An Analysis of issues against the adoption of Dynamic Carpooling

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Abstract

Using a private car is a transportation system very common in industrialized countries. However, it causes different problems such as overuse of oil, traffic jams causing earth pollution, health problems and an inefficient use of personal time.

One possible solution to these problems is carpooling, i.e. sharing a trip on a private car of a driver with one or more passengers. Carpooling would reduce the number of cars on streets hence providing worldwide environmental, economical and social benefits. The matching of drivers and passengers can be facilitated by information and communication technologies. Typically, a driver inserts on a web-site the availability of empty seats on his/her car for a planned trip and potential passengers can search for trips and contact the drivers. This process is slow and can be appropriate for long trips planned days in advance. We call this static carpooling and we note it is not used frequently by people even if there are already many web-sites offering this service and in fact the only real open challenge is widespread adoption.

Dynamic carpooling, on the other hand, takes advantage of the recent and increasing adoption of Internet-connected geo-aware mobile devices for enabling impromptu trip opportunities. Passengers request trips directly on the street and can find a suitable ride in just few minutes. Currently there are no dynamic carpooling systems widely used. Every attempt to create and organize such systems failed.

This paper reviews the state of the art of dynamic carpooling. It identifies the most important issues against the adoption of dynamic carpooling systems and the proposed solutions for such issues. It proposes a first input on solving the problem of mass-adopting dynamic carpooling systems.

1 Introduction

Using a private car is a transportation system very common in industrialized countries. Between 2004 and 2009, the worldwide production of private vehicles has been of 295 millions of new units and, as of 2004, there were 199 millions registered drivers in the U.S.A.3. Road transport is responsible for about 16% of man-made CO2 emissions3.

Private car travelling is a common but wasteful transportation system. Most cars are occupied by just one or two people. Average car occupancy in the U.K. is reported to be 1.59 persons/car, in Germany only 1.05 [4]. Private car travelling creates a number of different problems and societal costs worldwide. Environmentally, it is responsible for a wasteful use of a scarce and finite resource, i.e. oil, and causes unnecessary earth pollution. The traffic caused by single occupancy vehicles causes traffic jams and hugely increases the amount of time spent by people in queues on streets. This is a unsavvy use of another scarce resource: time. Moreover, the additional pollution creates health problems to millions of individuals. Lastly, lone drivers in separate cars miss opportunities to meet and talk, incurring in a loss of potential social capital.

One possible solution to all these problems is carpooling, i.e. the act of sharing a trip on a private vehicle between one or more other passengers. The shared use of a single car by two or more people would reduce the number of cars on streets. Carpooling helps the environment by allowing to use oil wisely, to reduce earth pollution and consequent health problems. It reduces traffic and - consequently - time that people spend in their cars. Carpooling has also the potential of increasing social capital by letting people meet and know each other.

Carpooling is not a widespread practice. There are already many systems facilitating the match between drivers and passengers, most of them in form of bulletin board-like web-sites. The intention of offering empty seats of a vehicle is usually announced by a driver many days before the start of the trip. The coordination between a driver and the passengers who are candidating for sharing the trip with him/her is usually carried out by e-mails or private messages in the web-site. Therefore, we may see carpooling as a static way of sharing a trip.
The availability of geo-aware, mobile devices connected to the Internet opens up possibilities for the formation of carpools in short notice, directly on streets. This phenomenon is called dynamic carpooling (also known as dynamic ridesharing, instant ridesharing and agile ridesharing). Dan Kirshner, researcher in this field and maintainer of http://dynamicridesharing.org website defines it as follows: “A system that facilitates the ability of drivers and passengers to make one-time ride matches close to their departure time, with sufficient convenience and flexibility to be used on a daily basis.”

Currently there are no dynamic carpooling systems widely used. In fact, there are many problematic issues related to the implementation and the adoption of dynamic carpooling systems. In Section 2 we present our analysis of the state of the art on dynamic carpooling. We collected all research papers about dynamic carpooling and issues against its mass adoption. We critically analyze the issues and the solution proposals in Section 3 of this paper. While we acknowledge all aspects are critical, we claim that the basic technological infrastructure is an important required and key building block. In Section 4 we summarize our thoughts and outcomes about this analysis.

1.1 Terminology

In Table 1 we introduce some key concepts used in this paper.

| Term     | Definition                                                                                                                                 |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Person   | A user registered in the system, with login and password                                                                                   |
| Trip     | The Driver can create Trips in the system. A Trip is the information about the availability of seats in a car going from a certain location to a certain destination, driven by a Driver on a certain date |
| Driver   | The role of a Person when he/she offers to share some seats on his/her car for a specific trip                                              |
| Passenger| The role of a Person when he/she accepts to occupy a seat on a car of a Driver                                                             |
| Participation | The act of taking part into a Trip. The Driver participates by default in a Trip he/she created. A Passenger can participate in Trips created by a Driver. Participation can be just requested by the passenger or already confirmed by the driver. |
| Location | A geographical location.                                                                                                                  |

Table 1: Key Terms of this paper

2 State of the art

This section contains a summary of previously published papers, in order of publication. In the next section we present the outcomes of the analysis of the whole state of the art and how we decided to move in order to provide a significant contribute in solving the problem of adopting dynamic ridesharing services.

Sociotechnical support for Ride Sharing[9]

This paper lists barriers to dynamic carpooling adoption and possible actions to reduce them. It reports about High Occupancy Vehicles (HOV) lane - which are lanes dedicated for people doing carpooling - on streets of San Francisco and Oakland and complains that there should be no fees on bridges for HOVs. The author suggests conventions developed between drivers and passengers (e.g. pickup points near public transportation stops). Regarding security, the paper suggests to give priority to female passengers, to not leave them alone waiting for a ride. The paper reports that there are no stories about rape, kidnapping or murder and the most common reported problem is bad driving.

There are suggestions on needed research:

- Need of location-aware devices, because dynamic carpooling is actually limited to fixed pickups and drop-off locations.
- Simple user interfaces for passengers and drivers.
- Routing matching algorithms: short window of opportunity to match passenger and driver.

Kirshner, D. (Accessed Dec 10th 2010) - http://dynamicridesharing.org
• Time-to-pickup algorithms: to help passenger decide whether to use carpooling or Public Transportation System.

• Safety and reputation system design: authenticate passenger and driver before making the match, monitor arrival at destination, feedback system.

The paper discusses about social capital impacts: there is the potential for creating new social connections and also matching drivers and passengers according to their profiles creates bridging across class, race and religious views.

**Pilot Tests of Dynamic Ridesharing[6]**

The author presents three pilot tests done in the USA, all of them failed. The reasons of failure are the following:

- Too complicated rules and user interface
- Too weak marketing effort
- Too few users. After 1 month, 1000 flyers distributed to the public and a proposed discount on parking, only 12 users were using the system.

The paper adds the idea of saving money when parking. It also enforces the idea of using social networks to allow car pooling on the fly. The author envisions using a web – and mobile service, also introducing some interesting user stories.

**The smart Jitney: Rapid, Realistic Transport [8]**

The paper focuses on environmental benefits of dynamic carpooling. It asserts that dynamic carpooling would lower greenhouse gas emissions in a better way than electric/hydrogen/hybrid cars would do. It introduces the idea of Smart Jitney: an unlicensed car driving on a defined route according to a schedule.

The author suggests the installation of Auto Event Recorders on cars, enforcing security. It complains that challenges are all focused in convincing the population to use the service, proposing a cooperative public development of the system.

**Auction negotiation for mobile Rideshare service[1]**

The paper proposes the use of agent-based systems powered auction mechanisms for driver-passenger matching.

**Casual Carpooling - enhanced[5]**

The author considers areas without HOV lanes and proposes the use of Radio Frequency IDentification (RFID) chips to quickly identify passengers and drivers. Readers should be installed at common pick-up points. The paper complains that it would cost less to pay passengers and drivers for using the service than to build a HOV lane.

**Empty seats travelling[4]**

This white paper by Nokia suggests to use the phone as a mean of transportation, creating a value in terms of a transport opportunity. It points out some factors limiting static carpooling, arranged via websites:

- Trip arrangements are not ad hoc
- It is impossible to arrange trips to head home from work or to drive shopping.

The paper notices that people are not widely encouraged to practice carpooling by local governments. It collects obstacles and success factors in terms of human sentences, and their solution. The authors say that the challenge is in the definition of a path leading from existing ride share services to a fully automated system.

**Interactive systems for real time dynamic multi hop carpooling[3]**

The author proposes a dynamic multi-hop system, by dividing a passenger route into smaller segments being part of other trips. The author claims that the problems of static carpooling are that matching drivers and passengers based on their destinations limits the number of possible rides, and with high waiting times. Carpooling is static and does not adapt itself well to ad hoc traveling. The paper asks governments to integrate carpooling in laws and to push for its use. The author complains that the perceived quality of service is increased even driving the
passenger away from destination: a driver and a passenger should not be matched only if they share the same or similar destination because perfect matching would require high waiting times.

The paper also addresses social aspects: in a single trip with 3 hops a passenger might meet 3 to 10 people, therefore passengers may be socially matched. It suggests to link the application with some social networks like Facebook, MySpace and use profile information to match drivers and passengers.

As security improvement, the paper suggests: the use of finger-prints, RFID, voice signature, display the location of vehicles on a map, using user pictures, assigning random numbers to be used as passwords.

**Instant Social Ride Sharing[2]**

The paper proposes matching methodologies based on both a minimization of detours and the maximization of social connections. It assumes the existence of a social network data source in which users are connected by means of groups, interests, etc. In such a network, the number of relatively short paths between a driver and a passenger indicates the strength of their social connection.

It provides algorithms and SQL queries. The authors assume that there is already a large scale of users, and no barriers to adoption are taken into account.

**Combining Ridesharing & Social Networks[10]**

The author envisions a mobile and web system that interacts with social networks profiles that should improve security and trust by users. Users can register to the system in a traditional way (e.g., by giving email, username, password), then complete their profiles by linking their accounts to multiple existing social networks account, to fill the remaining fields. Otherwise, they have to fill the fields manually and verify their identity in more classical ways. The paper proposes Opensocial5 as connection interface. An own rating system is also complained, which keeps scores of persons. Amongst the criteria are factors like reliability, safety and friendliness.

It suggests the use of mobile systems, that should make use of GPS and creation of a match on the fly (real-time algorithms). The paper provides some results of surveys: people are willing to loose 23% more time to pickup a friend of their social network rather than a stranger (6%). It also provides a high-level description of the system and implementation details.

The author asks for extra research on psychological factors that increase trust and perceived safety.

**SafeRide: Reducing Single Occupancy Vehicles [7]**

The publication is about a project in the U.S.A. It reports that there is a market-formation problem: to achieve the system that attracts passengers, there will have to be many drivers available. But the drivers will emerge only when it appears profitable or otherwise desiderable, and that depends on there being many passengers, etc. The author complains that someone must discover a winning formula before anyone will invest.

The paper lists some interesting user stories, as well as algorithms and requirements.

3 Comparative Analysis of Dynamic Carpooling Issues

The analysis of the state of the art brought some issues related to adopting dynamic carpooling systems. We categorized the issues gathered from the state of the art and their proposals in the following categories:

- Interface Design - all issues related to graphical implementation of clients and ease of use
- Algorithms - the instructions regarding driver/passengers matching problems
- Coordination - the aspects related on how to let people meet, authenticate and coordinate.
- Trustiness - the problems related on raising user confidence on dynamic carpooling systems
- Safety - the issues regarding ensuring protection of users
- Social Aspects - all the issues related to create social connections and raising social capital in dynamic carpooling systems
- Reaching Critical Mass - the problems on reaching a sufficient amount of persons using the system that would attract more other people
- Incentives - all the political, motivational and economical issues related to dynamic ridesharing systems
- System Suggestions - everything else that we consider relevant for building dynamic carpooling systems

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5Google, MySpace et al. (Accessed Dec. 19th 2010) - http://www.opensocial.org/
We attach the comparative analysis summarized in tables in Appendix, Table 2 up to Table 5. For each category (columns), we list the suggestions and interesting points made in the different research papers (rows), in form of imperative sentences. Tables 2 to 5 in Appendix is our contribution rationalizing the many problematic issues involved in the creation and deployment of dynamic carpooling systems and in summarizing best practices and suggestions in how to deal with them.

Our rationalization of dynamic carpooling issues and possible solutions shows how dynamic carpooling systems still have many important open issues to be addressed and solved. This fact explains the current absence of any dynamic carpooling system deployed and used for real. The most addressed issue is “Reaching the critical mass”. This problem has been faced in several ways but none of them worked. This issue seems very dependant to the issues named “Incentives”, “Safety” and “Trustiness”. In order to receive incentives from the government, there must be a system providing safety. Incentives and safety would produce positive feedbacks and provide trustiness among the general public, therefore providing at least a palliative for the critical mass issue.

We decided to address the overall challenge from a very core point of view and to focus on technical aspects. Among the projects, we observed that their source code and the prototypes produced were not freely accessible by the general public. There are no information regarding the servers, that are all proprietary and obscured. Another issue seems related to a missing standardization of the protocols used. Therefore, every project started from zero, “reinventing the wheel”. In order to overcome the “reaching critical mass” issue, we believe that it is important that providers of dynamic carpooling services can exchange their data easily so that cross provider matching are possible.

That is, the open problem of dynamic carpooling still needs the basic building blocks of research on which future work should be performed in order to overcome all the other issues.

4 Conclusions and future work

In this paper we presented the outcomes of a research aimed at providing a better understanding to the open problem of dynamic carpooling. Through an analysis of the state of the art (reported in Section 2), we identified the key issues in the domain of dynamic carpooling, presented in Section 3. Based on the comparative analysis of the open issues, we notice that the basic building block is missing: an open and extendable technological infrastructure. A future field of research will be to create an opensource framework providing basic dynamic carpooling functionalities and an open, discussable protocol. This framework should be as much clear and extendable as possible, to let other researchers work on different technical aspects. The other, non technical issues should be solved afterwards.

Concluding, we believe the topic of this paper is a recent and challenging one, still waiting for at least initial solutions and steps forwards. Common goal of solving an important problem for our world: too many cars on our streets with just one passenger in them.
## Appendix

| Paper | Interface Design | Algorithms | Coordination |
|-------|------------------|------------|-------------|
| Sociotechnical support for Ride Sharing[9] | Give start, ending points and clear indications. Filter what information to reveal |  |  |
| Pilot Tests of Dynamic Ridesharing[6] | Provide lots of flexible settings to satisfy users. |  | Provide a static/dynamic approach, let users insert entries days before the start |
| The smart Jitney: Rapid, Realistic Transport [8] | Provide different levels of services: - simple: just destination and pickup - groups preferences (only women etc.) - scheduling of rides |  |  |
| Auction negotiation for mobile Rideshare service[1] |  |  |  |
| Casual Carpooling - enhanced[5] |  |  | Implement one-time registration process, simple. Provide RFID devices for drivers and passengers |
| Empty seats travelling[4] |  |  |  |
| Interactive systems for real time dynamic multi hop carpooling[3] | Focus on simplicity. Provide voice, speech recognition. Allow users to communicate each other. |  | Driving passenger away from the destination but near transportation locations (e.g. a bus station) increases quality of service and enhances coordination. |
| Instant Social Ride Sharing[2] |  | Given, built around social connections. Social network needed. | Built around social connection between users |
| Combining Ridesharing & Social Networks[10] | Implement a simple registration system from mobile phone. In a second phase link social networks profiles, or manual fill. Develop a very simple UI |  |  |
| SafeRide: Reducing Single Occupancy Vehicles[7] |  | Both data structures and Algorithms for matching are given |  |

Table 2: Paper Analysis: Interface Design, Algorithms, Coordination
| Paper                                      | Trustiness                                                                 | Safety                                                                 | Social Aspects                                                                 |
|--------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Sociotechnical support for Ride Sharing[9] | Authenticate before the match: password / PIN monitor arrival at destination; Provide a feedback system a la EBay |ANNOUNCE MATCHING ITEMS IN PROFILES BEFORE THE RIDE; DO RESEARCH IN SOCIAL CAPITAL ASPECTS |
| Pilot Tests of Dynamic Ridesharing[6]      | Create a PIN at registration phase to be used by the client               |                                                                       | ADD SOCIAL NETWORKING SUPPORT TO HELP FINDING NEighbours                       |
| The smart Jitney: Rapid, Realistic Transport [8] | Brand the idea: apply stickers on every car that participates. Give limitations to drivers: age limits, extra driving tests, check on criminal records etc. | PROVIDE AUTO EVENT RECORDERS ON CARS; IMPLEMENT AN EMERGENCY BUTTON ON MOBILE PHONE, RECORD GPS DATA; PROVIDE A FEEDBACK SYSTEM A LA EBay |                                                                                         |
| Auction negotiation for mobile Rideshare service[1] |                                                                       |                                                                       |                                                                                |
| Casual Carpooling - enhanced[5]            | Record carpooling activity when cars pass through RFID readers             |BUILD IT AROUND RFID, RECORD LOTS OF DATA AND POSITIONS                 |                                                                                |
| Empty seats travelling[4]                  | Involve community and governments in planning and implementation phases    | LET THE SERVICE BE AVAILABLE ONLY TO REGISTERED USERS; PROVIDE A FEEDBACK SYSTEM | GIVE THE POSSIBILITY TO CREATE SOCIAL CONNECTIONS                               |
| Interactive systems for real time dynamic multi hop carpooling[3] | Use RFID, GPS. Implement a complete rating system. Display vehicle and driver information before entering a vehicle. Display participants pictures. Assign random numbers for passenger pickups to confirm the ride. Provide voice and video features. | MATCH PASSENGERS SOCIALLY; LINK THE APPLICATION TO SOCIAL NETWORKS. |                                                                                |
| Instant Social Ride Sharing[2]             | Use social networks to enhance it.                                        |                                                                       |                                                                                |
| Combining Ridesharing & Social Networks[10] | People are ready to spend 17% more time to pickup a friend of the social network rather than a stranger. Implement it. | IMPLEMENT A RATING SYSTEM. USE AND RECORD GPS DATA. DO EXTRA RESEARCH IN THIS FIELD. |                                                                                |
| SafeRide: Reducing Single Occupancy Vehicles[7] | Use social networks to enhance it.                                        | IMPLEMENT A GPS HELP BUTTON. RECORD TIME, PLACE, AND SOUND. DEVELOP A FEEDBACK SYSTEM |                                                                                |

Table 3: Paper Analysis: Trustiness, Safety, Social Aspects
| Paper                                                                 | Critical Mass                                                                 | Incentives                                                                 | Suggestions                                                                 |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Sociotechnical support for Ride Sharing[9]                           | Provide mass marketing before, during and after deployment. Search for start-up incentives | Search an institutional sponsor. Make the government provide parking spaces to participants | Provide a location-aware system Make use of mobile phones |
| Pilot Tests of Dynamic Ridesharing[6]                                | Provide mass marketing before, during and after deployment. Search for start-up incentives | Search an institutional sponsor. Make the government provide parking spaces to participants | Implement both Web and mobile clients. Implement a static and a dynamic approach. Start with a many-to-one system: all at a single destination |
| The smart Jitney: Rapid, Realistic Transport [8]                    | Use a cooperative, public development of the system                            | Implement a Web interface and mobile clients (using phone calls)            | Implement a Web interface and mobile clients (using phone calls) |
| Auction negotiation for mobile Rideshare service[1]                 | Make employers incentive employees. Involve Regional Transportation Boards     | Implement the system mobile only. Record GPS data. Provide a non-obtrusive system for authentication Research on quality of service measures | Implement the system mobile only. Record GPS data. Provide a non-obtrusive system for authentication Research on quality of service measures |
| Casual Carpooling - enhanced[5]                                     | Make employers incentive employees. Involve Regional Transportation Boards     | Implement the system mobile only. Record GPS data. Provide a non-obtrusive system for authentication Research on quality of service measures | Implement the system mobile only. Record GPS data. Provide a non-obtrusive system for authentication Research on quality of service measures |
| Empty seats travelling[4]                                           | Create an incremental service, starting from a thread of backwards compatible services (bus, taxi). Don’t introduce new devices for the service, use mobile phones | Find a way to make the service a business case. Search for public incentives | Implement the system mobile only. Record GPS data. Provide a non-obtrusive system for authentication Research on quality of service measures |
| Interactive systems for real time dynamic multi hop carpooling[9]     | A multi-hop system will solve the problem, as more rides will be available, waiting times will decrease and quality will rise. | Convince governments to change laws to enforce carpooling                   | Use a dynamic, multi-hop, real-time mobile system to minimize waiting times, one hop at a time |
| Instant Social Ride Sharing[2]                                      | Use mobile phones and sms. Use GPS. Use a provided high-level description of the system |                                                                            |                                                                            |

Table 4: Paper Analysis: Critical Mass, Incentives, Suggestions Pt. 1
| Paper | Critical Mass | Incentives | Suggestions |
|-------|---------------|------------|-------------|
| *Combining Ridesharing & Social Networks*[^10] | Involve users in some parts of development process. Research further on this topic. | Implement a mobile and a web system that interacts with social networks profiles. Use Opensocial and other social networks. Use our high level description of the whole system. | |
| *SafeRide: Reducing Single Occupancy Vehicles*[^7] | Market-formation problem: discover a new, winning formula. Start with an existing service, like taxis. Find large employers. Serve events (i.e., concerts) | Find money. Search for incentives from governments | Implement our Use Cases. Provide our functional requirements. Provide our non-functional requirements. |

[^10]: Table 5: Paper Analysis: Critical Mass, Incentives, Suggestions Pt.2
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