RideFriends:
More Rides, Fewer Cars

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ABSTRACT

Let's increase the vehicle occupancy rate to reduce congestion, pollution, and loneliness. This report is adapted from an NSF proposal from Morris, Resnick, Cranor, and Selker (Section 2) and a design for a ridesharing service created in co-operation with many Carnegie Mellon faculty and students (Section 3).

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1 Vision and Reality

Instead of using a personal car, a person uses her cell phone to travel. She enters her destination; and, within minutes, a proposal employing one or more vehicles is presented to her. The pick-up occurs within minutes of her start time, no matter how soon it is. Her trip, along with possible transfers of vehicles, is monitored via her phone and phones in the vehicles. She enjoys the companionship because she and her partners have a relationship beyond ridesharing. Payment and feedback are handled gracefully.

The RideFriends system (RF) employs a combination of ideas from 511.org, Google Transit, Zipcar, Facebook, eBay, and eHarmony. It exploits cell phones and the web. It is the central nervous system of the entire surface transportation system for a region. It links drivers and riders in an attempt to match the convenience of personal vehicles. It can be a service that helps the environment, improves the quality of lives, and supports community.

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. 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.

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[1]; and Carlotta Perez observed[2],

> *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?

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!) See dynamicridesharing.org for a list of past, present, and potential attempts. While this vision is possible. However, it is unlikely without advances in two areas: real-time control and human behavior.

Real-time control of thousands of moving agents

Consider a thousand or more active vehicle trajectories, defined by predicted times, points on a map, and capacities, and another thousand potential passengers defined by times, start points, and end points. There are also several hundred "wild card" vehicles, e.g. taxis that can be assigned arbitrary trajectories. RF assigns each rider to one or more vehicles whose trajectories will carry her from start to end, allowing for reasonable waits at pick-up locations. The vehicles report their position every few minutes, causing the predictions to be updated. Each participant is sent a "time and place to rendezvous message" at suitable intervals. Congestion throughout the region is monitored and RF revises predicted arrival times continually. Vehicles are re-routed, and plans are changed dependably. The performance of individuals, fleets, and RF itself is improved using the data exhaust from operations.

Changing human preferences and habits

As *Bowling Alone*[3]and other research shows, even if we create a system that approaches the convenience of a personal car, people have many other reasons for driving alone. There is uncertainty, fear, and the desire for solitude or control. In certain times and places carpooling, hitchhiking, and ridesharing are common.[4] We need to explain this behavior to understand how to promote it today in many places.

2 Theory

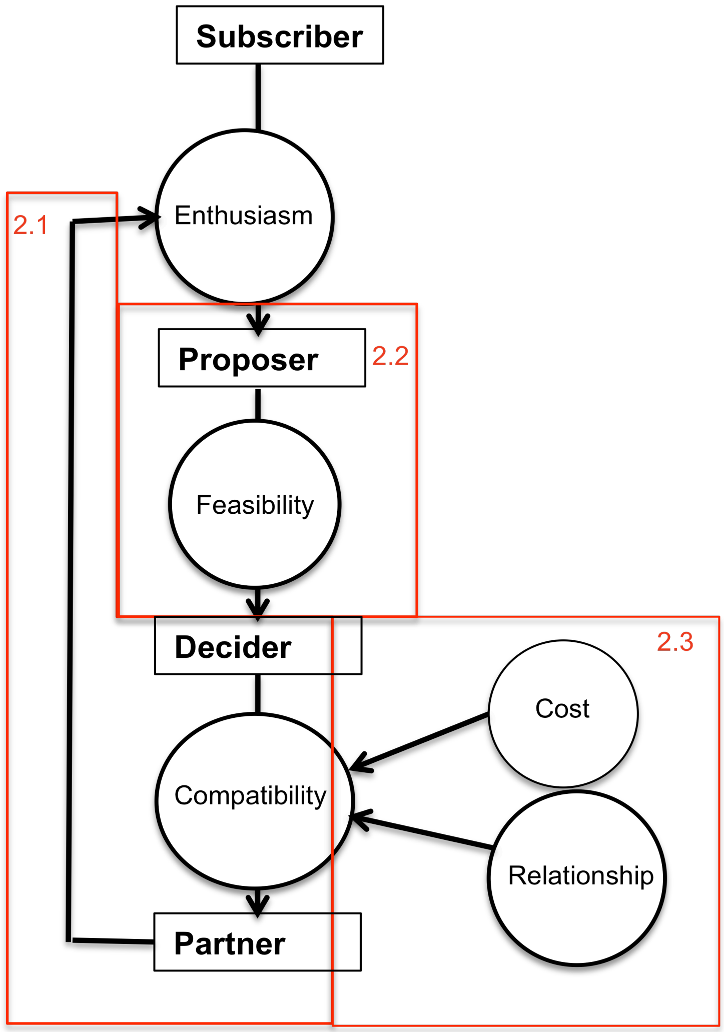

Figure 1. RideFriends's Pipeline

Figure 1 shows the crucial pipeline of RF. A person enters the service as a *Subscriber*. Her level of *Enthusiasm* determines how often she proposes giving or receiving a ride, thereby becoming a *Proposer*. The service matches proposing drivers and riders for time and location *Feasibility* and offers various partnerships to her, making her a *Decider*. She accepts a partnership based on its *Compatibility* with her needs, and then becomes a *Partner*, someone who actually participates in a ride. Compatibility is based upon two personal attributes, her perceived *Cost* of the trip and her *Relationship* with the proposed partners. Finally, being a successful Partner increases her Enthusiasm, so the model has a positive feedback loop. The red boxes identify which of the following three sections describe the components and their interactions.

2.1 Is there a Tipping Point?

Ridesharing can succeed only if there are enough riders and drivers. The density of users traveling similar routes must be high for matching to occur. If there is no tipping point at which a service attracts a self-sustaining critical mass, it is not going to succeed.

The feasibility for ridesharing can be estimated for a region, corridor, or an employer hub using information from planning data maintained by the metropolitan planning organizations or employers. Their databases are based on household activity and travel surveys. The information includes origin/destination flows by time of day by various modes, distributions of trip purposes, as well as demographic information. This will allow us to obtain upper limits of potential ridesharers, by age groups or other demographics, as well as origin/destination areas.

Generally, analysts have asked the question of how many people in a whole region might rideshare. We are asking a complementary question: how big does a group of willing ridesharers need to be in order to self-sustain. A ridesharing system, like a market, becomes self-sustaining when more people are joining and participating than dropping out. One needs a model that estimates where the tipping point is, thereby predicting the cost and timing of a recruitment campaign. A preliminary search of the economics literature has not found any theory of how new markets grow, only how they reach equilibrium.[5]

2.1.1 Does success increase exponentially with subscribers?

A very useful paper by Hall and Quershe[6] proposed a model for the effect of mutual compatibility. Suppose the number of feasible drivers for a given rider is Poisson distributed with mean N. Let P be the probability that one of those drivers is compatible with the rider. Then the probability that the rider actually gets a ride is $1\text{-}e^{-PN}$. Figure 2 shows how the probability of success depends upon P and N; e.g., if there are 20 drivers each with 0.20 probability of saying "yes", the rider has a better than 80% chance of getting a ride. Raising either N to 50 or P to 0.35 makes the other parameter irrelevant. At this level of abstraction, the same reasoning applies if we ask the question whether a given driver can find a partner among N riders.

The authors went on to measure P for subscribers to a real system, Los Angeles Smart Traveler. [7]The responses of drivers called with a rider's request was

Yes	9%
Maybe	11%
Not Today	28%
No	16%
No Answer	36%.

Sadly, the Smart Traveler system arbitrarily limited the number of drivers approached to 10 while Figure 2 suggests that calling 20 or more would have significantly improved performance. Also, this study was published in 1997, before widespread cell phone use, so the "No Answer" category might be smaller now.

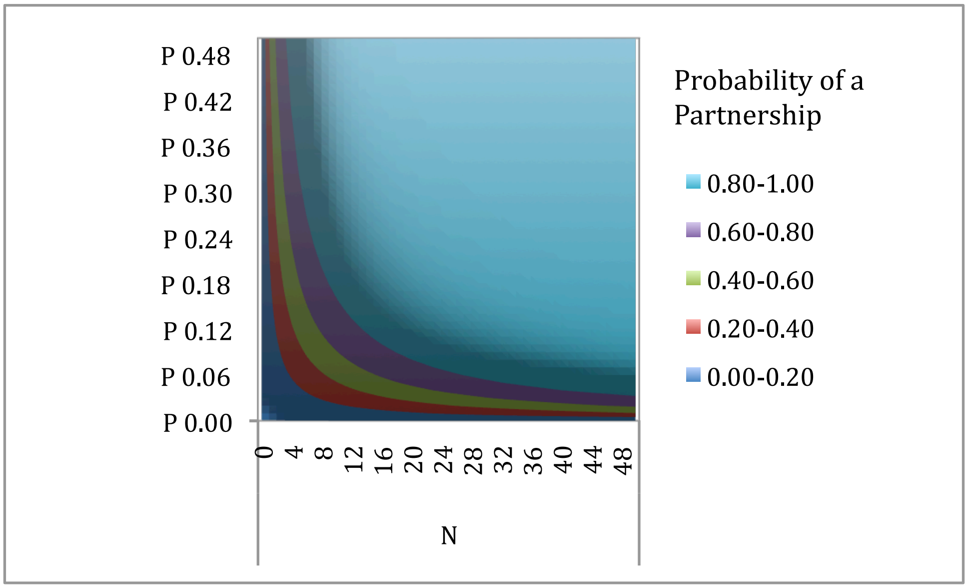

Figure 2. Effect of P and N on Successful Partnering

2.1.2 How do successful partnerships affect subscribers' enthusiasm?

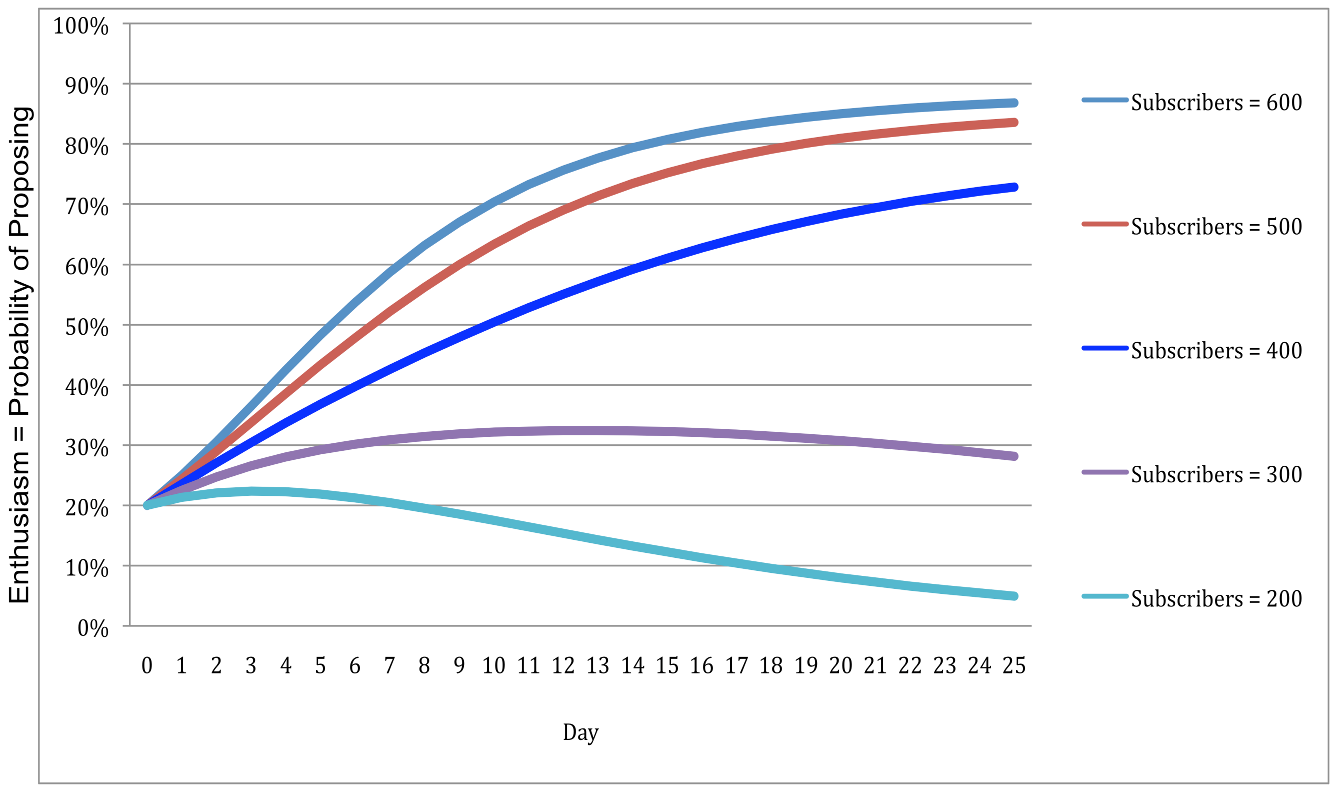

Figure 3. Effect of Success on Subscribers' Enthusiasm over 25 Days

Consider a range of subscriber populations from 200 to 600. Suppose each person's enthusiasm starts at 20%, the probability of making a proposal each day. If a proposal succeeds, she increases her enthusiasm by moving the probability half the distance to 1.0. If the proposal fails, she halves the probability. As enthusiasm increases, the number of proposers increases, the number of feasible partners increases, and the probability of a proposal succeeding increases, according to the exponential formula above. This causes enthusiasm to increase further—a positive feedback loop.

For this example, a subscriber population of 400 is sufficient for a sustained growth rate of proposers even if P is just 0.01 to account for the low probability of two subscribers being both feasible and compatible. On the first day 80 of the 400 propose, then $80*(1-e^{-0.8}) = 44$ find partners. The 44 increase their enthusiasm from 20% to 60%, the disappointed 36 decrease their enthusiasm to 10%, and the 320 who didn't propose remain at 20%. On the next day 44*0.6+320*0.2+36*0.1 = 94 propose, and the number of proposers continue to increase each day.

This is a straw man theory. Measurement of real market systems is needed to find a dependable theory. The system needn't be a ridesharing service; we can use any nascent service in which there are "buyers" and "sellers" who make more deals as the size of the market increases. If there is a powerful positive feedback effect, then a service that achieves critical mass also has the chance of monopolizing a regional market.

2.2 How can the number of feasible partnerships be increased?

Real data collected in Eastern Massachusetts considered two people to be feasible partners if their source and destination are within a mile and start times are within thirty minutes of each other. It showed that 60% of morning commuters had a feasible match.[8] Apparently, that was not enough.[20]

2.2.1 Can cell phones increase the feasibility of partnerships?

Figure 4. The Dispersal of Sources and Destinations for Commuters

Traditional carpools are difficult to set up and reduce one's travel flexibility. The internet and cell phones can greatly expand the options and convenience.

A concocted example, depicted in Figure 4, suggests how hubs can increase the number of feasible matches. 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, 100 in each neighborhood, 50 in each company. On average there are about 5 people in a typical neighborhood X who are also driving to company Y. So there are about 5 feasible partners for someone seeking a ride. If the basic probability of compatibility between rider and driver is 0.1, then the chance of a partnership 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 number of feasible trips has increased by more than a factor of 10 and the probability of success goes up to 1 (=0.993)! Generally, if there are D drivers, N neighborhoods, and C companies, the potential number of drivers for a given rider is about D/max(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 San Francisco 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. Transfers could occur anywhere along that highway.

This is where cell phones become crucial. Arranging the rendezvous without them would be unthinkable. However, if the two drivers can be in communication, then adjustments for traffic and confusion can be made. The method of rendezvous will have to be very carefully designed and tested to make this idea realistic.

2.2.2 How can we find feasible matches quickly?

We believe that a modern computer system (i.e. clusters of processors accessing common disk data) can find feasible matches and can function in real-time for thousands of people per minute. We will explore two approaches: find and use a suitable moving object data base system[9] (MOD) or build a special-purpose matcher.

2.2.2.1 Using a Moving Object Database

There are several MOD's under development. If ones performance is acceptable, using it might save significant work since it would provide many convenient features like transactions and data integrity.

When a driver proposes, RF uses the MOD, which holds a network of the region's transport system, to suggest a shortest route from start to finish, allow the driver to modify, and enter the resulting route into its MOD.

When a rider proposes, RF first queries the MOD for the best route for the rider, i.e. one she would take if she drove herself. RF queries the MOD for driver's routes that pass through the rider's start and finish location at the appropriate times, using the riders' best route to bound the possibilities at, say 25% longer than the rider's best. If a reasonable number, say twenty, are found, the routes are passed on to the next phases that eventually suggest them to the potential partners.

If the MOD does not find enough routes, RF asks the MOD for (a) driver's routes that pass through the rider's start location at an appropriate time and (b) driver's routes that pass through the rider's end location at a later time. Then it asks for intersections in space-time between pairs of routes from a and b. If this fails, it can search for routes involving three drivers.

We don't know of an available MOD that will support these operations and perform well, but will attempt to find one or collaborate with a group that is working on one.

2.2.2.2 Using a special-purpose matcher

The needs of RF might be better served by a tailor-made matching system. Here is a sketch of how we would build one:

The data structure is a directed graph where each vertex represents an intersection of streets, freeways, or rail lines. Edges represent planned travel by a driver, bus, train, or other vehicle. Each edge is labeled with its arrival time at its starting vertex, distance to the ending vertex, the driver, and the predicted speed of the driver on this edge.

Every pair of vertexes with a passage between them always has three edges representing the choices of driving alone, walking, and a taxi ride, with an arrival time signifying that travel can begin immediately.

From the driver's price, the rider's waiting time, and the rider's value of time, one can compute the cost to the rider for traversing the edge. Plausible prices are 0 for walking, $0.50/mile for driving alone, $2.50/mile for taxi, $.25/mile for riding with a friend, etc. Train, bus, and vans charge their standard fares. The rider's value of time varies, but $1/minute is a guess for a commuter, i.e. waiting for five minutes costs the rider $5, walking a mile costs $20.

When a driver proposes, RF inserts her chosen route by adding to the edge list at every vertex along the route. When a rider proposes, it finds matches by performing a cheapest path search in the graph. The cheapest path is not usually the shortest, which is likely to be a direct taxi ride or a very long walk.

To find cheap paths we will use a shortest path algorithm suggested by Karp that utilizes as-the-crow-flies lower bounds, forward and backward searches, and an upper-bound of about 125% of the shortest path to find about twenty feasible paths.[10] The paths may involve switches among drivers, but the algorithm should prefer continuing with the same driver because switching vehicles will involve a wait that adds to the rider's cost.

RF needs information about traffic. It can obtain it from public sources or reports from active travelers, as did the service Dash Express.[11] The information can be used for both prediction of general congestion patterns and real-time control. History will be used to initialize the speed component of edges as they are added to the graph. As the time associated with the edge approaches the present, current information will be used to adjust the speed component, possibly using models to predict congestion patterns that move down a highway. RF will re-compute arrival times to detect breakdowns in rendezvous plans and take corrective action.

Performing these computations for many users in real-time presents a challenge. The first step in this research is to try a simple algorithm on a large volume of real trip data and compare its performance with more general MOD products.[12]

2.3 How can people be induced to rideshare?

Virtually all analysts of ridesharing agree that human preferences are the primary obstacle to success. Why do so many of us drive alone? Table 1 lists some reasons and possible ways of mitigating them.

Driving Alone Advantage	**Mitigation**
Plan-free travel: We have our car with us all the time, can start a trip any time and change plans any time.	Quick scheduling with cell phone Easy re-scheduling. Critical mass of subscribers.
Reliability: Your car it is always available. Car pools, taxis, or other services are not.	Maintenance of a highly-disciplined social network Rendezvous prediction Critical mass of subscribers
Safety: There are bad drivers and bad people.	Vetting of subscribers, including driving records. Partner feedback Real-time monitoring of contacts. Need-to-know disclosure of personal information
Control	Rendezvous prediction Discovery and honoring of personal preferences
Status: Cars are like jewelry for men. [13]	Positive incentives for sharing Upscale image
Asociality: Many people prefer sometimes to be alone, or find the habits of some other people distasteful. [14]	Positive incentives for sharing Matching personal preferences Easy withdrawal from commitments
Habit: For a century, Americans have driven cars and become comfortable with the system.	Low-commitment ways to try new habits.

Table 1. Why Driving Alone is Preferred

Over the years, a variety of approaches have been proposed to estimate the number of people who would give up solo driving in favor of ridesharing.[6] [15] Some were from the perspective of ridesharing unit formation, and included assessing area wide maximum potential by estimating possible matches and identifying characteristics of people who would share rides. Another set of estimation methods centered on decision approaches and included utility maximization, simulation models, and games. Still another approach used demand/supply relationships in traffic equilibrium flows, to estimate the effects of high occupancy vehicle lanes. The approaches can be categorized roughly into three areas:

- **Rational Choice:** It includes predictability, time urgency, and control versus physiological, psychological, and behavioral penalties.
- **Emotional Choice:** This category is crystallized with the theory of planned behavior[16], claiming that people make their decisions with the combination of attitude, subjective norms, and perceived behavioral control.
- **Habit:** Even if a change is justified, people often act the same way they did before.[17] [18]

Most of the investigators—probably attuned to environmental concerns and themselves prosocial—seem to hope for positive attitudes about ridesharing, but are usually disappointed.[19] Refreshingly, a paper by Ory[15] faces reality: people have adapted to their driving routine, are generally satisfied with it, and may even like it. Unless the costs become exorbitant, the negative aspects of driving alone are not powerful enough to bring about change.

We believe the ways to change behavior are

- Rational: Reduce the difference in convenience and reliability between driving alone and ridesharing to an acceptable level.
- Emotional: Discover and promote positive, experiential inducements for ridesharing.
- Cultural: Exploit and promote the current impulse favoring sustainability and climate protection.

We formalize the first two approaches as *cost* and *relationships*. The probability that two deciders (i.e. a feasible rider-driver pair) are compatible for a given trip is made up of these components: C, the costs and R, the relationship. The cultural approach doesn't apply immediately to the operation of RF, but supports increases and retention of subscribers.

Compatibility might be proportional to R/C. On the other hand, these two components might not trade off against each other in a simple way; i.e. a great or terrible relationship trumps costs and an exorbitant cost trumps a neutral relationship. This question will be investigated.

2.3.1 Rational Costs

Section 2.1 and 2.2 presented ideas for reducing cost, but did not address the subscribers' perception and opinions about cost. Any service must have a firm grip on service quality metrics. These quality metrics are out-of-pocket cost, mean travel time, travel time variance, and lead-time for arranging.

The utility curves for each of the items are unknown, but we guess they would be super-linear. The cost function may not be additive; there may be a "deal breaker" threshold for each one.[20]

- Charging to share out-of-pocket costs is fine; much more is not.
- Increasing travel time by less than 10% is not noticed.
- Increasing travel time by more than 30% is unacceptable.
- Waiting is more frustrating than moving slowly.
- Lunch hour time is more valuable than commuting time.

Some other cost-related questions:

- What is the effect of owning a car?
- What is the tradeoff between probability of getting a match and the effort required to announce trips or monitor for answers?

- Would subscribers be comfortable with an auction system?[21]
- How much would subscribers pay the service itself, and what combination of subscription costs and per-trip fees is appropriate?

For each of these questions, each demographic group will have a distribution over people, since preferences differ. Simple surveys will not be useful in discovering a behavioral cost function. We plan to measure behavior *in vivo* through a novel preference elicitation method. Individuals will use a GPS-enabled cell-phone application to track their own movements. A web-based application will then prompt them to reflect on particular transportation incidents from the previous week, answering questions about how far in advance the trip was planned, and how acceptable various alternative transportation modes would have been. We have used a related technique before in a different realm, eliciting privacy preferences.[22]

Figure 5. A World War II Exhortation

2.3.2 Emotion and Relationships

We believe the approach represented by Figure 5—appealing to patriotism, social conscience, or guilt—is ineffective now, even if it once was. In fact, carpooling has been declining steadily for the past forty years.[23] As any parent learns, offering exciting, new experiences can be a superior way to motivate people. Ridesharing can be a life enhancer. Many people might respond to what it offers: richer experiences with people and better use of travel time. While this thesis is not obvious, experience and much research has proved that the negative aspects of driving alone are insufficient to change behavior permanently.

Furthermore, we believe that finding ways to make travel time more productive and pleasant should be found in the relationship among the travelers. Anecdotes suggest that good relationships are one of the most valuable outcomes of ridesharing, but they are usually serendipitous. Can we predict good relationships the way eHarmony *et al.* claim to? If we find that different demographics have distinctly different social needs and desires, then promoting distinct services may lead to better results.

2.3.2.1 How is relationship measured?

Some have suggested degrees of separation should be considered, e.g. $R=1/2^s$ where s=0 if we are friends, s=1 if we have a friend in common, etc. These can be gleaned from social networking sites to which subscribers belong.

An orthogonal measure is common declared interests, e.g. country music. These can be discovered from a questionnaire like those of dating services, but focused on the less intimate questions; e.g. “Do you like to talk while driving?”

As with costs, the interaction of these aspects in not well understood. We will conduct studies of different demographics to assess relationship prediction. Our targeted, personal scenarios related to their actual previous trips will probe for the value of rides with people with various kinds of relationships (e.g., a boss, a co-worker, a fellow wine enthusiast, or a native speaker of a foreign language one is studying)

2.3.2.2 Personal Safety

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 RF, and drivers get 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.

2.3.3 Culture and Symbols

Automobiles are imbedded in America's culture, and businesses that depend upon cultural change usually fail.[24] Until we can offer hope that change is possible, there will not be significant investment in ridesharing. The change in American smoking habits illustrate that change is possible over an extended period.

Aside from the extensive infrastructure that supports drivers, there are powerful symbolic values in car ownership and use.[25] A car permits the freedom and power that represent America to many people. In fact, different types of automobiles, ranging in price from $10,000 to $440,000, can be used to represent the specific values and aspirations of their drivers: economy (Chevrolet Aveo), wealth (Porsche), safety (Volvo), reliability (Toyota), Greenness (Prius). In a car culture, like California's, the kind of car one drives helps define one's status and values while inviting others to appreciate and perhaps emulate them. Hybrids might be more costly to drive than some coventional, small cars, but are preferred because they say "I'm green," not "I'm poor." The Prius's distinctive body style might have made it preferable to the Honda Civic hybrid, but the Honda Insight's strange style didn't overcome its practical shortcomings.

The cell phone is becoming another object through which people can express their values. The phones brand, color, and what appears a phones display can be expressive.[26] RF must offer its subscribers ways to express their values.

2.3.4 Demographics

Specific groups might demonstrate significantly different attitudes about ridesharing. In our surveys and behavior studies we shall compare the traits of several of the following demographics. This will be especially important in understand the role of relationship opportunities as well as acceptable cost ranges.

2.3.4.1 Millennials

In *Bowling Alone*, Putnam observes significant variation in social capital between generations. Some believe that the generation born between 1985 and 2005 might be more prosocial than earlier ones.[27] Young people contemplating buying their first car might have very different cost functions from older suburbanites. We will explore the decision-making process for buying one's first car.

2.3.4.2 Co-workers

A study[21] shows that ridesharing programs restricted to companies are more successful. For a large company co-workers share a location and a reasonable level of social capital. They either know potential partners or are open to meeting co-workers. A program of lower level workers occasionally partnering with executives might increase the social capital of the business.

2.3.4.3 Ticket Holders

People attending entertainment and sports events share a narrow time window, a parking problem, and a common interest. Are they more likely than commuters to be in a social mood?

Are they more willing to share a ride once rather than committing to carpool to work?

2.3.4.4 Students
Many subjects and skills can be learned and practiced orally. Students at the same school share narrow time windows, interests, and social life. What subjects and interests are best to practice orally, e.g. foreign languages?

2.3.4.5 Patients
People with periodic doctor's visits, e.g. chemotherapy patients, might share rides. Could ridesharing enhance the health-related social networks already on the internet? Is information or emotional support more valued?

2.3.4.6 Parents
Many parents find themselves chauffeuring their children for many hours a week. Often, they arrange with other parents to drive but these arrangements take time to set up and change with each year. How do attitudes change with the children's ages?

2.3.4.7 Singles
The current generation uses eHarmony.com, Match.com, Jdate.com, etc. without reservation. Would single people look on ridesharing as an opportunity for relationship exploration or as creepy?

2.3.5 Personality Types
People differ in ways that are not captured by demographics. There are many frameworks for parsing the differences, and it may be useful to consider them when considering motivations. Unlike demographics these frameworks might also hint at how people might be paired based on differences. The following tables summarizes how the various types might perceive their choices.

Dichotomies	**Preferences**	**Driving Alone**	**Driving Others**	**Riding**
Favorite world: Do you prefer to focus on…	*Extraversion* …the outer world?		Communicating	
	Introversion …your own inner world?	Solitude		
Information: Do you prefer to …	*Sensing* …focus on the basic information you take in?			
	Intuition …interpret and add meaning?			
Decisions: When making decisions, do you prefer to first look at…	*Thinking* …logic and consistency?	Saving Time	Economy Greenness	Economy Greenness Ease
	Feeling …the people and special circumstances?	Safety	Relationship s Control	Relationships
Structure: In dealing with the outside world, do you prefer to…	*Judging* …get things decided?			
	Perceiving …stay open to new information and options?	No planning needed		

Table 2. The Myers-Briggs Framework[28]

The VALS[29] system puts buyers into eight categories, based on three primary motivations—ideals, achievement, and self-expression—that are enduring and transcend age, gender, income, and geography. The categories are further refined by a measure of resources.

The most promising demographic to recruit to RF are younger city dwellers who might be more ecologically and communally minded than their elders and without cars. The youngest VALS group, Experiencers, are trend setters, early adopters of technology, and generally college students or graduates. They seem like the best group to start with, probably when they are in college. The next youngest group, Strivers, are influenced by advertising and peers, so might be brought along if a trend develops.

Rather than reach for a full-blown driver/rider market, it might be better to start by serving riders with a system that knits together public transit and taxis. Once a large community of riders is assembled, civilian drivers are more easily recruited since they will find riders easily. The best way to recruit taxi and limo drivers is to provide RF service with GPS navigators which they purchase. To maximize the potential rider population the primary interface should be a low-end cell phone driven by voice commands. Location services might be obtained from cell phone carriers.

Primary Motivation	Motivation and Resources	% of US	Age	Motivation to…		
				Drive Alone	Drive Others	Ride
	Innovators	10	44	Flexibility	Curiosity	Curiosity
Ideals	*Thinkers* follow ideas and principles.	11	56	Solitude	Greenness	Greenness
	Believers follow beliefs and principles.	16.5	52	Independence	Community Greenness Generosity	Community Greenness
Acheive ment	*Acheivers* seek success and control.	14	41	Control Time	Control	
	Strivers seek approval and money.	11.5	29	Status	Greenness Economy	Greenness Economy
Self-expression	*Experiencers* seek excitement and variety.	13	25	Moving and controlling	Moving and controlling	Meet people
	Makers act to impact the physical world.	12	46	Car as self	Car as self	
	Survival	12	70	Isolation		Economy Safety

Table 2. The VALS™ Framework

A venture capitalist we know says, "Always create products that facilitate some the Deadly Sins." These sins are sometimes associated with the nine Enneagram types.

Type	Drive Alone	Drive Others	Ride
1. Reformer, Critic, Perfectionist Sin: Anger	No restraint on road rage.	Back-up for traffic-induced confrontations. Self-righteous greenness	Self-righteous greenness
2. Helper, Giver, Caretaker Sin: Pride	Show off car's exterior.	Serve riders. Show off interior. Be greener than others.	Be greener than others.
3. Achiever, Performer, Succeeder Sin: Deceit	Use car to represent self.	Control	
4. Romantic, Individualist, Artist Sin: Envy			
5. Observer, Thinker, Investigator Sin: Avarice	Save time.	Save money. Get rewards.	

6. Loyalist, Devil's Advocate, Defender Sin: Fear	Safety		
7. Enthusiast, Adventurer, Materialist Sin: Gluttony		Meet new people.	
8. Leader, Protector, Challenger Sin: Lust	Control	Control	
9. Mediator, Peacemaker, Preservationist Sin: Sloth	No commitments to keep.		Sleep Less responsibility

Table 4. Enneagram Types[30]

3 Design for a Service

This section covers many aspects of the design for a real service. A business analysis is also available.[31]

3.1 User Stories

3.1.1 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 RF 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 RF. She can fill in lots of personal information along with privacy rules later.
- RF gets the availability and prices from rental agencies and Zipcar. It also finds some van services and commuters. The alternatives it suggests are
    - 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
    - Zipcar, $68 for the day, gas, parking & insurance included, 1.5 hrs travel time each way
    - Muni to Civic Center, Alamo Rental for day ($40), Gas ($40), Muni Home, 1.7 hrs travel time each way
    - Muni/Greyhound Bus/Taxi, , 3.2 hr each way (shortening stay in SC), $30
    - Bart, Caltrain, and Bus, $23, 3.5 hrs travel time each way
- Cheri doesn't feel like meeting anyone or negotiating his or her price down, so she opts for Zipcar, which she's already registered for.

- She makes the reservation through RF 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 RF 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 RF 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 RF
- A week later, while out clubbing she wants to go home earlier than her friends who brought her. She contacts RF through her cell phone to see the possibilities.
- RF checks taxis, Muni, and civilians and suggests
  - Terry Theatergoer, an acquaintance that, unbeknownst to Cheri, is at a nearby theater that gets out soon. She'll take her home for free, but will be available 20 minutes from now. Trip will take 23 minutes.
  - A taxi that will arrive in 3 minutes and charge $13. Trip will be 23 minutes.
  - 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 RF after discovering each other, but preferred using its rendezvous support.

3.1.2 Larry Language Learner

He registers to be either a driver or a rider; and checks the "Practice Mandarin" box in the special interests section. He finds several native Mandarin speakers who ride with him and practice their English half the time.

3.1.3 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 stockbroker. 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 RF, 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 RF.
- RF 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 RF 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 RF records the trip transferring some Money 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 whom 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 Money 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 RF and revealed every ten rides so that figuring out who said you were "Bad" is very difficult. If you rate someone as Bad, RF will never link you with them again.

3.1.4 Patricia Parent

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

- The school (which pays RF a fixed subscription fee) recommends RF. 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.
- RF 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 RF group, making Joan the captain and specifying some rules from a suggested list.
- Each group uses RF'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 drops 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 RF Foundation to support free community services.

3.1.5 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.

RF 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 RF, which promises confidentiality.

RF 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 RF 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; RF never links them again while Oprah can play dumb when she sees the losers at a fund-raiser.

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

3.1.6 Camilla Commuter

Camilla is a twenty-something engineer at SpikeSource 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 RF and registers a repeating trip from SF to SpikeSource, five days per week.
- RF 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 RF, 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.

3.1.7 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 RF 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. RF 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 RF'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 RF 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.

3.1.8 Peter Parknride

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 RF 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 RF 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 RF subscribers can become a real-time market place at which many drivers meet to sort out who drives whom each day. Eventually, Caltrans facilitates this activity by posting signs for various South Bay destinations where people can congregate. However, the services of RF 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.

3.1.9 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 RF and requests a round trip ride to the Opera House a few days in advance.
- RF gets offers from taxi companies in Palo Alto and SF to meet scheduled Caltrain trains. The taxi companies have registered standard rates with RF, so their response is automatic. Caltrain needn't be contacted, since they don't negotiate.
- RF 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). RF 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 RF'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.
- RF 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 RF's tracker using WiMax, WiFi, or Cell Network (whatever is available).
- RF 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 RF convention.

- They drive to SF, park, and walk to the Opera House. Their cell phones send the time of arrival to RF, 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 RF, 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 RF's query by giving each other good ratings.
- Time passes.
- For another opera, Oscar repeats the request for a trip. RF 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 RF 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 RF for opera trips.

3.1.10 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 fonder 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 RF (25th 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. RF 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 RF to put him on the hitchhikers' menu for extra rides. As he starts his route each day he activates his cell phone and RF plots his stored 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.

3.1.11 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 RF 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 RF was doing better than other dispatchers or his street pickups, so he would switch to the "I'm yours" service, allowing RF to schedule and route all his fares.

RF 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. RF 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 RF for the fare. He's happy to be accumulating less cash late at night. Also, the fact that every RF customer is registered and tracked during a ride makes him feel a little safer.

In idle periods RF suggests places Tom might go to be more available for anticipated riders. RF's extensive historical database 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.

3.1.12 Cab Companies

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

RF'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.

3.1.13 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 RF like a cab company, equips two limos with GPS cell phones and WiFi and chooses a region suggested by RF, 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 RF 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 RF'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.

3.2 New Technology

This section contains ideas for the underlying system. Figure 6 shows the system context.

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. Creating a voice interface for drivers is essential.

3.3 Use Cases

General User (either driver or rider):

1. Register
2. Log in
3. Adjust Profile
4. Give Feedback

Driver:

5. Offer Ride
6. Accept rider
7. Cancel Drive
8. Take Trip

Rider:

9. Request Ride
10. Accept driver
11. Cancel Ride
12. Join Trip

Operator:

13. Handle Emergency
14. Analyze and Manage Performance

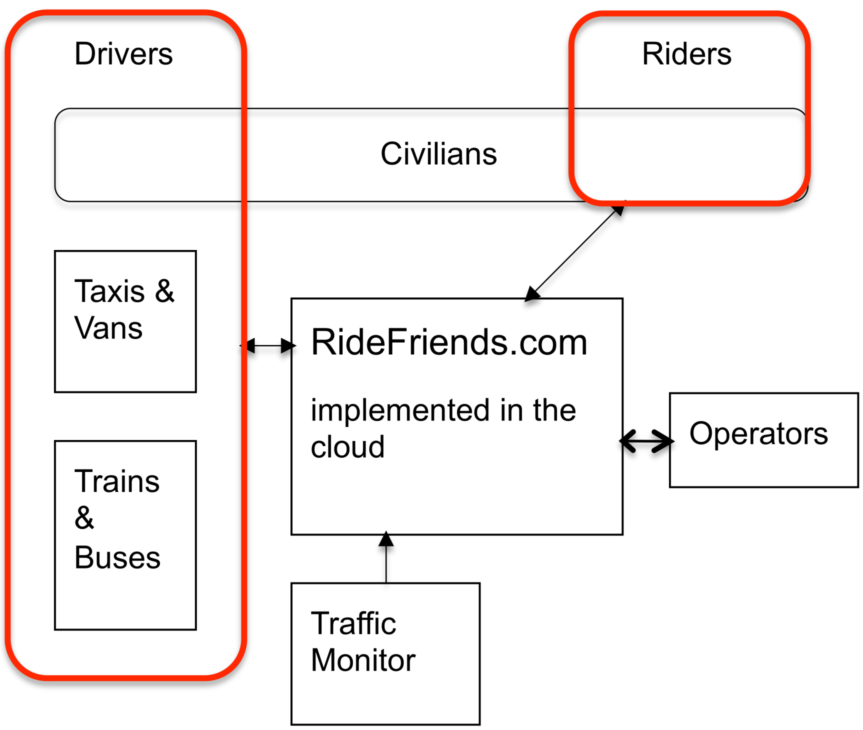

Figure 6. Gross System Architecture

3.3.1 Register

Actor: User

Goal: Get set up in RF so I can arrange rides with others

Scope: RF Web Site

1. User goes to RideFriends.com reaching Welcome page, possibly via Facebook or a similar relationship site.
2. User chooses "register"
3. User enters Name
4. User enters email (twice)
5. User choose credit card payment method
6. User enters cell phone number, triggering potential text messages.
7. RF sends text message to phone with numeric code
8. Use chooses communications preferences (email, phone, or both)
9. User enters code on web page
10. User enters Birthday, for compatibility matching.
11. User enters % delay he would tolerate beyond driving directly
12. User enters price he would ask as a driver. $Fixed+$per mile
13. User enters price he would pay as a rider $Fixed+$per mile
14. User enters other preferences, tbd, e.g. "Do you prefer to drive?" used for matching
15. Use clicks "Submit"
16. RF acknowledges, records data, and takes user to his personal page.

Extensions

- 2a. User chooses "login", perform Use case 2
- 3a. User leaves Name blank, RF requires Name when Submit is clicked.
- 4a. User leaves email blank, RF requires email when Submit is clicked.
- 4b. User provides differing emails blank, RF requires match when Submit is clicked.
- 5a. User leaves credit card blank, RF requires credit card when Submit is clicked.
- 6a. User leaves cell phone blank, RF requires cell phone when Submit is clicked.
- 7a. Phone company rejects phone call, RF asks for new number.
- 9a. User leaves code blank or different from correct one. RF reports and asks user to try again.
- 10a. User leaves Birthday blank. RF enters default.
- 11a. User leaves delay blank. RF enters default, e.g. 30.
- 12a. User leaves Birthday blank. RF enters default.
- 13a. User leaves driver price blank. RF enters default.
- 14a. User leaves rider price blank. RF enters default.

3.3.2 Login (boring)

1. Rider logs in, supplying email address and password.

3.3.3 Adjust Profile (a lot like Register)

3.3.4 Give Feedback

Actor: User

Goal: User reports on satisfaction with recent trip so that RF chooses desirable partners for future trips.

Scope: User cell phone interaction

Level: Sea Level

Main Success Scenario:

1. RF sends text message to Users phone within an hour of a completed trip, asking for evaluation, e.g. Bad, OK, and Good.
2. User checks simple reply, optionally adding text and send back.

Extensions

1a. If trip is first half of round trip, RF does not send message.
1b. If Telco rejects phone call RF sends an email to User asking to fix.
2a. If User ignores, RF forgets about it.

3.3.5 Offer a Ride

Primary Actor: Driver
Goal: Driver offers a ride so that she have companions and lower driving costs.
Level: Sea Level
Stakeholders and Interests

Driver wants limited delay, decent money.
RF wants the commission

Precondition: Driver has an account on RF, has logged in to RF
Success Guarantee: Complete and correct ride information is stored for matching to possible riders.
Minimum Guarantee: The RF database is not corrupted by incomplete or erroneous data.
Main Success Scenario:

1. Driver goes to "offer a ride" page. And fills in
   a. Date
   b. Departure time
   c. Return trip departure time (optional)
   d. Start Address
   e. End Address
   f. Repeat pattern (Every Weekday, once per week) (optional)
   g. Maximum number of riders
2. Driver submits offer.
3. RF acknowledges and stores request. If request is for repeating ride, stores in "Repeating Schedule".

Extensions

1a. If date, times, or either address are missing RF complains at submit.
1b. If either address cannot be found in map database, RF asks for clarification, *a la* Google
1.c. Return time is before departure time
    4.c.1. RF displays error message

3.3.6 Accept a Rider

Primary Actor: Driver
Goal: Driver wants to give ride for to have companions and lower costs.
Level: Sea Level
Stakeholders and Interests:

Driver wants limited delay, decent money.
RF wants the commission

Precondition: Driver has an account on RF, has offered a ride.
Success Guarantee: Driver agrees to give ride. Contract is stored in RF's schedule.
Minimum Guarantee: The RF database is not corrupted by incomplete or erroneous data.

Main Success Scenario:

1. RF sends driver a proposal including
    a. Date
    b. Departure time
    c. Pick-up address (without street number)
    d. Estimated arrival time
    e. Payment offered
    f. Pointer to complete proposed contract which additionally contains
        i. Proposed driving route and schedule
        ii. Return route and schedule (if applicable)
2. Driver accepts offer
3. RF sends driver (and rider) confirmation and pointer to contract that includes
    a. Date
    b. Departure time
    c. Name and email of driver and rider
    d. Exact pick-up address
    e. Estimated arrival time
    f. Payment
    g. Driving route and schedule
    h. Return route and schedule (if applicable)

Extensions

2a. Driver rejects offer. RF acknowledges (and informs rider).
3a. If more riders or drivers are added, RF updates contract and notifies driver.

3.3.7 Cancel Drive

Primary Actor: Driver
Secondary Actors: Riders and other Drivers
Precondition: Driver is part of an existing contract, has logged in
Goal: Wants to withdraw from contract
Scope: Cell phone and web interfaces
Level: User Goal
Stakeholders and Interests
Main Success Scenario

1. Driver locates contract and cancels.
2. RF notifies all other participants and restarts search for driver for open segment.

3.3.8 Take a Trip

Primary Actor: Driver
Secondary Actors: Riders, continuation drivers
Precondition: Driver and riders have agreed to contract. Driver has location-aware cell phone turned on.
Goal: Travel to destination without incident and on time.
Scope: Cell phone and web interfaces
Level: User Goal
Stakeholders and Interests
Driver: Wants to minimize difficulty and get paid.
Riders: Want to reach destination safely

Main Success Scenario:

1. RF reminds to start 5 minutes before scheduled start, notified (via email, IM, SMS, or whatever she prefers) and referred to contract document containing people, schedule, map, etc. . Driver can print if he's on a computer.
2. Driver's cell phone sends RF location information every few minutes.
3. RF notifies rider 5 minutes and 0 minutes before the arrival of driver. Riders can also access contract document any time to review plan.
4. When a rider gets in the car, her cell phone handshakes with driver's and reports rendezvous to RF.
5. Upon arrival at destination, all cell phones "de-handshake" and report to RF.
6. RF requests feedback. See case 4.
7. Account of driver and rider are updated with agreed payment.

Extensions

1a. Multiple drivers are needed. RF reminds drivers well before the transfer time and reports the position and progress of the previous. His cell phone reports his position to RF.
3a. More riders are waiting. Repeat steps 3 and 4 for each.
5a. If "destination" is transfer to another driver, RF notifies new driver that rider has reached rendezvous point.
5b. If rendezvous is jeopardized by delays, RF initiates emergency procedures. See case 11.

3.3.9 Request a Ride

Primary Actor: Rider
Goal: request a ride so that she can avoid driving and be safe
Level: Sea Level
Stakeholders and Interests

Rider wants limited delay, reasonable cost
RF wants the commission

Precondition: Rider has an account on RF, has logged in to RF
Success Guarantee: Complete and correct ride request is stored for matching to possible drivers.
Minimum Guarantee: The RF database is not corrupted by incomplete or erroneous data.
Main Success Scenario:

1. Rider goes to "Request a ride" page. And fills in
    a. Date
    b. Departure time
    c. Return trip departure time (optional)
    d. Start Address
    e. End Address
    f. Repeat pattern (Every Weekday, once per week) (optional)
2. Rider submits offer.
3. RF acknowledges and stores request. If request is for repeating ride, stores in "Repeating Schedule".

Extensions

1a. If date, times, or either address are missing RF complains at submit.
1b. If either address cannot be found in map database, RF asks for clarification.
    3.a. RF displays error message on login screen
1.c. Return time is before departure time
        4.c.1. RF displays error message

3.3.10 Accept a Driver

Primary Actor: Driver
Goal: Driver wants to give ride for to have companions and lower costs.
Level: Sea Level
Stakeholders and Interests:
Driver wants limited delay, decent money.
RF wants the commission
Precondition: Driver has an account on RF, has offered a ride.
Success Guarantee: Driver agrees to give ride. Contract is stored in RF's schedule.
Minimum Guarantee: The RF database is not corrupted by incomplete or erroneous data.
Main Success Scenario:

1. RF sends rider a proposal including
    a. Date
    b. Departure time
    c. Estimated arrival time
    d. Payment asked
    e. Pointer to complete proposed contract which additionally contains
        i. Proposed driving route and schedule
        ii. Return route and schedule (if applicable)
2. Rider accepts offer.
3. RF acknowledges and asks rider to wait for confirmation.
4. RF sends confirmation and pointer to contract that includes
    a. Date
    b. Departure time
    c. Name and email of driver and rider
    d. Exact pick-up address
    e. Estimated arrival time
    f. Payment
    g. Driving route and schedule
    h. Return route and schedule (if applicable)

Extensions
2a. If rider rejects offer, RF acknowledges and says it will keep looking.
4a. If multiple drivers are involved rendezvous points and secondary drivers are included.
4b. If more riders are added, schedule is updated and rider is notified.

3.3.11 Cancel Ride

Primary Actor: Rider
Secondary Actors: Driver(s) and other Riders
Precondition: Rider is part of an existing contract, has logged in
Goal: Wants to withdraw from contract
Scope: Cell phone and web interfaces
Level: User Goal
Main Success Scenario

1. Rider locates contract and cancels.
2. RF notifies driver(s).

Extensions
2a. If there are other riders, RF reworks contract to remove rider and notifies other participants that a change has occurred.

3.3.12 Join a Trip (See case 7)

3.3.13 Use Case 13: Handle Emergency (TBD)

3.3.14 Use Case 14: Analyze and Manage Performance (TBD)

3.4 Nonfunctional Requirements

RF will be implemented "in the cloud" with a network of computers so that it can me continuously scaled up for load and redundancy. Users will access it from web browsers running on desktop or laptop computers and phones, using voice, SMS, and web access. RF will interface with a traffic monitoring system, e.g. the Caltrans system.

RF is an SaaS and should match other such services, e.g. Google, in all features, unless otherwise specified. The "ilities" are listed in priority order. The annotations (Importance, Difficulty) are added to certain items rating them High, Medium, or Low. When nothing is said, assume "do it like Google".

3.4.1 Usability

3.4.1.1 Computers

Use Cases: 1, 6, 10

Ambition: Registration, requests, offers, responses, and reviews are simple and frictionless (H,L)

Scale: Minutes for any atomic operation.

Meter: Stopwatch measurement of 20 new users performing each type of task three times.

Must: Less than 10% of users fail to complete an operation. No operation takes more than five minutes. (H,L)

Wish: Less than 2% of users fail to complete an operation. No operation takes more than one minute. (M,M)

Platform: Any web browser with 5% of market. (M,H)

3.4.1.2 Phones

Use Cases: 7, 8, 9, 11, 12

Ambition: After 15 minutes of training a user can understand a voice message and respond using voice very quickly. An offer or request can be offered by text or voice quickly and simply. (H,H)

Scale: Seconds of elapsed time after initiation of message.

Meter: Stopwatch measurement of 20 elderly users driving a car at highway speeds.

Must: Offers and Requests entered with text using simple interface. Accepting or confirming offers done by voice or short key presses. User can understand voice queries after at most three repeats. User can respond with "yes" or "no" within 60 seconds of message beginning. (H,H) Dialog is duplicated in text on cell phone.

Wish: Offers and requests can be made by voice with feedback to confirm. User understands first message, can respond in 15 seconds.

Platform: Any cell phone with 5% market share in any country. (M,H)

3.4.2 Availability

3.4.3 Integrity

3.4.4 Efficiency

Use Cases: 6, 7, 8, 9, 10, 11

Ambition: Service approaches the speed of hitchhiking by the side of the road. An agreement requires a request, a driver offer, a rider acceptance, and a confirmation; so an agreement takes at least three times the message transmission time.

Scale: Seconds of elapsed time from click

Meter: Stopwatch measurement of 100 simple messages sent and received from computers and phones while RF is receiving 1000 messages per minute.

Must: Start time minutes away: 3 minutes (M,H)
Start time hours away: 15 minutes
Start time days away: 60 minutes

Wish: Start time minutes away: 30 seconds (M, H)
Start time hours away: 5 minutes
Start time days away: 30 minutes

Platform: Network of standard Intel processors

3.4.5 Reliability

3.4.6 Interoperability

3.4.6.1 User Computers

Use Cases: 1, 6, 10

RF should work on any web browser that has 5% of the market in any country (M,M)

3.4.6.2 User Phones

Use Cases: 7, 8, 9, 11, 12

RF should work on any cell phone that has 5% of the market in any country (M, H)

3.4.6.3 Traffic Monitors

Use Cases: 9

RF must be able to receive traffic speed indication from local service, tbd.

3.4.7 Testability

Use Case: 15

Ambition: This is an innovative SaaS system, and user preferences and capabilities are not well known. The early versions should produce extensive data on robustness, usability, and new requirements. As much as 25% of the early code should be devoted to reporting on use patterns.

Scale: Every user interaction should contribute to aggregate data.

Meter: Observation of daily operation and reports.

Must: Serious user difficulties should be detected and reported in a daily report. (H, L)
Time profiles of use are reported, e.g. how far in advance do users offer or request rides. (H, L)
Satisfaction reports are produced weekly. (H, L)

Wish: New requirements are detected by following user behavior. (M, M)

Platform: Network of standard Intel processors

3.4.8 Robustness

3.4.9 Flexibility

3.4.10 Maintainability

3.4.11 Portability

3.4.12 Reusability

3.4.13 Expected Architectural Tradeoffs

Phone coverage vs. Usability
Efficiency vs. Usability

3.4.14 Human Backup, Legal, Political, Organizational Issues

A small staff of human operators will be available to handle emergencies that RF cannot. The operator will typically talk to drivers and riders via phone. The must be trained on how to schedule trips in RF by fiat and how to handle very distraught travelers.

The system must be designed like current automotive GPS systems so that it doesn't distract drivers.

Certain regulations, e.g. restriction on taxis picking up multiple fares, must be understood, complied with, or altered.

If successful, RF will reduce congestion, pollution, and loneliness.

Operator sets payments from riders to drivers and commissions to RF globally.

The process of matching should take into account personal preferences when matching partners whose trips are compatible.

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.

Round trips and repeating trips are broken down into a sequence of individual trips and are submitted to the matching process at the appropriate time, e.g. no sooner than seven days before the trip.

3.4.14.1 Dependencies

RF needs to link with social networking sites

It needs mass transit information

It needs a source of advertising like AdSense

3.5 Product Roadmap

Investigations have revealed

- Human preferences and habits are the biggest obstacle to success.
    - Driving alone is the American way of life. In the Bay Area 76% of commuters drive alone.
    - Many ridesharing services have failed for lack of a critical mass of users.
    - Christensen warns against basing a business on changing behavior.
- The most accessible market is specific large company campuses with a thousand or more employees.
    - The single location and common time schedules concentrate needs.
    - Co-workers are more trusting of each other.
    - Selling can be concentrated on a small number of people.
    - Some companies will welcome having greenness taken care of.

The major impediment—and biggest "known unknown"—appears to be human behavior, learning more about it is the top priority. The engineering challenges seem less daunting, and the technical design of the product should be driven by discovered customer preferences. Thus, we are adopting a learn-build-sell sequence of products.

3.5.1 Learning

3.5.1.1 Goal

We wish for three companies with successful ridesharing programs. At least, we require, significant insight about market and requirements. We might discover "unknown unknowns" that will require new studies.

3.5.1.2 Time Duration

One year from start of project. Plan to sign up three companies in the first three quarters.

3.5.1.3 Product Features

The offering is a high-touch service, sold to companies one at a time. The computer system is the minimum we can get away with: non-stop trip matching, web/email interface only, no real-time support other than by voice phone.

3.5.1.4 Engineering
Produce a simple white box web interface to allow registration, proposing, commit, and feedback. There should be extensive customer tracking performed as specified by marketing. The purpose of this release is as much to learn about customers as it is to provide them service. Getting the system up quickly (one quarter) is crucial so that we have something to sell. We should consider acquiring or even partnering with an existing service. The system will require continual maintenance and enhancement through the first year. Work on Release 2 should start.

3.5.1.5 Sales
We should sell one-year contracts to companies for free! All we ask is commitment from the top and cooperation from personnel departments to approach employees. Small commissions from ridesharers will generate some revenue.

3.5.1.6 Operations
Each company will have an onsite coordinator who promotes the system, aids communication, solves problems. This person can be the salesperson who sold the deal. Their real assignment is to deeply understand and report on the attitudes, preferences, and practices of the subscribers.

3.5.1.7 Marketing
Aside from guiding sales, the marketing effort should design the questions we want answered and study other potential subscribers outside the target companies. Some of the questions are

- What is critical mass of subscribers. How does it grow?
- How do subscribers behave?
- What motivates subscribers more—relationships or cost savings?
- What are the pain points for subscribers?
- What does the company want besides ridesharing?
- Does integration with a GPS navigator help?

3.5.2 Conquer the SF Bay Area

3.5.2.1 Time Duration
Two Years

3.5.2.2 Product Features
Add cell phone support, cross-company partnerships, and other features from the revised vision document that emerges from the marketing studies of Release 1. This system should exceed the capability of any other known system, e.g. make the lead-time for arranging partnerships as small as possible, build reliability and safety into the process.

3.5.2.3 Engineering
Add cell phone support, real-time traveler monitoring, traffic measurement, sophisticated feasibility matching, and features deemed essential from the marketing studies. Make website open to allow registration by anyone in region.

3.5.2.4 Sales
Offer initial companies a continuation and sign up at least 10 new companies. Initiate public sales campaign in Bay Area to invite customers from anywhere.

3.5.2.5 Operations
Initiate central help desk. Draw down onsite support by assigning site managers to four companies each.

3.5.2.6 Marketing
Guide public campaign.

3.5.3 Conquer the United States

3.5.3.1 Time Duration

Two years.

3.5.3.2 Product Features

Unchanged expect for alteration of any SF Bay Area idiosyncrasies. Spanish Language version?

3.5.3.3 Engineering

Maintenance except for above. Begin work for Release 4.

3.5.3.4 Sales

Launch in a new region for six straight quarters. Each one should produce ten in-company deals plus open campaign.

3.5.3.5 Operations

Design and implement regional offices based on SF Bay Area experience.

3.5.3.6 Marketing

Determine the six regions to launch service in. Consider franchising model.

3.5.4 Conquer the World

3.5.4.1 Time Duration

Three years.

3.5.4.2 Product Features

Multiple Languages

3.5.4.3 Engineering

Multiple Language Platform.

3.5.4.4 Sales

Launch in three new region outside US. For three years. Each one should produce ten in-company deals plus open campaign.

3.5.4.5 Operations

Design and implement regional offices based on US experience.

3.5.4.6 Marketing

Determine the three regions to launch service in. Consider franchising model.

3.6 The Matching Process

This section is an elaboration of the earlier section 2.2.2.2

The data structure is a directed graph where each vertex represents an intersection of streets, freeways, and rail lines. Edges represent planned travel by a driver, bus, train, or other vehicle. Each edge is labeled with

- its arrival date and time at its starting vertex,
- distance to the ending vertex,
- the driver, and
- the predicted speed of the driver on this edge.

Every pair of vertexes with a passage between them always has three edges representing the choices of driving alone, walking, and a taxi ride, with an arrival time signifying that travel can begin immediately. (This assumption for taxis must be adjusted for arrival times less than 30 minutes in the future.)

From the edge e and the rider's value of time one can compute the cost to the rider for traversing the edge as

Cost(e,rider, waitTime)= e.distance*e.driver.price+

(waitTime+e.distance/e.speed)*rider.valueOfTime

Finding a ride for someone amounts to a solving a *cheapest* path problem. The cheapest path is not usually the shortest which is likely to be a direct taxi ride or a very long walk.

When a driver proposes, insert her chosen route by adding to the edge list at every vertex along the route. When a rider proposes, find the match by performing a cheapest path search in the graph. When a driver's trip ends remove all the edges associated with the trip.

3.6.1 Karp's Algorithm

We adapt Dijkstra's classic shortest path algorithm[32] using ideas suggested by Bovet and Karp.[7] It generates diverse paths from a source s to a sink t, all at most c times the length of a shortest path from s to t.

1. Define D(x,y) as the Euclidean distance between x and y and L(x,y) as the shortest-path distance between x and y. So D(x,y) is a lower bound on L(x,y) and D(x,y) can be computed in constant time from the Euclidean coordinates of x and y.
2. Conduct synchronized Dijkstra searches forward from s and backward from t until L(s,t) is determined. By "synchronized" we mean that the next vertex scanned is one with a minimum permanent label, among all vertexes not yet scanned, either in the forward search or the backward search.

   We exploit the fact that the Dijkstra algorithm assigns permanent labels to nodes in increasing order of their distance from the starting point of the search (i.e., s or t). At any stage in the computation, define lower bounds $H_s(v)$ and $H_t(v)$ as follows:

   > $H_s(v)$ = L(s,v) if v has already received a permanent label in the forward search, and otherwise = max(D(s,v), the largest permanent label obtained so far for any vertex in the forward search).
   >
   > $H_t(v)$ = L(v,t) if v has already received a permanent label in the backward search, and otherwise = max(D(t,v), the largest permanent label obtained so far for any vertex in the backward search).

   We end this stage when a vertex x occurs which has received permanent labels in both searches (i.e. L(s,x) and L(x,t) are both known, and L(s,x) + L(x,t) = $\min_v H_s(v) + H_t(v)$). We now know that L(s,t) = L(s,x) + L(x,t).
3. Let b = cL(s,t), where c is the allowed approximation ratio. We now abandon the forward search, so the bounds $H_s(v)$ will no longer change.

   Continue the backward search, but now scanning vertexes in increasing order of L(v,t) + $H_s(v)$, as long as we continue finding new vertexes v such L(v,t) + $H_s(v) \le b$. After this, we know L(v,t) for each vertex v such that L(v,t) + L(s,v) ≤ b. All other vertexes can be discarded.
4. Call a path from s to v a *good prefix* if its cost is less than or equal to b - L(v,t). Restricting attention to vertexes that have not been discarded, build the tree of good prefixes. There is a natural tree structure in which the nodes correspond to good prefixes and there is an edge from each good prefix to every good prefix that extends it by one edge. The leaves of this tree are in one-to-one correspondence with paths of

length ≤ b from s to t.

The idea of the algorithm is to simply keep shooting down this tree to different leaves. To avoid repetitions, define a node of the tree (i.e., a good prefix) as blocked if a chosen path has reached every leaf in the subtree beyond it. A leaf becomes blocked when it is becomes the terminus of a path and, recursively, an internal node becomes blocked when all its children have become blocked. So at every step the algorithm shoots down the tree, but avoiding blocked nodes. To achieve diversity, we can keep a count at each node of the number of paths generated so far that pass through the node, and, when moving from a node, always pick the edge with the smallest count, among edges to nodes that are not blocked.

We don't build the tree all at once, but do so lazily, a path at a time.

The space requirement is bounded above by the number of paths that have been generated, times the maximum length of a good path.

A defect of this method is that it generates non-simple paths (i.e., with repeated vertexes). If you want to restrict to simple paths don't allow a good prefix to be extended to a vertex already contained in the good prefix. This will eliminate cycles completely but will create dead ends.

Any discovered path may involve switches among drivers, but the algorithm should prefer continuing with the same driver because switching vehicles will involve a wait that adds to the rider's cost.

Adjustments will be required in practice.

- Riders and drivers may be willing to alter their plans to partner. For example, a ride that uses a short taxi ride may be tweaked by having a driver make a detour to eliminate the taxi ride. A driver may also be willing to delay his trip. We might handle this by altering the original driver route and proposing it to the driver.
- Each driver has a maximum number of riders so should be removed from the data structure when her conveyance is full.

The computation can run on many processors, and synchronization is needed to preserve the graph's integrity. Race conditions resulting from multiple outstanding proposals, however, occur only when a decider mistakenly accepts two conflicting proposals.

To approach the convenience of solo driving, the lead-time for arrangements should be shrunk to minutes rather than days or hours. Aside from saving riders' planning, a real-time system might cope with the many contingencies of travel.

Here is a sketch of how real-time adjustments can be made:

Upon receiving an active driver's new location:

1. Locate her position on an edge.
2. Trace the continuation of her route forward, updating arrival times.
3. From the driver's contracts, find riders that may be affected and re-run the matching algorithm, possibly to find better matches. Re-enter contract negotiations if appropriate.

Upon receiving new speed information for an edge:

1. Trace the continuations of all drivers passing through that edge in the immediate

future, updating their arrival times.
2. Perform step 3 from "driver's new location" procedure.
3. Suggest better route for driver. If she accepts change, modify outstanding contracts appropriately.

Until a rider has made a contract, she is kept in the "Ride Seekers Pen" which is rerun through the matching process periodically. As a rider's departure time gets closer she gets higher priority in the pen. Also, when a driver is added to an edge leaving her start node or arriving at her end node at about the right time, a new match attempt should be triggered. The addition of a new driver on an edge that links other drivers into a feasible path for the rider seems rather hard to detect easily.

The devices drivers carry must communicate with voice the way good GPS devices do today. There is nothing more dangerous than looking at a map on a cell phone while driving. Designing a good user interface for the system will draw upon and extend research in Human-Computer Interaction.

If the system acquires a large amount of historical data about ride demand and a comprehensive view of vehicle locations it can provide suggestions of where fares maybe available. It can even balance loads by warning drivers of an oversupply of vehicles at certain locations. Of course, this service depends upon the service having a huge subscribership.

4 Glossary

Civilian: A user other than a service
Compatibility: A measure of two feasible potential partners probability of contracting
Contract: An agreement among drivers and riders for a specific trip
Cost: A measure of the tangible cost of a particular partnership to each participant.
Decider: A proposer who has received an offer
Driver: A person or a service with a vehicle willing to offer rides
Enthusiasm: A subscriber's predilection to propose, represented by a daily probability
Feasibility: A measure of the logistical match of two proposers
MOD: Moving Object Database
Partner: A decider who agreed to a contract
Proposer: A subscriber who has proposed a ride as either driver or rider
Relationship: A measure of the human relationship between two deciders
RF: the RideFriends system
Rider: Someone seeking a ride
Subscriber: Someone who has registered with RF
Trip: A complete route for a particular driver.
User: Driver or Rider

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