

September 2, 2008

Interactive System for Real Time Dynamic Multi-hop Carpooling



Philip A. Gruebele

[pgruebele@cox.net](mailto:pgruebele@cox.net)

# Interactive System for Real Time Dynamic Multi-hop Carpooling

Philip A. Gruebele  
pgruebele@cox.net

## Abstract

An interactive system which automates real time dynamic multi-hop and multi-passenger routing through carpools and other transportation methods is described. Passengers and vehicles are matched without the requirements of sharing a similar destination or of passenger destination being positioned on or near driver route. Passengers can move towards destination one hop at a time and with minimal wait times. Route/hop planning is real time and dynamic, occurring at any time before or during travel along the route. The system attempts to maximize service quality through use of historical and/or current system state and external data to optimize for one or more route metrics including the cost, the number of hops, individual hop and total hop wait times, overall travel time, overall travel distance, personal preferences, and social networking. Potential passengers are socially matched to other overlapping passengers as well as drivers. Routes may include any number and kind of transportation vehicle. Overall transportation efficiency is improved.

## 1 Introduction

*This paper was originally not written to be published on the web like this. However, I have decided to remove some content and make it public in the hopes that it will have a small positive impact on society. If anyone has any questions or comments I really look forward to hearing from you. If you are aware of any blogs or social movements to make all this happen, please let me know. There exist many variations on the fundamental ideas presented here and I sincerely hope that such a system will succeed in the near future.*

Passenger transportation has not undergone any fundamental changes in the past 50 years and overall efficiency is low. Cars represent the most widespread transportation vehicle and their vacancy rate is high – many cars today only carry a single occupant and have four empty seats. Yet, due to their great number and the availability of a vast public road network, cars are the most flexible and untapped transportation resource. Doubling average car occupancy could almost halve overall vehicle-miles traveled, related transportation cost, and congestion. It is essential for modern society to greatly increase car occupancy in order to decrease consumption, pollution, and congestion and increase economic efficiency. The fundamental problem is that passenger car users make decisions without consideration of overall transportation network efficiency. This system adds such consideration and maximizes vehicle occupancy. It allows passengers to easily hop in and out of cars as it rapidly routes them to their destination without cumbersome planning. Drivers can easily pick up and drop off any number of routed passengers while driving. A variety of quality of service, routing, security, payment, matching, and social networking features make the system efficient, easy, and safe to use.

Carpooling has not yet taken a mainstream grip on society because of a number of limitations. For example:

1. Current carpooling systems try to match passengers and drivers based on their destination or based on passenger destinations being located on driver route. For a given potential passenger, this greatly limits the number of possi-

ble drivers to the extent that it is difficult and cumbersome to flexibly arrange carpooling.

2. Carpooling is generally static in that it requires extensive planning and it is difficult to make changes to a planned carpool. Carpooling does not lend itself well to ad hoc travelling. Work hours, errands, and unexpected events require transportation methods compatible with ad hoc traveling.
3. Carpools are very dependent on participant punctuality. Even if all participants are informed of everyone's arrival time through manual or automated means, delays and no-shows can still cause considerable inconvenience.
4. Security issues preclude certain individuals from participating in automated carpools systems: children riding to/from school or to/from camp. These types of carpools are generally arranged manually and only with people with whom one has established trust.

This multi-hop carpool system overcomes all these limitations.

Many industries already optimize their transportation network. This is both due to the competitiveness of most industries and the fact that such optimization is more easily applied to systems whose network is well defined, static, and centrally controlled. By network we mean a set of variably sized nodes connected in a systematic or arbitrary way by variably sized paths. The following are some simplified examples:

1. Shipping companies optimize package routing and handling. They have a known existing network which consists of branch and hub shipping offices as well as the truck/train/plane routes between those offices as well as the customer.
2. Airlines optimize the use of their airplane network (which consists of airports, airplanes, and routes) through techniques such as statistical prediction based on analysis of historical data, overbooking, and pricing.
3. Trains optimize their train network through scheduling and pricing.
4. Data network companies optimize their network by investing in strategic infrastructure such as routers, repeaters, hubs, and links between them. Packets are transferred

across the network efficiently and with error recovery. In addition packets generally experience short wait times at hubs/routers due to the real time nature of data networks.

All of these industries have evolved to be highly efficient due to competition. They manage their respective networks in order to maintain the highest possible quality of service and high occupancy rates. The problem with cars is that there is little real competition for individual drivers. How else could one obtain such a high degree of mobility? This multi-hop carpool system effectively competes with the single passenger car model by applying a central control model to maximize vehicle occupancy while preserving a high degree of mobility. The following are examples of services that poorly compete with the individual car driver for his/her transportation needs:

1. Trains can be very efficient when properly booked. However, the train network is very limited in schedule and reach, requiring that most customers spend considerable time planning and waiting, and use secondary modes of transportation to reach their destination.
2. Buses are more flexible than trains due to the larger network created by numerous bus lines. However, due to frequent stops and still limited routing and scheduling, they require considerable planning and waiting time and will generally not be able to accommodate users' source or destination locations.
3. Taxis are expensive and sometimes require considerable wait time.
4. Carpools are cumbersome to arrange and inflexible.
5. Hitchhiking is unreliable and dangerous.
6. Bicycling can be dangerous and tiring and reasonable bicycle routes to a destination may not exist. Inclement weather or night fall can cause cyclists to be stranded.

Although the multi-hop carpool system may be used with any transportation vehicle, the greatest effect on efficiency may be for cars since they are currently very inefficient. However, other vehicles such as trains and buses may be used for hops. Their networks are more static and limited making their inclusion into the routing algorithm simpler. A given route's hops might look as follows: (1) car->car->car (2) car (3) car -> airplane -> bus (4) foot -> car -> car -> car (5) car -> subway -> bus (6) bicycle -> car -> bicycle (7) walk (8) bicycle (9) walk -> bus -> walk. When bus, train, plane, and other transportation vehicles/systems are integrated into this multi-hop system, they can further optimize their routing/occupancy by allowing the system to route passengers through them. The system can thereby improve overall transportation efficiency in addition to car efficiency. For example, bus usage may increase if the system is capable of routing passengers through buses in addition to cars. Much of the planning effort – looking at schedules and routes and getting to the bus stop at the right time – may be taken care of by the system. Even ticketing and payment may be done through the system. The resultant overall transportation system may be more efficient than having separate optimized systems for cars and buses.

Government spends billions of tax dollars on toll road and road expansions and maintenance caused by the great number of cars on the road which is caused by low average car occupancy. Since this system would greatly reduce the need for this spending (fewer cars on the road means less traffic means fewer lanes and maintenance needed), government could encourage use of the

system through tolls, taxes, subsidies etc. Government already encourages its employees to stay out of their cars and use public transportation by subsidizing public transportation commute costs and encouraging telecommuting. Government also uses other barriers such as carpool lanes, tolls, and high parking prices to discourage individual car use. Government wants to encourage carpool use but does provide and real means of enabling people to do this. It would be in the government's and tax payers' best interest to encourage system use because compared to current government policies, this system may represent a more cost effective mechanism for minimizing car usage. Government controls how we use our road system. Cars have to undergo safety inspections, smog checks, registration etc. There is no reason why government may in the future not require use of a carpool system. Such a system client could be mandatory for all new cars or penalties and taxes might be applied to their sale. A multi-phase deployment plan may be necessary. First, government might require that by 2013, 10% of cars carry carpoolers through the use of this system. The system could track every car's yearly carpool record and yearly income tax deductions could be made available to those who use the system and therefore our roads responsibly. Cars may need additional features such as sensing number of passengers. The bottom line is that it is not a question of whether it should be done but when. In the end, government should make centralized control of our road network mandatory because it can be central to the success of our economy.

## 2 System Benefits

The system considers all vehicles as potential matches for passengers as long as they can carry the passenger closer in terms of PQOS (Perceived Quality of Service) to their destination. This may include driving away from the destination but to a location which will increase the overall PQOS - perhaps a location such as a large intersection or subway station where it will be easy to get a direct ride to the destination. In most cases this means moving physically closer to their destination. A driver and passenger are not matched only if they share the same or similar destination or if passenger destination is located on driver route, although such a match would minimize the number of hops in the route. However, since such matches usually require longer wait times, other matches which don't share a common destination and therefore require multiple drivers/hops may have shorter wait times and therefore a higher PQOS and would therefore be preferred.

The system's dynamic multi-hop principle provides the following major benefits when compared to matching drivers and passengers based on their destination:

1. System can route passengers one hop at a time. Users do not have to wait for a perfect single-hop route to start traveling along their route.
2. For a given driver the set of potential passengers becomes much larger, making it easier to find passengers that do not inconvenience the driver.
3. For the passenger the set of potential drivers becomes much larger. Effectively, if a passenger stands on the correct side of the street, every car coming down the street becomes a potential driver. Even a car with a completely different destination but which could simply take the passenger to a larger intersection some blocks away could be a good candidate if at that intersection the passenger would have a high

probability of quickly getting into another car which travels closer or even completely to the destination.

4. Therefore, users will find it easier and more reliable to arrange transportation from their source to their destination with less scheduling and planning effort and less waiting. Users can commit to each other later since this may minimize wait times between hops.
5. It is therefore much more likely that carpooling perceived quality of service (PQOS) will be much higher (shorter wait times, better matches etc) than current practices and patents allow.
6. This may allow for carpooling to be used by many more individuals. This increases PQOS further since the set of potential matches will be even greater. The final state of equilibrium may be that carpooling becomes ubiquitous and that the average occupancy rate for cars dramatically increases, thereby reducing pollution, consumption, and cost in the entire transportation industry.
7. This system can increase and improve social contact between neighbors and in society in general. Many people lead isolated lives and this system provides a practical method for meeting new people.
8. When the number of system users becomes high enough that people can depend on the system for transportation, user may greatly decrease the time required to plan trips. For example if passenger A flies to Denver Colorado to go skiing, A may use the system to arrange cost effective ground transportation from the airport to the ski resort after arriving at the airport. The system could present candidate routes to A, and A could choose based on convenience, cost, and other PQOS metrics. Routes might include taxi service, regular drivers, shuttles, buses etc. Without this system a passenger might have to pre-arrange something like a shuttle service (because traditional taxi service would be prohibitively expensive). With this system, no planning would be required yet the passenger could feel confident that travel will be completed with reasonable cost and travel time and with high PQOS.
9. Owning and driving a car can include considerable disadvantages such as registration, taxes, maintenance, insurance and parking. If users can engage the system in ad hoc and easy to use transportation similar to the traditional car usage model, then users could have all the advantages of driving a car without all the disadvantages of actually driving. Many users may opt not to own a car. The system could be used to fulfill both repetitive and ad hoc traveling requirements.

## 3 Detailed Description

### 3.1 Definition of Terms

The following terms are used throughout this patent and should be interpreted in the following manner. They are succinctly defined once here to make this document more readable.

#### 3.1.1 Hop

The term hop is borrowed from data networking terminology and represents the act of a passenger getting into a vehicle at the hop start location, driving along a path, and exiting the vehicle at hop end location. The final hop of a trip should have a hop end located at the destination. For clarity, if a route has  $N > 0$  hops,

hop 1 will start at the trip source, hop 2...N will be intermediate hops (if  $N > 1$ ), and hop N will end at the destination. For the participant, hops can be displayed similarly to waypoints in modern navigation systems. However, they have the additional meaning of dropping off and/or picking up one or more passengers.

Hop latency is the sum of the amount of time a passenger has to (1) wait to get on a vehicle and (2) once on the vehicle, wait to depart. Latency may also be analyzed as (1) and (2) separately.

#### 3.1.2 Committed Hop

A committed hop is a hop for which a driver and passenger(s) have mutually agreed to ride together. This commitment is equivalent to a service contract. Additional variations may be used such as a continuous or discrete scale of commitment. A contemporary analogy for committing to a hop is when a passenger gets on a bus and pays the bus fare. Making payment could therefore be considered the act of commitment, although this may or may not be required by the system.

#### 3.1.3 Vehicle

Any form of transportation such as car, bus, train, subway, bicycle, plane, boat, scooter, motorcycle, as well as walking. Note that when someone is not currently using any vehicle, then the act of walking may effectively become the vehicle. The system may therefore offer the act of walking or bicycling as the current hop – effectively making the driver and passenger the same.

#### 3.1.4 Driver

Someone or something (like computer or robot) driving a vehicle. In some cases the driver may be a representative of a larger entity such as (1) a taxi service or (2) a robotic/computer driver which may be part of a larger system. As such, the larger entity may make decisions on behalf of the driver.

#### 3.1.5 Passenger

Human, package of any size or type, animal, bicycle, wheelchair or combination thereof. When the passenger is an object such as a package, the guardian of that object will be able to make decision on behalf of the object. For instance if someone uses this system to ship a package, they may be interactively involved in making system decisions for the package. If someone hires a shipping company and that company uses this multi-hop service, then both the company and the person hiring the company may be able to make system decisions for the object. In all cases, the system may give visibility of package system state to the given persons. Note that if a passenger is a minor, the passenger's guardians may be able to make system decisions on behalf of the passenger. Passengers are considered overlapping if they are committed will at any time share the same vehicle due to overlapping hops.

#### 3.1.6 User

A person who is a member of the service. Users may form user groups or buddy lists in order to enable social aspects of the system.

#### 3.1.7 Candidate

A driver or passengers whom the system selects as possible carpool candidates for the same carpool. Automatic, semi-automatic and end-user selection of participants from a list of candidates is possible. Note that when a driver is shown to a passenger as a candidate, then effectively all overlapping

passengers from that driver are also candidates. Also note that when a driver is presented with a candidate passenger, candidate route changes may also be shown since the driver's route may have change to accommodate the passenger.

### 3.1.8 Participant

Any driver or passenger participating or possibly being a candidate for participation in the same carpool. Multiple participants sharing a vehicle at any time can be considered a co-participant. Committed co-participants are committed participants and overlapping committed participants.

### 3.1.9 Hub and Hub size

When a passenger is waiting for a vehicle at a given hop start, the passenger's location can be looked upon similarly to a network hub/router or shipping sorting center. These hubs may be large in terms of the number of vehicles/passengers with hop starts and ends currently or historically at that location. Hubs may also be considered of high quality for a given passenger if many good candidate vehicles pass by that hub.

### 3.1.10 Trip

A distinct act of traveling by a participant. A trip takes a participant from a source to a destination. It may require one or more hops along the route. Note that a trip may have waypoints in addition to a source and destination. Waypoints are considered to be user specified locations through which a route must pass. Waypoints may have associated latency times associated with them. For instance, if a waypoint has a latency of 30 minutes, then this means that the user wishes to remain at that location for 30 minutes after arrival. Latency may also be specified in absolute time. For example, one could specify a certain desired time of arrival and/or departure for a waypoint.

### 3.1.11 Route

For a passenger, a route is a sequence of one or more hops which in the process of taking a trip brings a user from a source to a destination. A route can be a partially defined route in the sense that although the destination is defined, no candidate drivers have been identified yet for one or more hops along the route. Hops may be added to such a route in order to make it a complete route. A complete route provides a complete path to the destination including all past and future candidate drivers and associated hops. Hops may be added to or deleted from untraveled route segments as route is dynamically changed. Note that for a given trip several routes may be possible. These routes may share some candidate drivers and hops. Routes may be calculated using modern routing algorithms, map data, traffic data, and additionally take into consideration PQOS metrics.

For a driver, a route is a path from driver's source to destination and may include zero or more passenger hops. Passenger hops may overlap along driver route as long as vehicle capacity is not exceeded. As driver commits to additional passenger hops, driver route may need to be modified since passenger hop start and hop end locations essentially become waypoints along driver route. Note that certain types of vehicles such as taxis may not have specific destinations since their only purpose is to provide hops to passengers.

A good analogy is routing as performed in data networks. If a packet is sent from a location in California to New York, that packet may travel along many hops in order to reach the final destination. The final number of hops and final exact path may

not be known yet as the packet travels along the network. Traffic congestion, downed segments and other conditions may dynamically change how the system as a whole ends up routing the packet. In addition, certain protocols such as QOS may be used to reserve a given route all the way to the destination.

### 3.1.12 Candidate Route

A possible route to which the participant has not yet committed a single hop. The same candidate driver(s) may be included in candidate routes of different candidate passengers and the same candidate passenger. The route may have one or more hops defined, but may not have all hops defined yet.

### 3.1.13 Partially Committed Route

For a passenger, this is a route for which the passenger has at least committed to one hop/driver, but for which parts of the route still do not have committed hops. For a driver, this is a route for which the driver has committed to at least one passenger.

### 3.1.14 Real Time Dynamic Routing

The system performs dynamic routing when it calculates routes in real time as the user plans, starts on, or progresses in a trip. Route changes may be made or proposed at any time before or during the trip. Hops may be added or deleted and candidate drivers/hops may be committed to. This contrasts with static routes which are similar to traditional carpooling in that the complete route has to be pre-defined ahead of time, possibly well before start of the trip.

### 3.1.15 Client

This is the interface that participants are presented with in order to participate in carpooling.

### 3.1.16 System

The entire system comprised of client hardware devices and client software, backend servers and server software, GPS or cellular triangulation subsystem and software, network communication technology and services, and possible human operators. Note that all types of computing devices and algorithms may be considered. This includes programming languages such as C, C++, Java, SQL etc. This also includes neural networks or other learning algorithms as well as any other methods of implementing algorithms. It also includes equivalent implementations of any of these in hardware. Note that some components may not belong to the system although the system uses them as part of the overall implementation.

Note that this system may be part of a larger system which optimizes transportation further but includes the multi-hop routing and carpooling principles of this system.

### 3.1.17 System state

The system keeps track system wide participants and their planned trips, current state, locations, routes, and carpool settings. It may also store such data in order to provide future predictions of system state. System state may also include weather, traffic, special events and other traffic related information.

### 3.1.18 Static Carpool Settings

These are settings that change infrequently and that may be part of a registration process. These may include type and color of vehicle(s) driven by participant, license plate number, total

number of seats in vehicles, number of bicycles storable on racks, wheelchair access, child seats, defaults for dynamic carpool settings, luggage space, trailer space etc. Some types of vehicles such as walking or bicycles may have no carpool seats and therefore preclude a participant as a driver. In addition, security related settings such as driver's license may be part of these settings.

### 3.1.19 Dynamic Carpool Settings

These are settings that change frequently and may be reconfigured at the beginning of each trip and could be considered trip settings. Participant settings may include current location (through GPS or manual setting), destination, current disposition to act as active participant, preferred contract settings etc. Additionally, users may specify preferences which will bias routing: trying to ride with specific individuals, emphasizing low cost, emphasizing short travel time, emphasizing social networking metrics such as dating preferences or degrees of separation, user ratings etc.

For participant drivers additional settings may include which vehicle is currently being driven, number of seats available for carpooling, number of bicycles spaces available for carpooling, luggage space available, how far in time or distance a driver is willing to deviate from the current or ideal route in order to pick up or drop off a passenger, contract settings etc.

For participant passengers additional settings may include luggage number and size, bicycle storage required, required wheelchair storage, maximum cost etc. It may also include contract settings such as requesting that the driver take passenger directly to their destination without picking up additional passengers.

### 3.1.20 Service

The carpool service consisting of systems, methods, computer software and or hardware that are part of this system. The system is interactive because its users may constantly communicate with the system and each other.

### 3.1.21 Carpooling

The use of this term is more inclusive than in the traditional sense. Carpooling is defined as 2 or more people sharing a vehicle for the purpose of transportation. This vehicle will often be a car due to the ubiquity of cars but may also include any other type of vehicle. Ridesharing is another similar commonly use term.

### 3.1.22 PQOS

Perceived Quality of Service refers to the quality of the transportation service as perceived by a participant. The routing algorithm should generally try to maximize PQOS on a user and system level. PQOS may be a function of one or more metrics such as trip cost, social networking, trip time, wait time etc

## 3.2 Core System Concepts

The following summarizes some of the key system concepts:

- Multi-hop routing. System routes passengers to destination one hop at a time. A hop is equivalent to getting on a vehicle at location A and getting off at location B. Passenger may reach destination in one or more hops. The final hop should take passenger to destination. Any vehicle including walking may be used for a hop.
- It is not required that passenger(s) and driver share a similar destination or that passenger destination is located on or near driver route. This greatly increases the number of potential driver/passenger matches. This can in turn reduce required planning and wait times, allowing participants to quickly travel along their route to the destination.
- It is not required that passenger and driver route overlap. Driver may accept route changes for the purpose of driving a passenger.
- It is not required that the entire route is well defined before passenger can travel. Passenger may move towards destination as long as a vehicle/driver can take passenger closer to destination via a hop.
- Interactive, automated, dynamic and real time. User and system can suggest and make route changes before and during trip. Scenarios where trip is completely planned and no dynamic changes are made are degenerate cases and are also supported. The system automates trip planning and execution as much as possible but allows for interaction between users and system and among users.
- A driver can pick up and drop off any number of passengers at any number of locations as long as capacity is not exceeded.
- When a driver and passenger commit to a hop this may represent a contract among driver and passengers. This committal may reserve a seat or a specific seat in the vehicle. Processes for cancelling such a contract may be system supported.
- When sufficient candidate drivers are likely to be available, passengers may commit to upcoming hops as late as possible, reducing hop latency (Passenger does not want to have to wait to get on next vehicle).
- When sufficient candidate passengers are available, drivers can commit to new passengers as late as possible, reducing hop latency. (Driver does not want to have to wait for passenger).
- Routing takes into account a wide variety of metrics in order to maximize overall user perceived quality of service (PQOS) while maximizing occupancy. These metrics include standard system measurable metrics such as trip time, distance, cost, as well as social metrics such as social networking distance, shared interests, degrees of separation, dating preferences, ratings etc.
- Since multiple passengers may ride in a car, routing may use social metrics to match passengers with overlapping passengers as well as drivers. System induces users to meet new or previously acquainted people. The social aspects of the system may be a large driving force for system success.
- Current and historical system state may be used to perform actual routing or predict future routing possibilities.
- System may maintain database of hubs. Hub size and placement may be a function of system usage, user choice, business advertising, mapping data, and more.
- System may automate or semi-automate all travel related processes including payment, security, planning, user interaction, committing etc.
- The system may include any type of vehicle (car, truck, train, boat, airplane, bus etc.) and any type of passenger (person, package, animal etc).
- The system may support methods for candidate participants to find and identify each other in person.

### 3.3 General Description

After passenger uses client to configure trip settings such as destination and any number of PQOS metric routing biases such as cost or social networking metrics and user ratings – which are used to match passenger with other overlapping passengers as well as the driver - passenger is presented with one or more PQOS optimized candidate routes which satisfy the trip through one or more hops/drivers and their associated overlapping passengers. A variety of information about the routes and their drivers and overlapping passengers is displayed. Routes are dynamic in that upcoming hops for the trip may not yet have been defined or committed and as drivers become available changes to the route will be interactively proposed to the passenger for committal in real time. Also, even if a route is fully or partially committed, better options (higher PQOS) may come up and the system may dynamically suggest potential hop changes for the current route to the passenger. Hop placement can dynamically change. For example, if passenger is in a car and driving towards next hop start, then the exact location of the hop may be a function of who the next driver is and what that driver's route looks like. Participants may also request changes in hop locations. Passenger commits to hops/drivers and moves along route through one or more hops until destination is reached. Any vehicle including walking may be used as a hop.

A candidate driver is similarly presented by the client with one or more candidate hops/passengers. The driver may already carry other committed passengers or may already have committed to other future passengers, some of which may have overlapping hops with each other as well as with the candidate hops/passengers. Driver may commit to any number of hops. A variety of information about the candidate passengers and their hops is displayed, including candidate route changes and various PQOS metrics such as changes in travel distance, social networking metrics, and ratings. This information may also be displayed to committed overlapping passengers and these passengers may also participate in the committal process. Driver and committed passengers may request changes to their committed hops. A process for such changes may be supported by the system. Drivers may use any type of vehicle.

The process outlined above occurs for all active system participants simultaneously so as to match all drivers and passengers as part of an overall optimized system. Passengers enter and exit vehicles as part of their hops until they arrive at their destination. Drivers pick up and drop off committed passengers. All co-participants are made aware of their social proximity so that they may interact socially. The system may process data in a centralized and distributed manner.

In order to minimize passenger/driver hop wait times, passenger should arrive at hop N+1 start at the same time as next hop's driver. As passenger moves along route hop N and gets closer to hop N+1 start, system will have more accurate information regarding hop N+1 start arrival times and routes of other vehicles. It may therefore be beneficial to leave future hops of the route uncommitted so that the best possible driver match can be made at time of next hop start arrival. This is especially true if system reaches critical mass and there are sufficient candidate drivers to insure that there is little risk of not immediately finding a driver and moving forward along the route.

Routing should be as automatic as possible but may include user settings and user choice. In general users may bias routing and

filtering by specifying weights and limits and other formulas for any PQOS metrics used in route optimization. For example, the user may prioritize travel time above all other metrics but place an upper limit on cost and a high priority on user personal rating. Ideally the system would have sufficient information and algorithm complexity to make all choices for the user automatically, but system limitations in anticipating user preference and choice as well as environmental factors such as weather and traffic may require the system to include user choice in final route/hop choice. For instance, system could propose some routes to user and user could choose actual route based on arbitrary preferences not known to system or not included in routing optimization. Ideally, user can input trip settings so that the routing algorithm can find optimized routes and display route information to user as automatically and intelligently as possible, thereby allowing users to make decisions which actually end up maximizing user PQOS and overall system PQOS. The exact client interface for accomplishing this is outside the scope of this document, but the interface should be simple to use yet sufficiently flexible to allow the system to realistically maximize user PQOS.

The system may generally try to maximize passenger and driver PQOS by optimizing routes/hops for PQOS metrics. Those same metrics can be used to quantify the quality of the resultant routes/hops. Since cost is an important metric and cost can be reduced by maximizing system occupancy, the system may effectively optimize for maximum occupancy as well. Since optimization may take all relevant PQOS metrics into account, and since many metrics impede each other, metric weighting or other function will affect final optimized routes. This means that the overall system will never have 100% occupancy since this would probably adversely affect other metrics. Optimization techniques similar to current and future best practices may be used for this, but with the additional consideration for multi-passenger multi-hop routing and a broad range of PQOS metrics and social networking metrics. Given the set of all driver and passenger users, the system may try to find best possible routing in order to optimize the overall system in addition to individual users. During route optimization, system may try to socially match passengers to drivers as well as other passengers who will be sharing a vehicle.

The system may use a database which stores landmarks/locations which will be good hubs. Geographic locations may be dynamically designated as hubs of a given size based on their current and historical system usage, mapping data, user input, and third party marketing. For example:

1. Users may make adjustments to system-proposed hop start/end placement. For instance if user knows that there is a good hub at a certain location, user may move the hop start/end to that location. Hubs could also be rated by users. This essentially allows users to "vote" on hub size and placement.
2. Mapping data may be used to extract landmarks such as bus stops or train stations and make them hubs since they are already designed to be used for picking up and dropping off passengers. As mapping data is updated, the system may update extracted hub data.
3. Service companies such as coffee shops or book stores may pay the system for a new form of advertising/marketing, which is to attempt to increase the probability of dynamically placing hops/hubs near their businesses. Since these

businesses are typically good hubs, this could also maximize user PQOS.

In general, the system can be thought of as dynamically maintaining a virtual network definition based on locations that are or become hubs of varying sizes and may route passengers along those hubs. Any geographic location which is suitable as a hop/hub could be stored. Of course any arbitrary location – even one which was never used before or which does not represent any special landmark – can be used in a hop and therefore be a small hub in that only a single hop start/end ever existed at the given arbitrary location. Of course such arbitrary locations should still be safe and legal for passenger exchange. The routing algorithm may bias dynamic hop start/end placement towards good hub locations in order to increase system and participant PQOS - especially the safety as well as legality of route and associated hubs metrics. As hub usage is collected and analyzed, government and businesses may improve those locations in order to accommodate high hub usage or cater to system users.

When a candidate passenger is being matched to a driver, then the candidate passenger may also be matched to any already committed overlapping passengers. To do this the system may effectively have to “or” or otherwise combine the committed passenger and driver route biasing social networking metrics and user rating metrics. Because of this, the candidate passenger client may display driver’s and committed overlapping passengers’ information and vice versa. This also brings up issues with conflicting route biasing PQOS metrics between co-participants. Further use case analysis is needed to understand these issues.

Note that all processes described in this document – committal, committal changes, contract changes, rating, etcetera – may be partially or fully automated. Ideally the system would automate them to the point where no user choice or even user update is necessary. The ideal system would always make the right choices on behalf of its users. While this may not be possible and realistically users may always be involved in making system choices, further use case analysis is needed to more clearly define all these processes and their possible automation.

### 3.3.1 PQOS

Perceived Quality of Service refers to the quality of the transportation service as perceived by a participant. The routing algorithm should generally try to maximize PQOS on a user and system level. PQOS may be a function of one or more metrics. Any metrics used in modern navigation systems may be used. In order for the routing algorithm to optimize routes based on these metrics, they should be measurable by the system. Metrics may interact with each other in a way that requires tradeoffs during route optimization. For example there may be a tradeoff between number of hops and per-hop wait times. Note that user carpool settings may affect route optimization, and finally manual user choice may finalize route/hop choice. For example, a user’s settings may put strong emphasis on being matched with certain personally highly rated users. Metrics may include but are not limited to:

1. **Required planning.** Having to plan a trip in advance is generally undesirable since user plans can change. For instance it is usually less expensive to buy airline tickets in advance, but doing so will make it very inconvenient if any changes need to be made to the trip. Ideally, a trip requires zero planning but still performs well in terms of other metrics.
2. **Cost.** This is an important metric. Users generally want to minimize cost, but this may conflict with other metrics such as number of hops or total trip time.
3. **Cost Savings.** For a driver, cost savings is of more interest than cost and is the result of receiving payment in return for driving one or more passengers. Cost savings may also be the result of being able to use a toll free carpool lane. For a passenger, cost savings are the result of receiving transportation services at lower cost than other routes or forms of transportation. Cost savings for both driver and passengers may increase as the number of passengers per vehicle increases.
4. **Trip Time.** Users usually want to get where they want to go as fast as possible. Minimizing hop latency and continuously moving a passenger towards the destination generally reduces overall trip time. Traffic can have a considerable impact on this metric and therefore needs to be considered.
5. **Trip Time Savings.** For a driver, time savings are the result of things like using carpool-only lanes. For a passenger, travel time may be considerably shorter than when using traditional public transportation. Use of carpool-only lanes may further increase time savings beyond what that passenger might be able to achieve as a non-carpooling driver.
6. **Travel distance.** Shorter travel distance may translate into shorter travel time, but traffic and speed limits may make longer routes faster.
7. **Changes in travel distance.** This could be a positive or negative number and can be used to compare routes or candidate route changes such as when a driver commits to a passenger.
8. **Ease of Use.** Arranging traditional carpools or looking through train schedules and connecting trains is cumbersome. Also, the client should present candidate routes/hops in a manner which makes it easy for the user to select high PQOS hops. Too many user choices or disorganized choices will lower ease of use.
9. **Number of Hops.** It is generally desirable to have minimal hops. However single hop routes may greatly limit the number of possible candidates and may therefore often perform poorly in other metrics.
10. **System Reliability.** The system should be both reliable in terms of hardware/software and in terms of allowing users to depend on the system for their transportation needs. If the system causes unreasonable wait times or cannot find matching drivers it would score poorly with this metric.
11. **Safety and Security.** This is very important since anyone who feels unsafe will have a very low overall PQOS of the service. Particularly at hop start and end, safety is a major consideration when users enter or leave vehicles.
12. **Legality of route and associated hubs.** Since the system may propose routes with multiple hops, user would want to enter/leave a vehicle in a way that is safe and legal.
13. **Per-hop and total latency.** This includes both awaiting a vehicle’s arrival and departure. For example, waiting a long time for a bus to arrive or a train to arrive and then depart greatly degrades the end-user experience. Even if users are required to change buses or trains, as long as they can immediately depart on the next vehicle, the PQOS may still be good. Much like data/voice networks people have low



tolerance for waiting. One may consider awaiting a vehicle differently from waiting in a vehicle. For instance, once a passenger gets on a train it removes much uncertainty about the hop and, if the train is comfortable, additional wait time before departure may not be judged very negatively by the passenger.

14. **Uncertainty.** This is one of the reasons why wait time has a significant impact on PQOS. Whenever a passenger is not in a vehicle there is doubt as to if and when a vehicle will arrive. Worst case is that a vehicle will never arrive and the passenger will never arrive at the destination. Using a multi-hop routing scheme greatly reduces uncertainty since a given passenger will have many drivers to choose from and vice versa.
15. **Hub rating.** User could rate hubs so that system may provide higher PQOS routing.
16. **User Reliability.** Users who frequently cancel committed hops or do not follow agreed upon routes may automatically obtain a low reliability rating.
17. **User Social Networking Metrics.** A wide variety of sub-metrics may exist. In general these metrics determine the social proximity between users. Any attributes used by services in the fields of dating, professional networking, and personal networking may be used. This includes proximity in terms of degrees of separation, shared interests (video games, hobbies etc.), common friends, work, dating preferences/matching, commonalities on social networking sites, ethnicity, languages, language proficiency, work, age, citizenship, free-form text entry, user groups or buddy lists etc. The closer co-participants are socially, the higher PQOS may be. In other words, if a co-participant is a friend of a friend, then a participant will generally have higher PQOS of the trip. Also, people that share common interests are generally better carpool matches than people that have nothing in common. Of course some users may prefer to ride with strangers.

There may be a set of pre-defined metrics which may have a specialized client interface to allow users to (1) set these metrics in their static settings and (2) configure non-default route biasing based on these metrics.

The majority of these metrics are entered by the users themselves. For example, if two users determine that they share the interest "Warcraft game", then they should each make sure that this is part of their static settings if they want to allow the system to match them with each other or other future participants based on that metric.

18. **User Public Rating.** This is a publicly visible rating of a user by other users. This may be a single rating as used by many web services or a compound rating consisting of several sub-categories such as (1) likability (2) driving ability (3) accommodation level (4) reliability (5) messiness (6) temperature (Driving with someone who likes their car too hot or too cold) (7) vehicle luxuriousness/comfort (8) any other user rating related metrics commonly used by internet sites, including clear text comments.
19. **User Personal Rating.** This is a publicly non-visible rating of a user by another user. It may optionally be visible to the user who received the rating. Users may have arbitrary personal opinions of different users. Passenger A may really like passenger B and vice versa. If they rate each other as

such, then the system may optimize future routes to match them up together, thereby increasing PQOS. Similarly, co-participants that dislike each other should not be routed in the same vehicle together. User might also decide that they share a similar work commute and may wish to specify that the system will attempt to route them together. As part of the rating process, users may be able to include additional textual information for rating recipient to see.

High PQOS is achieved through minimizing the negative aspects of these metrics (e.g. cost should be minimized, reliability should be maximized, and user personal rating should be maximized). For example, even if reaching a destination requires changing vehicles (multiple hops), as long as wait time is minimized PQOS is still good. In some cases PQOS may be maximized by entering a vehicle which takes the passenger further from the destination in terms of distance, but either (1) closer to the destination in terms of total trip time or (2) decreasing wait times and therefore increasing PQOS.

Note that the User Public Rating and User Personal Rating metrics are also part of a user ratings subsystem. For example, users may rate each other high in user personal rating or user public messiness rating. The system may use these ratings to bias future routing. For example user A may dislike messiness of user B and rate user B poorly for that metric. User C may specify carpool settings that prevent her from riding with messy people unless necessary. User C might give user D a high rating for a personal rating and the system may in the future bias routes such that C and D are more likely to travel together.

### 3.3.2 The Client

This is the interface that participants are presented with in order to participate in carpooling. The client enables communication between users and system as well as among users via one or more of the human senses. The client may use speech, speech recognition, computer vision, motion detection and any other means to enable user communication with the system. Additionally, the client may provide ways for participants to directly communicate with each other via any common ways that mobile devices allow people to communicate: voice, text, email etc. The client can also be considered a super set of current GPS navigation technology in that it may satisfy all present and future common navigation functions in addition to multi-hop specific system functionality.

The client may be based on a variety of technologies, including one or more of the following: thin-client, client/server, web page, web 2.0, email, IM etc. The client may run on a portable device such as cell phone, hand held computing device, PDA, laptop, or any computing device built into a vehicle. It may also run on a non-portable device such as a desktop or kiosk computer. All clients should have network communications such as provided by WiMax, cellular, Ethernet, Wi-Fi or any other existing or upcoming technology used for networking and communications. The preferred client hardware would provide GPS or equivalent location tracking services. However, desktop kiosk clients can be considered stationary and therefore do not require GPS services. Clients regularly send their location to the system such that system is aware of user movement. Client and system also regularly communicate so as to provide an interactive user experience. Different clients may be available for varying computing platforms and participant needs. For example, a desktop client will typically be optimized for a large screen high-

bandwidth experience while a hand held client may be optimized for a smaller screen or lower network and computing bandwidth. Certain users such as the disabled may require a special client interface. For instance blind users may require a human or computer voice guided operator or a brail-enabled handheld device and client. Note that the actual hardware that client system software components run on may be generic. For instance modern cellular phones already have GPS, data network, GUI and other functionality and client may simply be a software component which runs on such a client platform.

The client may display a variety of information to participants. This includes but is not limited to: a map with planned route, committed and candidate hops and their users along the route, and PQOS metrics such as cost, per-hop wait time, social networking metrics, or personal ratings. A driver's client may display committed passengers along the route as well as their hops. It may also display route changes needed by individual candidate passenger hops. A passenger's client may display committed drivers associated with hops as well as other passengers with overlapping hops. Effective cost savings of trip compared to other possible vehicles (cost of equivalent taxi ride, single occupancy car ride etc) may be displayed. Any user-related information may be displayed: ratings, degrees of separation, shared interest, links to MySpace and other web site data, pictures, etc. Static user settings may determine what other users are allowed to see. Due to the large amount of relevant data users may wish to see, the client may be organized in a tabbed or layered interface. Users may be able to access their client state from multiple clients. For example, when in a car, an on-board computer may be the active client. As the driver exits the car, a hand held client may become the active client. Or both clients could be active at all times. This is similar to the impersonation capabilities discussed under security.

Certain passengers may not have a client or even a user account but may travel with system users who do. For example a family with children may have two clients for the adults and none for the two children. In this case, all four persons should be able to travel as a single unit and use a single client as a system interface.

Additional client features may include: (1) when multiple participants are in a vehicle, system may use GPS/locating service of one or more phones to track the vehicle. This provides better tracking redundancy. Averaging of multiple GPS locations may be used to increase accuracy. (2) The system may help users find misplaced clients through the use of another client. (3) Client can remind users of planned trips (4) Client could turn on car at beginning of trip (5) Client may use secondary positioning systems such as accelerometers, compasses, and gyroscopes to determine motion and position when GPS is unavailable such as indoors or when higher accuracy is required. Client may measure its position relative to other clients. (6) Client may auto-detect state such as driving in vehicle or walking. It may use historical trip statistics to make intelligent guess at destination and prompt driver to confirm and engage in system. (7) Client may allow user to rate overall system or route performance and make suggestions regarding system improvements.

### 3.3.3 Predictive Carpooling

The system may use historical and current system state data to estimate routes that will be available for a future trip. For example if a potential passenger plans a trip for the next day, the system could display worst and best case scenarios to the user. If

estimates show that there will not be sufficient candidates for the route available to safely do unplanned traveling or that hop wait times are likely to be long, then the potential passenger could tell the system to find actual future routes/hops and commit to a route/hop ahead of time as in a traditional static carpool scenario. As matches become available over time – or instantly if system immediately finds matches - the system may provide updated candidate routes/hops to the user and allow the user to commit ahead of time. Essentially, the higher the carpool volume for a given route will be, the less planning ahead and committing needs to be done and the more dynamic routing can be. In many cases dynamic routing is preferable because it is difficult for users to plan exactly when they will travel where. This is due to frequent ad hoc travelling and environmental factors such as work etc. Also, hop start arrival times are a function of many factors such as traffic, weather, current participants, etcetera, making non-dynamic routing more likely to have longer wait times and therefore lower PQOS. In addition to planning future traveling, if the system is unable to find candidate drivers for a current trip, the system could display statistical information which tells the user how long the wait at the given hop might be and how long overall travel time may end up being. If a user is waiting at a hop and there is no vehicle immediately available for commitment, then the system might tell the user that statistically speaking, a 5 to 10 minute wait should be expected for a viable vehicle to pick that user up for the next hop and that total trip time may be 20 to 30 minutes. This type of information may also be used when deciding whether or not to enter a vehicle for a multi-hop trip when it might be likely that a vehicle with no additional hops may be available within a reasonable amount of time.

The total trip time PQOS metric may be calculated based not only on the physical route parameters, but also based on current or historical traffic conditions, predicted weather, and other factors such as special events which might increase traffic (for example storm warnings will generally cause a surge of drivers leaving their work early, or large sports events can greatly increase traffic along certain routes). This data may be collected by this system (through GPS enabled clients) and/or imported from another system which specializes in traffic measurement and prediction.

The system may store users' travelling patterns in order to improve statistical forecasting and in order to attempt to match users even before they configure trip preferences on their client. For example person A drives to work every morning at about 8:30am. Perhaps some of those trips are done through a system carpool. Person B is asking the system for a forecast of the next day carpool to work. Persons A and B would be a perfect match but person A has not configured carpool settings yet or may have declined to carpool for a while. The system could contact person A and ask if she would like participate in the given carpool. Another example could be that person A is not actively using the system but the system tracks and knows the travel history of Person A. System could advertise possible carpool routes to Person A in order to encourage carpooling. Further promotions could be used to encourage system use.

Users may enter future planned trips without actively engaging the system. This will allow buddies to view their future traveling plans and arrange travel together. It will also allow the system to do more accurate system state prediction. Also, as users engage in a trip, they may permit buddies to see information about their

trip and current state so that the buddies can try to route or meet with them.

The system may track users to see if they engaged in carpooling without using the system. If persons A and B used system to share a ride today, then in the future they may bypass the system and share a ride without using the system. The system can detect this since both portable client devices will move along identical routes. The system may market itself to such customers by providing lower cost for repetitive longer term carpool arrangements.

The system may use a variety of methods to encourage behavior which reduces congestion during peak commuting periods: (1) compare route PQOS metrics such as trip time during peak and non-peak traffic hours (2) discounts or credits during non-peak usage (3) system could integrate with toll booths and allow for reduced off-peak tolls (4) government imposed taxes during peak usage.

### 3.3.4 Social Aspects

Carpooling is primarily a form of transportation, but social aspects may play a significant role in system success. Historically, carpooling is a relatively static arrangement between a fixed set of people. Relatively little opportunity for meeting new people exists. This system allows users to meet many people. In a single trip with 3 hops a passenger might meet 3 to 10 people and talk to strangers for a total of 30 minutes. Who can say that they speak to strangers this much in our current society? Of course a participant could choose to take a nap or spend the duration of a trip otherwise. Riding with the right type of people would of course increase one's desire to socialize. Therefore, in the process of maximizing participant PQOS, certain social networking metrics may have a very strong positive impact on PQOS. When candidates are displayed on a user's client, additional information which would enable social networking may be displayed about candidates. Note that when a passenger views information about a candidate driver then information about overlapping passengers should also be displayed. This is necessary since passengers may be socially matched to overlapping passengers as well as drivers

Routing may be biased towards specific social networking metrics. For instance, if a passenger has an opportunity to ride with a friend, then she may want to wait at a hop in order to use that friend as a driver or overlapping passenger. Also, if a candidate likes a certain type of music or band, then very high PQOS may be achieved by matching candidate with other candidates of similar interest. Even if a passenger shares nothing in common with driver, the passenger may share something in common with other passengers, thereby increasing passenger PQOS. This in addition to contracts is another reason why all committed passengers may be involved in the process of committing to additional overlapping passengers. The system may prioritize or highlight candidate routes based on this type of information and user settings. This may include things like:

1. This system may be linked with social networking tools such as MySpace or FaceBook and bias routing based on participants' connections at these services.
2. Carpool dating could be implemented by biasing routing in order to match participants based on dating preferences. These preferences may come through linking this system with a dating service system.

3. Degrees of (Carpool) Separation. Many people are familiar with this concept. The general idea is that everyone is acquainted with everyone else in the world by six or fewer degrees of separation. The same concept can be applied to system users. If a candidate passenger is presented with a possible route/hop, the system may show the degrees of separation between the passenger and each candidate co-participant in the route/hop. So, if person A gave person B a ride 2 days ago, and candidate passenger C gave a ride to person A, then system may show passenger C that current overlapped candidate passenger B is 2 degrees of freedom away (C met A and A met B) and the time span of the connection (2 days).
4. System may also present rating related information. For instance if C likes A but A dislikes B, then this might not make C want to ride with B.
5. System may also display the list or a graph of users which form the acquaintance chain.
6. System may also allow users to push information such as ratings, contact information, or social connections back into secondary systems such as FaceBook, email etc.
7. A hard wired set of PQOS social networking metrics may exist to accommodate common items. However, free-form text based entries may be used for metrics such as interests. For instance a user may enter "table tennis" as an interest even if such an entry did not previously exist. This will allow matching based on extended social networking metrics which might not be built into the system.

For example, if candidate driver A is coming down the street and candidate passenger B is standing on the street corner waiting for a ride, and if the system proposes for both of them to commit to each other for a given hop, then each candidate may be shown additional social networking information about the other, thereby making them more likely to commit to each other than other candidates. Driver A may configure system settings such that metrics such as degrees of separation heavily bias the routing algorithm. In this case the system will attempt to route Driver A with passengers which perform well in this metric.

At a coffee shop or other public location which naturally lends itself to being a large hub, users could select other participants not only through the client but in person. The system may support a method of helping candidate participants find each other. This could be accomplished through picture, description, phone call etc. Client hardware could have mechanism of physically locating other close-by candidate participants' client devices. System may also allow two users to verbally decide to carpool together and then use the clients to configure this. For instance if persons A and B meet in a coffee shop, they may decide to carpool together. For security reasons and to simplify cost sharing, they may decide to use the system to manage their carpool, so instead of just getting in a car together they create a common route using the client.

Users may form user groups in order to make it easier to perform social networking. For example, a set of students may form a user group in order to make it easier to tell the system to route them together. The system could also highlight candidate hops which include a user from a certain group. This is a form of social networking and could be quite popular among students.

Companies could create user groups since employees of the same company would have an inherent higher level of trust and they

share a common work location. It would be beneficial to a company to encourage employees to ride together and form a social bond. Companies may also financially subsidize employee system use.

The system may support the concept of a buddy system. Users may be able to add other users as buddies, and the system will make it easier for buddies to share rides. For instance when presented with candidate participants, users may see their buddy flagged in a route and the system may attempt to increase the chance of riding with a buddy even if it makes other PQOS metrics slightly worse. Users which know each other may make themselves buddies in order to carpool to work together regularly. User settings can also control routing bias towards these buddies.

Multiple users could opt to travel as buddies. For instance, two children at tennis camp could use the system to get a ride home. They could request that they carpool together only. This could mean that they can only get in and out of the car together, or that they can get in and out separately if they have different sources and/or destinations. Buddies could use a single client to arrange the ride for all of them or they could use multiple clients.

Users may request for the system to route them with specific users (i.e. invite users). For instance friends could use this system to pick each other up to go out. They could then use the system to track each other and make trip planning and exceptions such as tardiness easier to deal with. The system could automatically alert passengers of the arrival of the vehicle. The system could also alert drivers of the arrival of a passenger.

Users may find other users based on shared destinations. For example, a set of users might regularly go to a karate club. The system may allow someone to bias routing towards riding with users that go to the same club and perhaps even go to that club at a certain time or day. Destination addresses as well as raw locations and times spent at those locations could be tracked by the system. This type of filtering could be accessible outside of routing – for instance someone might be able to contact users that share this social aspect. This applies to any other social and personal metrics as well. Users may be able to search for other users based on social networking metrics and contact these users. Security measures may be needed in order to prevent abuse of this capability.

### 3.3.5 Compensation or Payment

The system may support one or more of the following compensation methods:

1. **Payment for services.** This is the traditional buyer seller model used for selling goods and services. This applies to today's taxis, public transportation, and delivery services of today.
2. **Cost sharing.** This is the model associated with traditional carpooling. People may take turns driving or contribute for driver, gas, and vehicle cost.
3. **Acknowledgement.** In this model participants do not receive actual monetary compensation but acknowledgement from other users. This may apply to parents carpooling children, or friends driving each other.
4. **Tipping.** This is optional compensation which could be made to participants at any time.
5. **Any other commonly used methods**

In many cases a hybrid model may be used. For instance, if drivers wish to use acknowledgement as compensation, then passengers may still make payments that go to the system provider.

The following entities may be involved in the compensation system:

1. Passengers should generally pay since they are the biggest service consumers.
2. Drivers should generally be paid for driving services and costs such as gas, vehicle wear and maintenance, and tolls.
3. The system provider may be paid since it provides the system services to the participant end users.
4. Insurance carriers may be paid in order to provide secondary insurance for all participants and to cover any participant or system provider liability.
5. Third party entities which use the system as a sales/marketing tool may pay since they benefit from the service. For instance coffee shops could pay the system in order to bias routing such that hops are placed at their location.
6. Government may collect tolls and taxes, give credits, collect parking fees, and monitor carpool lane usage through the system. Tolls may be a function of occupancy and time of day.
7. Car manufacturers may integrate the client into a car, sell the car at a considerably discount with the agreement that buyer actively participates in system. Manufacturer may then collect all or part of compensation buyer/driver would normally receive. Long term, manufacturer may more than compensate for the sales discount. This concept contributes to the notion that cars belong to society as a whole instead of just the driver.

In order to maximize PQOS, the system may automate or semi-automate compensation. Cost could be calculated based on a number of factors including travel distance, convenience, comfort, participant contract etc. Billing may be performed similarly to current cell phone monthly billing statements (with debits and credits), or services similar to PayPal may be used to automate payment procedures in real time. Even an auctioning model may be used. Users could also negotiate prices directly. Regardless of system used, a well integrated automated compensation system will greatly increase system ease of use and therefore PQOS. The compensation models used will most likely evolve as the system matures and becomes more widely accepted.

The cost sharing model may be a desirable model for driver and passenger compensation. Otherwise government entities may try to regulate drivers similarly to the way taxis are regulated. Such a model may automatically make adjustments in order to reflect actual trip costs. For example, when a driver is able to save time or fuel cost on a trip through the use of a passenger(s), then passenger(s) may compensate driver less since driver is already being partially or completely compensated through use of the passenger. If the driver has to go out of her way to pick up or drop of a passenger then the driver may receive more compensation. The system may help manage this aspect of cost equalization by calculating compensation based on contract premiums, mileage, trip time, luxury cars etc.

All forms of vehicles can be included in payment services. For instance, potentially paperless bus or train tickets could

automatically be purchased on behalf of the passenger, providing a complete managed transportation solution.

Luxury cars represent higher cost and higher comfort. Passengers in a luxury car may pay more than riders in a low end car. This lowers cost PQOS for routes that include hops on luxury cars. However, it increases comfort PQOS because of the luxury of the car. Relative weighting may determine overall PQOS and finally passenger settings and preference may be the deciding factor.

Note that payment and commitment are related and may be handled as such.

### 3.3.6 Additional Vehicle and Passenger Types

This system's general goal is to increase transportation efficiency. In addition to increasing car/carpooling efficiency, this system can further enhance the efficiency of all transportation systems as a whole. Many types of vehicles could increase occupancy by participating in this system.

Buses could increase their occupancy by picking up people along their route. Buses could decrease participant cost as occupancy increases (or increase rates if bus becomes overly crowded). Buses could also use adaptive scheduling based on system state in order to decrease cost or improve PQOS.

Planes and trains could increase occupancy by having people routed through their flights in either a planned or dynamically routed trip. Note that planes and trains may have service levels and seat categories so the committal process may support reserving specific seats, quality levels of seats, and service levels.

A taxi service may also elect to participate in the system. Taxis could charge higher rates because they may be more willing to drive passengers to their destination in a single hop. Taxis may also give passengers the option of participating in the decision of picking up additional candidate passengers. Since this inconveniences passengers, the taxi could compensate passengers with lower cost. Taxi drivers can also be considered professional drivers and participants might generally give taxis high marks for certain PQOS metrics such as security and low hop count. In fact, part of their membership may include additional security checks such that they are elite security members. Therefore, taxis could charge a premium for their service. When presented with candidate drivers, a candidate passenger could choose a higher cost taxi for convenience or a less convenient multi-hop route at lower cost. If a non-taxi potential driver happens to share the exact same route as the potential passenger then this may be the best and lowest cost option, and therefore the highest PQOS option for the potential passenger. Through use of this system, taxis could offer lower prices because they would have higher average occupancy. Today's taxis spend much of their time waiting or driving around empty.

The system may be used to route packages from their source to their destination. Packages are similar to passengers except that they do not have the ability to make their own decision and are not able to move on their own. For security purposes, packages could be scanned by a portable computing device such as a cell phone. For example, a picture could be taken of the bar codes on the package and this picture or data obtained from this picture could be sent back to the system in order to identify the package. The current driver could allow the new driver to take this picture and the system could confirm the handoff for the current driver. Other technologies such as RFID could also be used. Exceptions

may be raised at hops. For instance if there is apparent damage to the package or if fraud is apparent the system could support a process for handling such events. The system may effectively operate as a package delivery company. Because of the flexibility of cars, it may be able to outperform dedicated shipping companies. For instance it could easily route a package 50 miles with 2 hour service, something that today is only possible with expensive courier services.

A package delivery or trucking company may elect to participate in the system. System flexibility could allow for delivery types which were previously not possible. For instance, 2 hour delivery to a location 50 miles away is generally not possible with current delivery companies. This would be fairly easily achievable with multi-hop routing of cars. Delivery companies may also be able to charge less for such services – especially since people may also be passengers in the carpool, further reducing overall travel costs and increasing transportation efficiency as a whole.

Regardless of vehicle type used, the system may offer complete integrated services including payment, social networking, security etc. It is clear that the more vehicles types and passenger types partake in the system, the more effective routing optimization may be and the more efficient overall transportation may be.

### 3.3.7 Ratings

Users may be able to rate each other during or after being co-participants in a carpool. Drivers may rate passengers, passengers may rate drivers, and passengers may rate overlapping passengers. Users may rate each other based on one or more applicable PQOS user ratable metrics such as public user ratings and private user ratings. The system may calculate some user ratings such as reliability automatically since actions like cancelling commitments is a system measurable event that negatively affects this rating. In order to prevent retaliatory rating a transactional multi user process may optionally be employed and may work as follows:

As co-participants determine how other vehicle occupants should be rated, they could enter this information through the client. Co-participants would not be able to see each other's ratings until all co-participants entered rating information or until a certain time limits expires, thereby preventing further ratings. At this time, the ratings could be applied as a single transaction and the results may become visible. This type of mechanism would reduce the fear that users may have of retaliatory rating and would therefore encourage more honest rating of co-participants.

Note any common mechanism and method for user ratings may be applied and system supported user interfaces for both entering these ratings as well as biasing/filtering routing/hops based on these ratings may be supported.

### 3.3.8 Committing and Contracts

Any system user may have an explicit or implicit service agreement with the system. This commitment may be established during system registration or later.

Additionally when participants commit to each other, it may be looked upon as a temporary service agreement or contract among participants and between participants and service provider. Drivers and passengers can commit to each other for a given hop so that they can ride together. Essentially this reserves a seat – a specific seat or any seat - for the passenger in the

driver's vehicle. Note that commitment and making payment may be related or atomic since this is the model used by most current commerce.

All committed co-participants for a single vehicle are at some level committed to each other. This means that multiple passengers may be committed to each other. One can also consider each passenger only indirectly being committed to each other through their contract with the driver. A number of variations on this commit concept and ensuing processes is possible. The system may also support a process for changing contract settings after committing. Users that are committed to traveling together should adhere to the contract. The system may also enforce adherence to the contract and penalize any contract violations through monetary and ratings means.

In addition to system default contract settings, drivers and passengers may request additional or modified contract settings. For instance, a couple going on a date may want no additional passengers in the car, and may choose a "no additional passenger" contract settings, which is the implicit contract used by traditional taxis. A driver may want to maximize the carpool and may choose a "no permission needed from committed passengers to add additional commitments as long as passenger trip length/time is not increased by more than XX%" contract setting. This driver would not be matched up with the dating couple since they want a different contract setting. If the system does not find matches due to contract limitations, it may make suggestions on how to change the contract in order to find matches. Also, users may specify preferred contract settings which simply bias routing but do not absolutely limit candidate matches. For example, the dating couple may specify that it "prefers to ride alone" and the system will try to satisfy that request as best as possible. The main difference between contract settings and other system settings such as social networking settings is that the contractual settings may limit user activity (e.g. a driver may not be able to add additional passengers) and that the system may punish contract violations.

There may be circumstances when participants wish to cancel committed hops. For instance a better match that takes a passenger straight to the destination may appear and the system may show this to the user. The user may wish to cancel a previous commitment in order to get the direct ride. This change may require a change in the passenger's hop location for the current driver as well and might therefore change the route for all committed participants. Cancelling a commitment may also mean that a refund will increase other committed participants' costs. The system may support a process for handling this. Such changes in multiple commit states may require an atomically transacted process which includes multiple users and their commit states. In this example it may involve the passenger, current driver, previously committed driver, overlapping passengers, and the new candidate driver. Users that cancel too frequently may have low a PQOS reliability rating since this may inconvenience other committed users. Note that payment and commitment are related and cancelling a commitment may involve partial or full refunds and commensurate rating adjustment. If a committed passenger cancels a hop but does not receive a refund then this may not affect the reliability rating if co-participants are not inconvenienced more than they are cost compensated.

The fact that a direct or indirect contract may exist between committed co-participants means that a co-participant may have a say in any relevant route changes another co-participant wants to make. For example, if passenger A and driver B committed to each other and are currently traveling along A's hop, the system may present another candidate passengers C to the driver. C's hop may require that the driver's route is changed. If this route change decreases A's current hop PQOS more than allowed by the contract settings between A and B, B may need to get A's permission to commit to C's hop (since it inconveniences A). The system may support such a process in a variety of ways:

1. Committal is required by A, B, and C in order to consider C's hop committed. This three or more way committal process could involve all co-participants' clients.
2. Cost could be reduced for A and B since more participants share the ride the cost.

Further use case analysis is needed to more clearly define these processes and their possible automation or simplification.

### 3.3.9 Security

Security is a major concern in carpooling and should be directly addressed by the system. In general, as portable computing devices such as cell phones are increasingly used for automated payment in the retail industry, upcoming security features can be employed by this system as well. These types of technologies include finger print ID, RF ID, voice signature etc.

The client interface may provide a variety of security features which deter criminal activity, including but not limited to:

1. Passengers may view vehicle and driver information before entering a vehicle. This may include location of vehicle on map as it approaches passenger, license plate, car model and color and picture, and a description of the driver and existing passengers including pictures, names, age, height etc. This information may be shown so that user may positively identify the committed vehicle.
2. Taking participants' pictures and storing by the system.
3. Exchanging finger print data by touching client devices.
4. Assigning random numbers for passenger pickup so that passengers and drivers can confirm that they are supposed to ride together. Driver needs to say passenger's assigned number and vice versa so that no fraud can be committed.
5. Client portable computing devices may communicate directly with each other in order to reliably allow the participants to find each other and verify each other's identity.

#### 3.3.9.1 Membership

As with any system that requires considerable security, membership may be the first step in securing the system. Since drivers are already licensed through the government, some pre-existing security information could be used: DMV or equivalent information including picture, insurance information, driver license number, age, height, accident history, ticket/DUI history, insurance coverage etc. Passengers that have driver licenses could use the same information. Additionally the system could perform background checks. This information could be updated automatically used to cancel or limit membership under certain conditions.

There may be multiple levels of membership. Professional drivers such as taxis may be willing to invest more time or money in their

membership in order to increase passenger PQOS. They may also carry additional insurance.

### 3.3.9.2 Compensation

Compensation methods such as payment or tipping should be secure and prevent co-participants or third parties from committing fraud.

### 3.3.9.3 Insurance

The system should insure that in case of accidents or other mishaps all participants can be properly handled from a liability perspective. Existing driver insurance may partially cover this but a secondary insurance carrier may be needed. Therefore, part of the carpool cost may go to an insurance carrier who will insure the particular carpool. Other insurance structures may be used as long as the end result is that participants are either properly insured or waive their right to a limited and potential zero insurance coverage.

Drivers could optionally pay the system in order to buy ticket insurance. This would allow for the driver to be compensated in case a ticket is issued for a traffic violation. If a driver has too many tickets then this insurance could become costly or the driver could even be declined for this service. The system may also measure vehicle speed and warn users about imminent speed limit violations.

### 3.3.9.4 User Groups, Buddy Groups, or Buddies

The system may support processes for creating and maintaining special relationships between users. Such relationships may provide special abilities between users such as tracking each other's planned and current trip states, or biasing routing towards each other. Therefore system supported processes should ensure the security of such relationships. For example, to be notified of a user's trip, that user must be one's buddy. The act of making that user one's buddy might require permission from that buddy and additionally, that buddy might assign specific permissions to that relationship: allowing tracking/notification, allowing routing bias towards buddy, allowing alerts, etc. This relationship may be mutual between two friends, or it may be one-directional between parent and child.

Parents or guardians will require special system security features in order to insure sufficiently high PQOS. These features are mainly geared towards increasing security/safety. The following is a sample set of options parents may be able to control: possible travel destinations, area of possible travel, forcing their minor to always ride with one or more other passengers as defined in a user group (the buddy system), travel time restrictions, route deviation alerts, specific driver or driver group restrictions, specific passenger or passenger group restrictions, alerting the parents of all or specific system state changes relative to the minor. Also, interactive video feeds or voice feeds may be used to increase parent comfort level. Parents could also make carpooling decisions with or on behalf of children, similarly to the way packages are handled.

Parents may also create user groups. For instance all parents whose children go to 7<sup>th</sup> grade at the same school may be part of a trusted carpool group. Parents may then limit their children to only get candidate drivers from this group. They may additionally enforce a buddy system. This is an example of how the system could be used to make school carpooling much more efficient. Candidate drivers could choose to accept a child's destination even though it is considerably out of the way. However, the

system should provide information to users in such a way that it is easy to optimize PQOS.

It is clear that a variety of special relationships and associated permissions may exist and that these will evolve with system maturity and further use case analysis.

### 3.3.9.5 Settings

There may be several layers of security settings. Some settings may only be available to parents/guardians of minor participants or guardians of disabled participants. Users may be able to control what other users are allowed to see about them. For instance, some user might be quite liberal and allow other users to see their picture and age while others would not want this information to be available. Of course the picture may be required for a passenger to get on a car.

### 3.3.9.6 User State Changes and Events

The system may track one or more member states and may automate or semi-automate these state changes. Some possible states may include:

1. Offline
2. Becoming candidate driver
3. Becoming candidate passenger
4. Becoming driver
5. Becoming passenger
6. Between/at hop
7. Reached destination

When participants change state such as when passengers start a trip or get on/off a vehicle at a hop or destination, they should have a way of telling the system of their state change. The system may also automatically detect state changes. When entering a vehicle, a passenger could also take any of the following system supported actions: verify vehicle picture and color, verify license plate, verify registered driver picture, and take picture of driver etc. The system may enforce processes such as this for state changes.

In addition to states, certain alertable events may be supported:

1. Client device lost system communication connectivity
2. Client device turned off
3. Client device low on battery
4. Client device charging
5. No GPS signal
6. Significantly deviating from route.
7. Leaving permitted travel zone (as configured by parent)
8. Violation of travel restrictions (child not travelling with buddy although security settings require it).

Certain state changes may trigger alerts. For instance deviating from a predefined route or permitted traveling zone may alert a parent.

### 3.3.9.7 Alerts

The system may generate alerts under certain system and user defined conditions. Minors may have alerts configured by their guardians. Adults may use their own judgment in configuring alerts. The system may calculate certain alerts automatically, but may only perform an alert if the user configured it as such. A user has to configure alert recipients. This may be a user or group of users. In order to prevent overflow of unwanted alerts, alert recipients may be allowed to decline being added to a user's alerts. Certain types of alerts could be equivalent to a 911 phone

call in that they alert the police or other public entity. A fail safe panic button on the client device could be used for this as well.

Alerts may also have positive aspects. For example users may configure system settings such that when their buddies use the system or enters a specified area, their client will alert them.

If a package is routed through the system, package state changes could cause alerts similar to those provided by modern shipping companies.

It is obvious that a wide range of alerts may be supported by the system. Therefore special care needs to be taken in the client UI design in order to make these easily accessible yet simple to use. Further use case analysis is needed.

### 3.3.9.8 Client Passwords

All participants may have the option of locking their client device such that use by another individual is not possible. This could be implemented through a password or other mechanism. This would prevent someone from forcefully obtaining a client and pretending that they are the rightful owner. While the phone is locked it should still be able to display status information about the current trip and may even allow entering certain information which does not affect the system security. For instance it may be acceptable to pick up an incoming cell phone call while the client on the cell phone is locked. Additionally, the user may program one or more special passwords which could be used to signal emergency alerts. If a passenger is forced to hand over the client to someone then the wrong password may be entered to signal the system of the emergency. This may trigger a security alert process such as a voice call to the client device, alerting designated trusted individuals etc. Note that new technological advances may be applied including finger printing, voice recognition, and RFID in order to insure that a client is being used by its rightful owner.

### 3.3.9.9 Live Monitoring

Live sound and/or video monitoring could be used to further increase security. The principal is the same as security cameras used in stationary security applications such as cameras at banks. Both live monitoring or simple recording could be used. Video and sound may be transferred to the backend system via the network connection or could be processed directly on the client. Increasingly powerful client hardware and software may make things such as voice and stress analysis possible, thereby allowing the client to monitor conversation and sounds for alertable incidents.

### 3.3.10 Safety

There are several safety concerns which need to be addressed:

Driver interaction with client may cause accidents. Several system functions may be used to minimize this. As with current car navigation systems the general goal is to allow the driver to focus on the task of driving. Looking at a client computing device can be dangerous while the vehicle is moving. Spoken prompts as well as voice recognition technology may be used to minimize the required visual client interaction. Specifically, improvements in voice recognition technology can greatly increase system safety. If the client is running on an in-vehicle computing device then the driver may allow a passenger to interact with the driver's client. Another safety method could be that the driver can temporarily lend his identity to another user (an impersonator). This impersonator could be a current passenger or any

other system user. If driver A lends his identity to passenger B, then passenger B could switch back and forth on his client between his identity and the driver's identity and could therefore make decisions for both. The driver may at any time cancel this impersonation process and continue using the driver's client in the state that the impersonator left it. The driver's client may also update the display so that the driver can follow impersonator's actions and system displayed information. Security provisions could prevent an impersonator from making inappropriate system changes such as changing static settings. Finally, while stopped at a hop, the driver may safely interact with her client as any other user would.

Allowing passengers to enter or leave a vehicle at a hop may cause accidents. The system should place hops in locations that are legal and safe. As system use increases, government may need to improve the number and quality of locations used as hops.

Passengers should be able to decide to leave a vehicle at any time.

## 3.4 Sample Trip Scenarios Made Possible by System

The following samples provide high level highlights of how travelling might be done with the system. A detailed use case analysis of these samples would provide useful insight into additional system requirements.

### 3.4.1 Multi-hop allows for efficient carpooling to any location.

A passenger starts a trip from work to home. Work is located on a major street with considerable traffic. Home is located 10 miles away on a long remote road which gets very little traffic. This means that wait time for a single-hop route would be very long. Therefore, user decides to commit to a route's first hop which takes user to a major intersection 2 miles from home. Once user approaches this location, user commits to next hop which takes user to the intersection at the start of her long remote road. Because road is so remote, user commits ahead of time to a car which will arrive at the given intersection 3 minutes after user does. After waiting for 3 minutes, user gets ride straight to house.

### 3.4.2 Travelling cross-country with or without trip planning

A user could decide to travel from San Francisco to New York. The system would in real time provide possible routes to user. Some routes may have longer hops but more wait time (the extreme case may be that user would have to wait 1 day to get a single hop all the way to New York). Other routes may have very little wait time and more hops. Instead of waiting, user takes vehicle to Colorado immediately. Once user approaches hop in Colorado, system suggests committing to next driver(s) by offering direct route to New York leaving in 5 hours or immediate ride to New Jersey. User chooses to take direct ride to New York so user can spend 5 hours in Colorado. While driving to New York, user sees that vehicle passes through Kansas City which that user has always wanted to see. User adds Kansas City as a waypoint to route and system automatically suggests possible route changes for part of route between Kansas City and New York. Eventually user arrives in New York with very high PQOS.



Other vehicles such as trains may also be included as candidates in such a trip.

### 3.4.3 User decides for the first time to use system to commute to work

After user wakes up, user enters trip settings and is immediately presented with several routes. The user chooses route leaving in 5 minutes and with one hop. User finishes coffee and walks out the door as system indicates vehicle time to arrival approaches zero. As user rides towards first hop end, user sees that this is located at a coffee shop, so user tells client that he wishes to have a 5 minute wait at the hop. Before and after user arrives at hop system continuously updates candidate routes since system state is changing with respect to given trip. User sees that there are many options for getting ride to work so user decides not to commit to any proposed hops until after reading the newspaper. System then shows a single hop directly to work which is leaving immediately. User commits to hop and rides to work with very high PQOS.

### 3.4.4 A cyclist may wish to commute by bicycle

There may be several obstacles preventing this: dangerous roads, car-only bridges, great distance, and possible rain. A cyclist may configure trip preferences for the system to create a hybrid bicycle/car/bicycle route. For example, a bicyclist may ride a bike on the first hop of a route. The second hop may consist of a car-only bridge for which the cyclist places the bike on the vehicle rack. At the end of the bridge the cyclist takes the bike off the rack and cycles along the last hop all the way to the destination.

### 3.4.5 Social Networking

A driver and passenger were previously co-participants and gave each other a high user personal rating. At a later date, as driver and passenger engage in new trips, system shows multiple possible routes and associated hops and highlights co-participants to each other so that they may choose to commit to each other again.

Another example: A driver is presented with candidate passengers. A variety of metrics including compensation amount, cost savings, and amount of distance and time driver would have to go out of his/her way to pick up passenger are displayed on client device. One passenger/hop is highlighted because driver's friend gave this passenger a ride previously (only 2 degrees of separation). Additionally, the fact that driver's friend gave this passenger a high rating is displayed. Driver commits to the respective passenger. As driver and passenger drive along hop, more candidate passengers are displayed to driver. Because of driver/passenger contract, passenger client displays two views: (1) regular client centric view and (2) driver centric view. Driver centric view only shows information relevant to the passenger. This may include additional candidate passengers/hops being presented to driver. Both participants commit to the new passenger.

Another example: A passenger enters "table tennis" as an interest and asks system to route with co-participants with similar interest. Due to the large set of available drivers, system finds candidates with "table tennis" interest and routes passenger with drivers and passengers who share that interest.

## 4 Future Ancillary System Features

Because of its enormous benefit, it is within reason to imagine that as the system matures, a large percentage of the population may use the system and will therefore be registered users with the system. The system could then evolve into something greater than a mere transportation system. Possible service may include:

1. 411/Information system. If the system has access to general user data such as home/cell phone, address, name etc it can provide information services on par or better than current services.
2. Social networking service. Since the system may store extended user information such as special interest, it could provide an extended 411 type service. For example, one could run a query such as "show me all table tennis players within a 50 mile radius" and engage in any form of communication with the resultant users.
3. Since system needs to track user location it can already measure traffic speed anywhere where users are present. If the system is ubiquitous then it can also predict future traffic conditions based on planned and current user trips. If a highway has a certain amount of traffic during trip planning, it does not mean that this traffic will be the same once vehicle is on that highway. Therefore, the system's predictive capability could be used to estimate future traffic more reliably.
4. Universal identification service. Many companies provide identification services for the purpose of identifying web and retail customers and enabling secure transactions. The problem is that such services are fragmented and have limited population coverage. This system could provide a unified identification service that includes the majority of the population.
5. Universal payment services. This system may integrate payment services for purposes of maximizing PQOS. As system become ubiquitous, it may provide a new form of online and retail payment service outside of carpooling.
6. When participants arrive at a destination, system may allow them to rate their destination. For example, if passenger A is traveling to a restaurant, then system may automatically allow passenger A to rate the restaurant.
7. System may provide secondary services and advertising based on participant destination. For instance if passenger is traveling to a movie theater, then system may directly or indirectly allow passenger to buy tickets.
8. System may collect user trends and preferences including: (1) types of restaurants and stores visited (2) amount of time spent at stores or restaurants. System or third parties may use this information to perform direct marketing to users. System may also integrate with other systems to collect further data such as items or food purchased at destinations etc. This may include destinations or locations that users walk to. High quality direct marketing/advertising may be performed with such data. System may also predict user destination based on historical patterns and perform marketing/advertising which is relevant for the destination or route.
9. This system may be part of a larger traffic management system which optimizes not only occupancy and routing but also optimizes driving behavior of individual vehicles. For example, some train systems already use computer based operators which drive the train in a fashion which may be

better than human operators. For example, times and amounts of acceleration and deceleration may be optimized by computer based operators based on fuel efficiency, comfort, performance, and distance to next stop etc.

## 5 Conclusion

Considerable investments are being made in developing more efficient cars and in increasing public road infrastructure. Yet it is clear that through the use of the described multi-hop routing system overall passenger transportation efficiency can be greatly improved even without these investments. Doubling the average car occupancy rate can nearly double effective car fuel efficiency by halving total vehicle-miles of travel. The average car fuel efficiency would effectively double from 30 to nearly 60 mpg and public roads could be proportionately less congested, leading to shorter commute times. If the average occupancy rate more than doubles and if integration of all transportation systems/vehicles further increases overall efficiency, the effective increase in efficiency can be much higher. According to a recent study<sup>1</sup> total industry and household spending on transportation represents roughly 10% of GDP (over \$1 trillion), and on average U.S. households spend approximately one-fifth or \$8,300 of their income on transportation per year, of which 95% is spent on self-provided transportation. Given such statistics, recent economic trends, and environmental awareness and sustainable thinking, it is clear that now is the time to improve transportation efficiency through a multi-hop carpool/transportation system.

Systemic individualism associated with car ownership has blinded society from creating transportation solutions which treat cars as part of a larger more efficient system. Society should adopt the view that by using public roads, cars effectively become public entities. Should we continue to perfect an octagonal wheel or should we make the wheel round so that it may better serve its purpose? It would be unimaginable to run a train system without some sort of centralized control, so why should we expect to run a road system without similar control? The described system betters society as a whole by reducing transportation waste. It also individually benefits all participating entities including drivers, passengers, service provider, government, and tax payers. Drivers and passengers in particular may also benefit from a desirable social experience. Everyone gains through use of the system, making it a logical and revolutionary step in transportation as we know it.

## References

1. NSSGA Government Affairs Division web page accessed August 20<sup>th</sup> 2008 at [http://www.nssga.org/government/The\\_Transportation\\_Challenge.cfm#Executive\\_Summary](http://www.nssga.org/government/The_Transportation_Challenge.cfm#Executive_Summary)