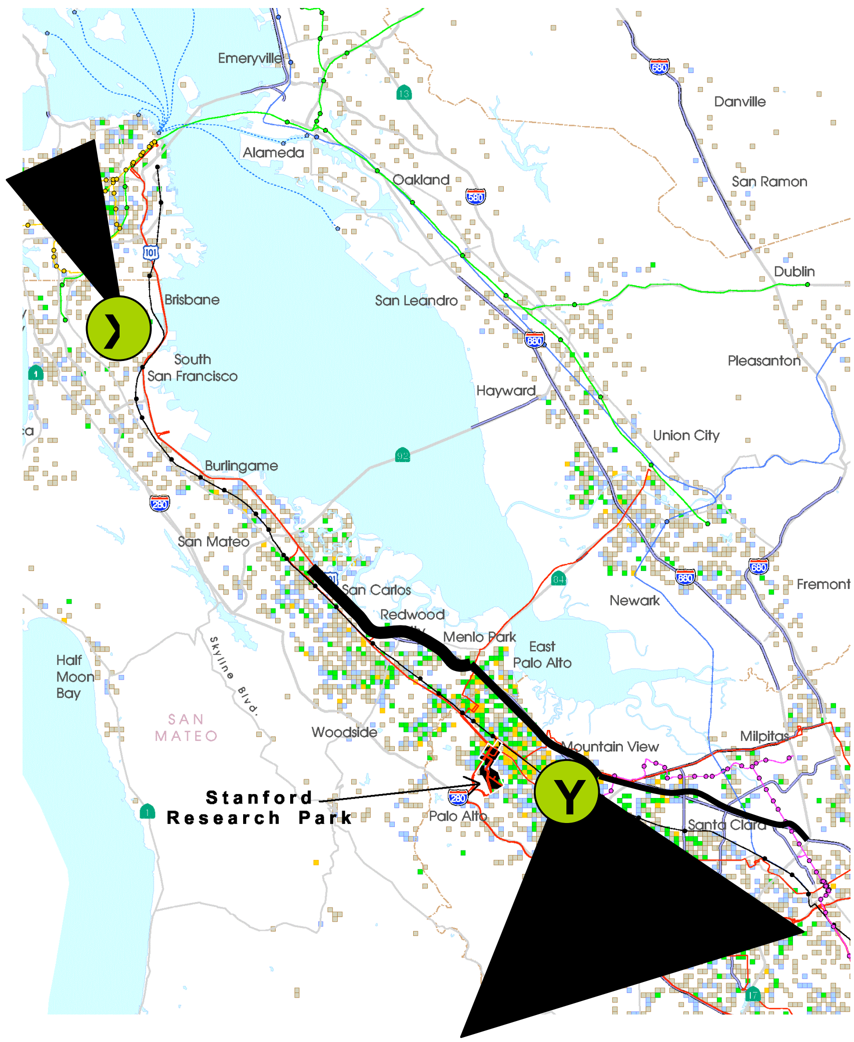

Figure 5. Extended Neighborhoods for Ride Sharing Partners

Most ridesharing systems are aimed at setting up carpools among people leaving and going to the same places. We can increase the possibilities by proposing rides from drivers who simply pass by the rider's location and arranging round trips involving different drivers for the two directions. For example, in Figure 5 the drivers who can provide a ride from X to Y might be start and end anywhere in the black triangles. Such complications are hard to manage without a good data base system.

Something to Simulate

Here is an abstract model that we could simulate to get an idea of the dynamics of market formation:

Assume a circular track on which everyone wants to travel clockwise. Create a large pool of travelers each of which has starting and ending locations on the track and some distinct probabilities of entering the market as a driver or a rider in the next time interval, e.g. an hour. Each also has a distribution function of lead times—the time after entry that they wish to begin their trip. For each time interval:

1. Select a set of drivers and riders to enter the market based on their various characteristic parameters.
2. Perform all possible matches.
    a. For each rider, find the smallest set of available drivers that can sequentially pick him up and drop him off until he reaches his destination, not requiring him to wait more than five minutes anywhere on the track. If such a set is found move the rider from the market back to the pool. Also record the capacity left in the various drivers' cars.
    b. Record successful matches in for all participants by increasing their probabilities of entering the market again.
3. When the start time for any rider or driver passes, move them from the market to the pool. If they failed to find any match reduce their probability of entering the market.

A simulation might end up "dying" because the probabilities of entering the market decay or stabilizing with some portion of the pool continuing to be active. We would learn the influence of various parameters and have a guide for what to measure.

This simulation could be greatly simplified by eliminating the track and giving all travelers identical trips. It might even be studied analytically.

Of course, if one had an operational system, data could be collected to test a predictive model of the clients based on these ideas.

Money Exchange

There are many open questions about how to handle money.

Ignore it? Some people may be turned off by payments if they view ridesharing as a social activity. On the other hand, payments should increase participation and help balance drivers and riders.

Run through SafeRide? One can let people exchange cash, but GoLoco keeps the accounts, saving a certain amount of hassle for the travelers. It suggests they share $0.50 per mile total operating cost and adds a 10% commission. So if a lone rider on a ten mile trip would pay the driver $2.50 and GoLoco $0.25. Handling the money offers an opportunity to charge a commission unobtrusively.

Negotiated Price? The price could float, based on market balance. There are anecdotes that driving is more popular than riding. An open auction could be run for people who like that sort of thing.

Funny Money? NuRide simply awards points to the drivers. Funny money might change the psychology and an exchange market could emerge to convert to cash.

Law and Taxes? At some point—typically making a profit—charging riders may trigger legal liability or taxes.

Are Vans a Solution?

Over the last few years the attitudes of planners and policy makers has begun to look on vans as solutions as well as sources of problems. This interest is also starting to take shape in the more advanced economies which are looking more closely at movement solutions where regulations have changed to allow such services, many of which are supported by advanced information technology, including GPS tracking, internet booking systems and mobile phones to coordinate passengers and vehicles.

Various studies have shown that gasoline-powered vehicles are cheaper in fuel costs per passenger mile than railroads. Furthermore, the mpg per passenger for gasoline vehicles is roughly linear; so you can choose any size you like. The choice of size then comes done to balancing the cost of the driver (paid or not) with the flexibility and number of stops. A one-passenger vehicle (i.e. a motorcycle) has one stop at each end and requires the rider to be the driver. A 40-passenger bus has a negligible driver cost but reduces passenger convenience because one must start and stop at a few fixed bus stops. Cars and vans of various sizes compromise by having few passengers to pay for the driver but the ability to customize stops.

Vans seem a good compromise because one can afford a professional driver, making passengers feel safer, while controlling pick-up delays and allowing for a decent social experience.

But it is not necessary to design the right-sized vehicle for any area. Let the market place create the right mix of cars, taxi's, vans, and buses along with their routes and schedules. All the market needs is a central clearing house of information.

Helsinki

A simulation study analyzing the market in Helsinki (http://www.biomedcentral.com/1471-2458/5/123) suggests that *if* drivers and riders were supported with a perfect scheduler

- The net social benefit would be over 600,000 € per day if 50% of car users switch to vans.
- About 40% of car users would save money if they switched, including amortized vehicle and driving costs. (Fewer would save if marginal costs are used).
- 50% switching to vans is a sort of sweet spot with respect to aggregate delays; congestion disappears but peoples' time waiting for vans increases beyond 50%.
- The social benefit is negative if less than 25% of car users switch because of the cost of underutilized vans.
- A profitable business for metropolitan Helsinki could be run with 250 vehicles, which is

10% of the taxis in the area.

Because the social benefit calculation include things like reduced pollution and accidents, it is unlikely that passenger preference and driver revenues are sufficient to support the system without significant subsidy.

Los Angeles

A 1994 study of Los Angeles (http://www.reason.org/ps176.html) suggests that most trips there would be cheaper and about 15% longer in a van. It also cited the following figures:

- SuperShuttle's total cost per van mile, including capital, and profit: $1.40
- SuperShuttle's average passenger load: 3.25 (more like 7 in San Francisco in 2008)
- SuperShuttle's cost per passenger mile. $0.43/mile
- Average LA car commute: 12.5 miles, 23.7 minutes.
- Estimated average van commute: 28.5 minutes
- Estimated marginal operating costs for private car: $0.15 per mile.
- Estimated total costs (including purchase) for private car: $0.34/mile

While these numbers make van usage appear unattractive, today's gasoline prices, higher van occupancy, and threatened congestion charges probably tilt the balance in favor of vans. However, the cost of van riding would have to be considerably cheaper to induce behavior change.

One of the effects of the van adoption would be reduced road congestion that benefits everyone, including those who drive themselves. Thus, the adoption process may stall. To nudge the process along, a community could revise traffic rules, e.g. HOV lane requirements, to advantage vans further.

Where to Pilot

Even if the economic and cultural fundamentals were favorable, it is still a challenge to build the market. Choosing where to pilot the service is crucial. There are many possibilities:

- Before inducing more drivers into service we improve the hourly occupancy rate for dedicated vehicles by marshalling demand. Create or extend an existing taxi/van dispatching system like WebRideUSA and sell it to private transportation firms.
- Create a free hitchhikers guide that builds a large number of people who use it simply for *ad hoc* travel. Big numbers of people will get the attention of established services like taxis and vans.
- Find large employers that will sign up all their people, as NuRide has done.
- Build or consolidate ridesharing services like NuRide, ReadySetGoose, ZimRide, or GoLoco.
- Serve events. A concert or sporting event is a perfect aggregator of interests since it has a very focused time and audience. Even better would be school away sporting events because the audience is co-located. Zimride has tried this.
- Get the City of San Francisco, whose current mayor is proactive, to mandate its use by all licensed transportation services.
- Enlist universities. They have green inclinations, fewer cars, more community, more trust, and more comfort with technology. It worked for Facebook and Zimride.

- Serve Moffett Field. The NASA Ames Research Center and other organizations there have a loose community and a predilection for environmentalism. It's two mile from the Caltrain station and underserved by public transportation. It is the home of Carnegie Mellon in Silicon Valley.
- Serving K-12 schools
  - Trust is less of an issue. Parents have already committed socially to the school.
  - Scheduling is easier; schools have fixed schedules.
  - Students don't require much flexibility. Businessmen have meetings outside the office during the day, children do not.
  - School-based ride sharing already occurs and has critical mass. The school bus is a common sight across the country. Car pooling to athletic events happens frequently. Driving kids who are not your own is widely done, and understood.

Subsidies

There are many ways to buy participation in the beginning.

- Some companies are pay employees to alleviate parking costs.
- Smart phone manufacturers may support pilots.
- Better parking space from employers or cities is often offered.
- Free transit passes can be offered.

Guaranteed Backup

Since reliability is so crucial, SafeRide could guarantee rides by paying for taxis or vans. Perhaps deals with taxi companies could combine the basic dispatching service with a discounted rate for emergency back-up support.

Other Attempts and Studies

There is much to learn from many past and ongoing efforts. As with many not-apparently-profitable enterprises, most players are open and helpful.

Scott Adams, creator of *Dilbert*, blogged about this idea.

Stephan Hartwig and Michael Buchmann of Nokia wrote a good analysis of the ridesharing idea complete with a summary of several patents.

Ride Now! ®

A must-read is Dan Kirshner's wonderful but plaintive story of a six-year failed effort to get a system called Ride Now! started in the East Bay. We need to explain why this system didn't fly because plenty of good ideas were tried. A notable innovation was guaranteeing riders would not get stranded halfway through a commute by paying for taxis when necessary.

RideNow

Paul Resnick ran a pilot project at the University of Michigan. It had notable ideas: Start with a close community. Use email with semi-structured input as the default medium, but move to web page later. Start with minimal matching algorithm; let the people sort it out.

Sustainable Suburb Silver Bullet

Steve Raney wrote a fascinating MS thesis 2003 containing prescient ideas: Using cell phones and GPS to improve reliability and personal safety, car sharing like Zipcar, parking spot finders, as well as an ambitious autonomous electric car system.

Smart Jitney is a proposal containing many common elements with the ideas here. It suggests more organized vetting of the drivers; getting them to put a "Smart Jitney" logo on their cars is a nice marketing touch. It cites the startling fact that the BTU/passenger efficiency of commuter mass transit is not much better than automobiles at their current load factors. It also includes some ideas about improving law enforcement that are best ignored.

Company Programs

There are many ride-sharing and van arrangements sponsored by Bay Area employers—Google, Genentech, Yahoo, SUN, Oracle, and Stanford. Some are like buses with schedules and drivers; others are driven by the commuters themselves.

Devices

Cisco Systems is prototyping a Personal Travel Assistant, a handheld device that provides real-time guidance for an urban traveler.

Taxi Dispatchers

Leading edge companies already combine computers, GPS, and cell phones to support dispatching of vehicles. A typical service for taxis offers:

- Automatic closest vehicle dispatching and zone verification dispatching using GPS
- Automatic vehicle location using GPS technology and Map Displays
- Automated Customer Callout features
- Billing and Driver Cashiering Systems
- Car owner balancing
- Vehicle Monitoring Systems
- Personnel planning/driver schedules
- Precalculation of distance per booking for the call center
- Internal messaging (call center – car(s) and between cars)
- Invoicing (of corporate clients)
- Multi language support

There is a patent for a fully automated dispatching system that appears to be backed up by a real embodiment. It appears to be related to a company service that specializes in fleet management for ambulance services and others. It doesn't support any sort of negotiation or auctioning.

Institutional Obstacles

There are many commercial and regulatory threats that need to be evaluated and, if necessary, evaded.

- Insurance for civilian drivers who charge.
- Taxi licensing controls.
- Bans on sharing taxis.
- Companies or institutions wanting to keep their existing commuter support systems closed.

If drivers limit charges to normal expenses, about $0.50 per mile according to the IRS, common carrier liability should not be a problem. Subscribers to SafeRide can be asked to click a waiver.

Use Cases

The following sections are lengthy stories intended to guide the design and user studies.

Cheri Carless

She lives South of Mission and works in San Francisco as an insurance adjuster, doesn't own a car, uses the Muni to get to work an most other things. She is twenty-eight, single, straight and looking for a serious boy friend. Her problem is getting around the Bay Area or getting home late at night. She used to solve such problems by depending on friends, taking taxis, and renting cars.

- She goes to the SafeRide web interface from her home computer when she wants to visit a friend in Santa Cruz on a Saturday. She must register before looking for rides. The main requirement is that she has a personal cell phone that can be verified by SafeRide. She can fill in lots of personal information along with privacy rules later. She gets a starting balance of 100 SafeBucks, each worth a mile of travel.
- SafeRide gets the availability and prices from rental agencies and Zipcar. It also finds some van services and commuters. The alternatives it suggests are
    1. An anonymous person is driving to Santa Cruz from SF Saturday, will take her along for gas money ($40), but is returning later than she wanted. 1.5 hrs. travel time each way
    2. Zipcar, $68 for the day, gas, parking & insurance included, 1.5 hrs travel time each way
    3. Muni to Civic Center, Alamo Rental for day ($40), Gas ($40), Muni Home, 1.7 hrs travel time each way
    4. Muni/Greyhound Bus/Taxi, , 3.2 hr each way (shortening stay in SC), $30
    5. Bart, Caltrain, and Bus, $23, 3.5 hrs travel time each way
- Cheri doesn't feel like meeting anyone or negotiating their price down, so she opts for Zipcar which she's already registered for.
- She makes the reservation through SafeRide which charges Zipcar $2.
- On the trip, Cheri puts her GPS-equipped cell phone on the dashboard and it supplies navigation help via her Bluetooth earpiece. It also sends occasional messages to SafeRide giving her

location and ETA, which her friend in Santa Cruz can check because she listed her as a trip buddy. On the way back, it alerts Zipcar of the ETA at its parking place.

- In her spare time, she embellishes her profile by linking her SafeRide account to her Facebook account. The only additional work is to specify what prospective travel partners can see.
  - Just the facts: the beginning, end, and timing of a trip, plus a price when driving.
  - Careful: What any Facebook member can see.
  - Friend: What Facebook friends can see.
- A Facebook friend who happens to be a prospective travel partner can see the Friend information in any case. Cheri chooses "Careful".
- She rates her experience with Zipcar “good” when asked by SafeRide
- A week later, while out clubbing she wants to go home earlier than her friends who brought her. She contacts SafeRide through her cell phone to see the possibilities.
- SafeRide checks taxis, Muni, and civilians and suggests
  1. Terry Theatergoer, an acquaintance who, unbeknownst to Cheri, is at a nearby theater that gets out soon. She'll take her home for free, but will be 20 minutes from now. Trip will be 23 minutes after that.
  2. A taxi that will arrive in 3 minutes and charge $13. Trip will be 23 minutes.
  3. The Muni is available for $1 and will take 1.1 hour including a transfer.
- Cheri chooses Terry, follows her progress to the club, and goes outside precisely as she pulls up, waits for her. There was no charge since no money was exchanged. Cheri and Terry could have gone outside SafeRide after discovering each other, but preferred using its rendezvous support.

Harry Hitchhiker

Hitchhiking seems to have died, but Harry and many of his fellow East Bay executives are still at it. He lives in Piedmont and works in San Francisco's financial district as a stock broker. He likes reading more than driving. Most mornings he used to walk to a bus stop and someone often picked him up and drove him to a standard drop-off place in the financial district. The driver got the advantage of using the HOV gate to get across the bridge. If Harry didn't get a ride after a while, there was always the bus. There is a cultural tradition that the rider doesn't speak unless invited. Activist Dan Kirschner instituted a system of destination specific pick-up spots in San Francisco that allow people to reverse the process although the divers have less incentive since there is no toll in the Eastward direction.

Harry tried Kirshner’s Ride Now! system until it was discontinued. Now he uses SafeRide, which works better because of its improved cell phone interface and somewhat different model.

- Shortly in advance of his desired departure time Harry sends his desired trip to SafeRide.
- SafeRide finds all the drivers who have registered intercepting Harry's location and going near his destination and proposes them to Harry. He is presented a list along with their ratings for reliability and congeniality gathered from previous passengers.
- He selects one, sometimes someone he knows from Piedmont.
- As they move towards a rendezvous SafeRide uses their GPS's to keep them apprised of where

and when they will meet.

- When Harry enters and exits the car their phones perform a Bluetooth handshake and SafeRide records the trip transferring some SafeBucks from Harry's account to the driver's.
- The confirmation of rendezvous is crucial to maintain a reliability rating for drivers and riders. These ratings are used by subscribers to decide who to contract with. A rating of under 95% is a red flag for most people.
- They don't exchange money, so the service is free.
- Participants can give SafeBucks to each other independently, too. Sometimes people buy them from others.
- Harry and whoever drives him each get the right to rate each other on a three-point scale: Good, OK, or Bad. These ratings are accumulated by SafeRide and revealed every ten rides so that figuring out who said you were “Bad” is very difficult. If you rate someone as Bad, SafeRide will never link you with them again.

Patricia Parent

She is married, works at home, lives on Russian Hill and has a young child enrolled at the French American International School. She has a car, but would prefer to car pool.

- The school (which pays SafeRide a fixed subscription fee) recommends SafeRide. She goes there, registers, and puts in her desires: Carpool both ways five days a week, 8:00 and 15:00, between her home and the school, no money exchange.
- SafeRide finds two existing groups that go from her area to a few schools in FAIS's area and two registered individuals interested in a similar deal. It submits the information Patricia was willing to share with the "captains" of the two groups and the individuals.
- In a few days, Patricia gets three invitations to meet the groups and one of the individuals. After meeting and judging the alternatives she joins one group with five other people and agrees to start a new, two-person group with the individual, Joan. They create a SafeRide group, making Joan the captain and specifying some rules from a suggested list.
- Each group uses SafeRide's carpool calendar system that maintains the plan for each day: who drives, who rides, recommended routes, special time requests, a bulletin board, etc. It sorts outs many complications automatically, but each group's captain monitors it frequently for exceptions.
- Each driver uses their GPS-equipped cell phone to keep parents and schools up to date on their location and ETA.
- After a year, Patricia and Joan find a third person, and Patricia drop out of the group which has six people in it because it necessitated too many stops for her.
- Patricia and her banker husband give $1,000 a year to the SafeRide Foundation to support free community services.

Oprah Overachiever

Oprah and her husband live in Atherton and send their kids to the International School of the Peninsula (ISTP) in Palo Alto. Every morning at 7AM a school bus pulls up in front of her door to takes the kids and other neighborhood children to ISTP. However, four out five days she must leaves the house at 3PM to pick the children up at school at 3:30PM and drive them to the community baseball field, tennis courts, or Kumon school and back home at 6:00PM. She complains that she has become a full-time chauffeur. She doesn't discuss the environment as she pulls up to school in her SUV.

She thought about organizing car pools with fellow parents at the school but doesn't know them well enough and is concerned about the social embarrassment that will result if she begins a car pool and finds it uncongenial. The school itself resists organizing things for similar reasons.

- SafeRide comes to their rescue by offering to run an exclusive service for the school. The parents association approves, and the school provides the basic information to SafeRide which promises confidentiality.

- SafeRide allows each family to lay out their calendar, including all non-school trips. It proposes link-ups that work, always signifying whether the partner is from ISTP or not and revealing only information the participants wish.

- Some parents eventually opt to organize their own groups; but Oprah prefers to leave all the arranging to SafeRide on a day-to-day basis. This not only saves organizing but also saves embarrassment if Oprah or her kids decide to give someone a Bad rating; SafeRide never links them again while Oprah can play dumb when she sees the losers at a fund-raiser.

SafeRide saves Oprah 600 hours a year or 25 full days.

Camilla Commuter

Camilla is a twenty-something engineer at SpikeSouce in Redwood City but lives in San Francisco for the social life. She owns a car, but would rather ride with someone else so she can read or work for the hour-long rush hour commute. Her hours at SpikeSource are regular, 8:00 to 5:00, but often get extended an hour or two. Every few weeks she has a meeting or errand somewhere else on the Peninsula in the middle of the day. Unlike Oracle and other companies, SpikeSource is currently too small to provide commuter support services.

- She registers for SafeRide and registers a repeating trip from SF to SpikeSource, five days per week.
- SafeRide finds three options for her.
    1. Caltrain to Redwood City ($4), Reserved Taxi to SpikeSource ($15). Travel time: 1.2 hrs.
    2. Caltrain to Redwood City ($4), bicycle to SpikeSource. Travel time: 1.6 hrs.
    3. Gary Bauer Luxury Van, $20 each way, 1.4 hours counting other stops in SF and Redwood Shores. One week's commitment is required.
- She tries all options.
    1. works well because she can often get a ride with a colleague to the train station going home. Also, the taxi can be shared, so Camilla organizes a taxi-sharing pool, using SafeRide, among several people working in the same vicinity and using the same trains. The reserved taxi can be canceled without penalty one hour before pick-up.
    2. Bicycling is fine during daylight savings when work ends on time, but less pleasant

otherwise.

3. is nice to do some weeks because the vans have WiFi, coffee, snacks, TV, and a congenial group. It must be canceled a day in advance, however.

- Her occasional trips around the Peninsula during the day are handled by taxi or she just drives to work on some days.

Charlie Car Switcher

Charlie lives in Russian Hill and works at PARC in Palo Alto. He has tried everyone he knows in both places and never found a car pool partner. He enrolls in SafeRide describing his daily commute needs and it suggests two possibilities.

- Start the commute with Rhonda Russian who leaves his neighborhood at 8:00 for her job in Redwood City. Then rendezvous with Peter Parker who lives in Burlingame and drives to PARC. SafeRide notes that there is a fifteen minute window during which both drivers are close on Highway 101. Normally, Charlie would think this very undependable, but SafeRide's continuous track rendezvous service allows the drivers to adjust to any highway contingency. Normally, they do the change at the Anza exchange on 101, but sometimes adjust if traffic conditions require it.
- Start the commute with Boris K. who drops him off at Caltrain in San Francisco. Take Caltrain to the Palo Alto station where Sally S, who drives to PARC from Newark will pick him up for the rest of the trip. Again, cell phones coordinated by SafeRide are crucial for coping with any delays or mix-ups.

Charlie chooses the first alternative and similar one for the ride home, on the theory that a single transfer between conveyances is less risky than two.

Peter Parkinride

Peter lives in San Francisco and usually drives his job in San Jose. He would like a way to read rather than cope with traffic, but is too far away from the San Francisco Caltrain station. He enrolls in SafeRide and among the few conventional car pooling offers gets the suggestion that he drive his own car to the Park-and-Ride lot in Brisbane and then meet other commuters coming down 101 or take Caltrain to San Jose. The train takes about 30 minutes longer than driving.

This solution appeals to him because it has many backup options. First, there are far more opportunities to get a ride from someone driving down 101 when he arrives at the Park-and-Ride. Second, if there are no drivers, he can take Caltrain and be only 30 minutes late for work. Third, he can get back on the road with his own car.

In the beginning, he arranges rides from the Park-and-Ride on the night before but, when that fails, he uses the SafeRide mobile access to either find a late-registering Park-and-Ride driver or become a driver for someone else in his same situation. In other words, a Park-and-Ride site with enough SafeRide subscribers can become a real-time market place at which many drivers meet to sort out who drives who each day. Eventually, Caltrans facilitates this activity by posting signs for various South Bay destinations where people can congregate. However, the services of SafeRide are still useful to support return trips; even if Peter finds someone to take him to San Jose, he might drive his own car if he is unsure of a convenient return plan.

Oscar Opera Lover

He lives and practices dentistry in Palo Alto, owns a car, and often attends the San Francisco Opera. He could drive to the opera, but the trip is a drag after a day at work.

- He registers with SafeRide and requests a round trip ride to the Opera House a few days in advance.
- SafeRide gets offers from taxi companies in Palo Alto and SF to meet scheduled Caltrain trains. The taxi companies have registered standard rates with SafeRide, so their response is automatic. Caltrain needn't be contacted, since they don't negotiate.
- SafeRide finds two options and presents them to Oscar:
    1. Sally from Sunnyvale happens to be going to the opera that night and has registered her expected schedule and price ($15, because she could use HOV lane and is going anyway. Cost of gas and parking is about $30). SafeRide estimates the travel time, including the time to pick up Oscar. Sally agreed to schedule and price after checking Oscar's member information.
    2. Taxi Palo Alto Train Station/Train to BART/BART to Civic Center/Walk to Opera House, Cost: $14 (including SafeRide's $1 fee = min ($1, 10% of transport cost)), Travel Time: 1:30h. Return: Taxi to SF station/Train to Palo Alto/ Taxi home Cost: $24, Travel time 2:50h, including 1:15 wait for train in SF.
- Oscar checks Sally's reputation and chooses her. He doesn't learn anything else about Sally (even her gender) because Sally has specified minimum exposure in her profile.
- SafeRide charges Oscar's account $16, then sends confirmation to Oscar and Sally with location, times, and a one-time credentials that each of them loads into their cell phones.
- On the appointed day Sally sets off for Palo Alto, placing her GPS-equipped cell phone on the dashboard, set to communicate with SafeRide's tracker using WiMax, WiFi, or Cell Network (whatever is available).
- SafeRide provides Sally driving directions, displaying a map on the phone and giving turning commands by voice in her Bluetooth earphone.
- Oscar activates his phone and sees a similar map showing Sally's location and ETA.
- As Sally approaches Oscar's house their phones make appropriate, brief noises.
- Sally arrives, they get their cell phones to handshake, confirming their identities and the contract. Oscar gets in the back seat and doesn't talk until Sally gives him permission, a SafeRide convention.
- They drive to SF, park, and walk to the Opera House. Their cell phones send the time of arrival to SafeRide, allowing them to indicate satisfaction so far and designate a rendezvous place for after the opera.
- After the opera, they meet with the aid of their cell phones signaling proximity, walk to the parking garage. Sally invites Oscar to sit in the front seat for the return trip.
- Sally, again aided by directions from her cell phone, drives Oscar home. Their cell phones confirm the satisfactory end of the contract to SafeRide which transfers $15 to Sally's account.
- Sally and Oscar exchange email addresses and tentatively agree to car pool again for other

operas. Each replies to SafeRide's query by giving each other good ratings.

- Time passes.
- For another opera, Oscar repeats the request for a trip. SafeRide finds only the Caltrain option this time, so he decides to drive himself after learning from Sally via email that she's not going this time.
- Time passes.
- Sally emails Oscar that she's going to an opera in two days. Since he is too, they agree to car pool again, this time with no formal charge. They go through the SafeRide process again so as to get the rendezvous and directions support, but Sally proposes a $0 fee upon getting Oscar's request.
- They proceed as before, but Oscar pays $15 for the parking.
- Time passes.
- Oscar and Sally, after several more operas, get married, and stop using SafeRide for opera trips.

Driver Use Cases

The Muni, BART, Caltrain, Samtrans, VTA, and the rest make their schedules available on line. They don't have time or desire to coordinate with SafeRide.

Claude Commuter

He lives in San Francisco and commutes to Redwood City, a 40-minute drive at 55 mph. He likes driving himself, but would like to have riders to give him access to HOV lanes, share expenses, and maybe conversation. He is not concerned about personal safety, but is no more fond of irritating people than the rest of us. He would like to reduce CO_2 emissions if it's easy.

- He registers his Monday-Friday trip with SafeRide (25^{th} Avenue to 280 to 84 to Redwood City, 7:30-8:45, and returning 17:30-18:45) and his tolerance for detour time (20%) and desired number of riders (3), type of car (BMW).

- He is given four possible regular commuters with their start and end points and times. Three of them are identified just by their travel information, the fourth allows his profile to be seen. All have average to good reputations. Claude accepts the fourth and asks for more information about two who fit his commute well.

- One of the two answer by giving some personal information and he accepts them. SafeRide provides a suggested route with pick-up and drop-off times for everyone.

- The three people are put in a group so that they can use the calendar system to permit timely notifications of cancellations.

- Claude asks SafeRide to put him on the hitchhikers' menu for extra rides. As he starts his route each day he activates his cell phone and SafeRide plots his route, remembering any cancellations and sometimes finding someone additional for him to pick up.

- Claude and his group have their estimated CO_2 savings tallied and displayed on their individual and group pages.

Tom Taxidriver

Tom is San Francisco cabbie. His region covers all of San Francisco, trips to the airport, and stops in between. He leases his taxi from Yellow Cab and works the maximum ten hours per night. He makes about $300 per day after paying about $90 to Yellow and $100 for gas. He pays $60/week for the dispatching service. He would like to make more money. He used to depend on Yellow's dispatching service for fares plus picking up riders at popular places and times. After buying a GPS cell phone and signing up for SafeRide his methods changed.

- He specified his region as San Francisco and San Mateo counties and specified his shift from 16:00 to 02:00.
- He started with the "Ask me" dispatching service which proposed trips to his phone and accepted one-button responses. He discovered during busy times that SafeRide was doing better than other dispatchers or his street pickups, so he would switch to the "I'm yours" service, allowing SafeRide to schedule and route all his fares.
- SafeRide is licensed as taxi dispatcher and advertises itself as Rainbow Taxi since it will support any taxi from any company.
- It tracks Tom's cab continuously and offers his service to all appropriate riders. It dictates his routes based on traffic conditions and locates second and third riders for his routes if all riders are agreeable to the "one block out of your way" sharing agreement. SafeRide collects negotiated fares from each rider and pays Tom weekly, charging $0.50 per rider.
- The standard rendezvous support features help Tom and his riders locate each other with less anxiety. He buys a roof display that flashes a rider's name taken from his cell phone.
- Tom's occupancy rate doubles, and his tips increase because riders are paying SafeRide for the fare. He's happy to be accumulating less cash late at night. Also, the fact that every SafeRide customer is registered and tracked during a ride makes him feel a little safer.
- In idle periods SafeRide suggests places Tom might go to be more available for anticipated riders. SafeRide's extensive historical data base makes it a better predictor of rider demand than Tom's intuition or other, smaller dispatchers. Also, it uses information about all its client vehicles to spread their supply based on predicted demand.

In the end, his nightly income rises to $700, including the saved cost of his original dispatcher.

Cab Companies

The companies hear from their drivers about SafeRide and begin to notice less traffic through their dispatchers which are independent services. Eventually, most discontinue their dispatching service since it was a free service to the drivers. They redirect their phone number to SafeRide which agrees to give each company priority for any rider that calls through its number.

SafeRide's predominance as a San Francisco dispatcher makes all the taxis more active because of its ability to marshal more demand and balance loads in different regions.

Victor's Van Service

Victor runs a high-end limo and van service with twenty limos and ten vans. He rents them for four or more hours at a time to groups sized from four to sixteen. All his drivers work on a will-call basis. The average vehicle duty time is 17 hours per week. He would like to expand business but can't compete with SuperShuttle and larger limo services that have more marketing muscle.

- He registers with SafeRide like a cab company, equips two limos with GPS cell phones and WiFi and chooses a region suggested by SafeRide, Redwood City down to San Jose. The limos are advised to circulate in the 101 corridor when idle.

- Silicon Valley workers that have been using SafeRide for commuting try the limousines for local business trips because of the WiFi service, the ability to schedule at the last hour, and the chance to have pre-meeting conferences on the way. They are immune to the fares, higher than taxis, because their companies pay.

- The limos also operate as taxis, charging taxi fares and seeking multiple pick-ups and drops-offs. They do a good business servicing Caltrain stations during rush hours.

- To accommodate larger groups Victor puts a few vans into roaming service. He refits the vans with tables, projectors, and a complimentary drink service. Larger teams start to use the vans for big meetings and even internal offsite trips to places like Santa Cruz.

- Finally, Victor puts more vans into service for San Francisco – Silicon Valley commuters. The vans compete well with Caltrain and even the free company-paid vans because of their superior amenities. Eventually, some companies replace their dedicated van services with Victor's, using SafeRide's dispatching system. Some vans are dedicated to a single company's staff, but the employees of any signed up company can ride any open van when more convenient.

The Implementation

New Technology

Intelligent cell phones and internet services like Google Maps indicate how a system could be built that makes ride sharing much more desirable.

GPS and cell tower triangulation make it possible to track the locations of vehicles and people.

Powerful cell phones allow continual connections between passengers, vehicles, and a central scheduler.

Computer scheduling and machine learning can be used to get the most out of a pool of vehicles. There is no limit to the strategies that can be employed to maximize convenience. Real time scheduling can coordinate the pool while demand data is collected to improve the planning and coordination of vans over time.

There are many technical challenges:

- Systems challenges, e.g. how to get good, real-time location information
- Data base and algorithms, e.g. real-time scheduling, route guessing, fare negotiation.
- User interface, e.g. specifying routes, notifying drivers.
- Social networking, e.g. trusting drivers and fellow passengers, creating positive experiences
- Marketing/network effect challenges, e.g. how to build critical mass of passengers and vehicles

in selected locations, then expanding to less dense areas.

- Policy/joint powers issues, e.g. Caltrain, Bart and VTA agreeing to improve schedule compatibility, to allow dynamic flexibility, etc.

Personal Safety: Chaperoning

One of the reasons people don't car pool or hitchhike is the awkwardness of dealing with strangers. This makes services with professional drivers preferable for many people. However, we can do a few things to mitigate the natural lack of trust.

- All participants are registered with the scheduler, and drivers need more vetting in the form of licenses, driving records, financial information, etc. Participants are encouraged to include pictures and personal information but have the option of restricting information. The service might be done as a Facebook application.
- For the wary, only the information necessary to carry out a driving transaction need be given to participants by the system. Payments to drivers come through the system like cash.
- Cell phones facilitate the rendezvous by keeping parties aware of each other's location, possibly signaling when line-of-sight is established.
- Participants, upon meeting, authenticate each other using Bluetooth cell phones equipped with secure, privacy-sensitive software.
- The phones record the proximity of participants for purposes of billing and complaint documentation.
- Any participant can call for police assistance via their cell phone during a ride.
- Ideally, all cell phones would be equipped with two standard buttons: "Help!" and "Interesting!"
    - The first would be a 911 call that needed no voice interaction, i.e. it would simply read a script to whoever answers, saying "I am XXX located at YYY (, moving ZZZ at AAA mph). I require immediate, emergency assistance."
    - The second would record the time and place along with the last(!) 5 seconds and next 5 seconds of sound. It can be used for a variety of purposes: taking notes, alerting friends to cool things, warning others of a danger in the area, etc.
- The system maintains an eBay-like reputation system to which drivers and riders can report without fear of reprisals.

The Information System

Functional Requirements (key use cases)

Register Subscriber

A person registers directly or through a social networking site like Facebook providing contact information (email, IM, cell phone), social network, and credit card.

Request a ride

Subscriber describes trip in same style as Orbitz
It's possible to make it a repeating ride, e.g. a week-day commute.
A person desiring transportation enters

- Start Location
- Desired Start Time (optional)
- End Location
- Desired Arrival Time
- Offer Price
- Constraints: Number of fellow riders, number of transfers, qualifications of driver, amenities
- Round-Trip?
    - Desired Start Time
    - Desired Arrival Time
- Park-and-Ride possible?
    - If the subscriber can drive a car to a meeting place and leave it for a return trip, he will be offered options starting from there.
    - He also has the option of offering rides to others from the same place.

Offer a ride

Subscriber describes trip by specifying a particular route or region and a time window.
An individual offering transportation

- Starting Location
- Starting Time
- Destination
- Route. SafeRide could use Google Maps to propose a route and let the subscriber modify it.
- Park-and-Ride possible?
    - If the subscriber can drive a car to a meeting place pick up people, he will be offered options starting from there.
    - He also has the option of being a rider from the same place.
- Asking Price
- Details of service: Number of seats, driver qualifications, amenities

A Professional Service offering transportation

- Region of Service
- Lead time needed for guaranteed pick-up.

- Hours of operation
- Rates

Connect for Tracking

Any subscriber who is on the move can connect with a cell phone, whether or not they have requested or offered a ride, something they can also do when connecting. After this, their phone will periodically report their location to SafeRide.

Propose Agreement

SafeRide sends a message to a requesting rider with multiple alternatives and a messages to each provider with a description of the need. The timing, route, and costs are supplied.

Examine Proposer

The potential partner of any proposer can examine their reputation and any other information they have made available for potential partners.

Agree to proposal

A rider or provider agrees to a proposal. There may be limited scope for counter-proposals, e.g. different prices or times.

Confirm Agreement

SafeRide, upon getting agreements from matching partners, notifies them and sends rendezvous instructions including time, place, helpful descriptions.

Report Position

Each partner can periodically refresh a map view showing the position of them and their partner and the expected rendezvous time.

Report Rendezvous

When the rider gets in the car, the driver's and rider's cell phones handshake and report to SafeRide.

Report Problem, Revise Plan

At any time a driver or rider can signal a problem and enter a revision protocol. This requires extensive design since it is the main value-creating feature of the entire system. Eventually, it might involve multi-way voice communication among the drivers, riders, and the service.

Request Help

Either partner can surreptitiously signal 911 for help during a ride.

Report Destination Approach

Crucially, when mass transport is being used, your phone tells you when to get off as a stop approaches.

Report Parting

When the rider exits the car, the driver's and rider's cell phones handshake and report to SafeRide.

Report Experience

Partners in a ride can rate the quality of each other for the reputation maintenance system

Manage Account

Subscribers can review their accounts for history and Green Miles accumulated.

Nonfunctional Requirements

- All operations must be possible from either cell phone or web browser.
- A humanned service desk is needed.
- The information disclosed about any subscriber should be minimized subject to the goal of achieving matches. Subscribers reporting negative experiences should be protected from detection. In other words, the system should error on the side of complainers.

Dependencies

- SafeRide needs to link with social networking sites
- It needs mass transit information
- It needs a source of advertising like AdSense

The Matching Process

A preliminary scan of the literature led me to believe the old-fashioned OR-style algorithms are not appropriate. Optimization is unneeded; matching is naturally fuzzy; and the participants make the final choices. Here is a sketch of how I would do matching for purely *ad hoc* trips.

Data Structure

Conceptually, you can think of the data structure as a three dimensional grid with each horizontal plane representing the physical region and the vertical dimension representing time. Each planned driver's trip is a line through the space, ascending through time. The space can be made into a discreet graph by choosing five minute intervals and forcing each line to go through street intersections. Then finding a ride for someone amounts to a solving a single-source-destination shortest path problem.

Because the graph is very sparse and other considerations, the actual data structure is a directed graph of every intersection where a pick-up or drop-off could occur. Permanent edges to adjacent intersections are labeled "driving", "walking", "bicycling", etc. along with transit times. There is no third dimension; instead each node has a time-ordered list of expected arrivals of drivers.

The Algorithm

When a driver enters, plot their route using a shortest path algorithm, allow them to modify, and insert them in the arrival schedule at every node along the route.

When a rider enters, we find the match by performing a shortest path search in which the edges between vertices are actual drivers traveling between those vertices at an appropriate time.

The algorithm is Dijksta's

```
function Dijkstra(Graph, source, destination, startTime):
    for each vertex v in Graph:       // Initializations
        time[v] := infinity           // Unknown arrival time at v
        previous[v] := undefined
    time[source] := startTime
    Q := copy(Graph)       // All nodes in the graph are unoptimized - thus are in Q
    while Q is not empty:            // The main loop
        u := extract_min(Q)          // Remove and return earliest vertex reached
        if u=destination then return previous []
        for each neighbor v of u:    // where v is still in Q
            len := shortest(v, arrivalList(u))
            alt := time[u] + len
            if alt < dist[v]             // Relax (u,v)
                time[v]:= alt
                previous[v]:= u
    return failure[]
```

The function shortest(v, arrivalList(u)) scans the arrival list, finds all the drivers that arrive after time[u], finds the one that would reach v first, and returns the waiting time plus the time it takes it to get from u to v. If, as is likely, the rider is not changing drivers at this node, the waiting time will be zero; i.e. the smallest arrival time is time[u].

Assuming maximum cleverness is employed in the function extract_min, this algorithm is bounded by $O(|E|+|V|\log |V|)$ time where V is the number of intersections and E is the number of vertex pairs that have any driver moving from one to the other. Many things can be done to speed up the algorithm. For example, one can compute the earliest arrival time for the rider assuming that a driver exists between any two adjacent intersections, and then stop searching if the current time exceeds it by 30%.

Note that the shortest path may involve switches among drivers, but the algorithm should naturally prefer continuing with the same driver since switching usually involves a wait. Nevertheless, some changes may be necessary to bias it towards fewer transfers. Also, it may be desirable to find the second or third shortest path to offer more choice.

Many other issues and adjustments will be required in practice.

- Riders and drivers may be willing to alter their plans to find a ride; e.g. the matching might be made “fuzzy.” Since the probability of a match increases exponentially with the number of candidates this is important. The algorithm can be extended by starting it from many intersections near the rider’s start point and stopping it at any intersection near his destination. The acceptable detour time for the drivers determines the definition of “near”.
- If a rider fails to find a ride, they must be put in a waiting pen and tried later, triggered by the entry of a likely driver.
- Public transit schedules can be inserted as drivers, but arrival times might need to be made conservative.
- Each driver has a maximum number of riders so should be removed from the data structure when the car is full.
- Taxi services with no fixed route must be treated specially. They don’t fit into the shortest path approach very well. Patching a short taxi ride into an otherwise complete route is algorithmically difficult.

A negotiator module proposes contracts to potential matches, closes deals, and collects payment from each rider for the account of driver.

Automated auctions could be run once the volume of possible rides exceeds what a person can consider.

Today's Plan

- Conduct in depth user studies to identify needs and obstacles to adoption, supported by CyLab and Google.
- Develop a simulation model that can estimate the tipping point for a given population. This is crucial to decide among new markets and guide marketing campaigns.
- Build on internet mapping services to add scheduling, negotiation, auctions, and reputation maintenance.
- Provide a free service in a limited area.
- Get companies that already offer commute service to employees to combine and offer it to others.
- Promote the emergence of independent services, regulated to insure safety, reliability and profitability. In principle, the system can extend to “civilian” drivers who drive for their own purposes.
- Access data from existing mapping services or Caltrans to understand demand patterns.

Scraps & Ideas

Make a hub at SFO, challenge SuperShuttle.

SafeRide fixes prices to reduce social anxiety.

Number of feasible rides decreases as window narrows, but likelihood of “yes” increases.

Lead time shortens as Number increases.

Ad *hoc Personal Travel* (aka *adaptive/dynamic inter-model transportation)*

- A social networking aspect is to connect with a ride sharing/car polling community, offering to share gas costs and allow diamond lane sharing.
- Some times a feasible routing is not possible because of unknown or incompatible schedules, or slight delays.
    - Dynamic ticketing - One scenario might be to have a train wait up to 5 minutes if a enough people could indicate their desire to transfer from some other mode (e.g., cal train to Bart interchange in Millbrae). If all transport schedules (actual, not just published), and projected ETA based on load were available, a dynamically optimal routing could be proposed; if accepted, this could place a time limited reservation on a resource, ensuring better loading and better utilization of energy and other resources.
    - This is a form of "congestion management". One could also sell an electronic ticket that places "reservations" on multiple services with different probabilities or weights, which get adjusted as the inter modal travel decision gets closer
- See Yin & Griss paper, **SCATEAgent: Context-Aware Software Agents for Multi-Modal Travel**, AAMAS 2004 workshop on transportation, New York, July, 2004 (http://martin.griss.com/pubs/aamas2004-workshop.pdf)

Personal Goals of Personae

- saving money
- saving time
- doing good for the environment
- being safe

The public transit system in the San Francisco Bay Area and many other places is unsatisfactory and very expensive to extend. California is a car culture, so land use has sprawled; and no new static transit system can serve everyone. Autonomous vehicles supported by a great information system may be a viable, profitable solution as the cost and inconvenience of surface transport inevitably increases. Modern information technology can revitalize the old ideas of ride-sharing, van pools, taxis, and van services to complement mass transit systems. The methods used by airlines to sell tickets can be shrunk in time by orders of magnitude to apply to short haul surface travel. This possibility occurred to me at Cisco’s recent Connected Urban Development conference in San Francisco.