Current Trends in Dynamic Ridesharing, Identification of Bottleneck Problems and Propositions of Solutions

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1. Abstract

The paper reviews the most recent research papers on dynamic ridesharing and screens former, existing and planned projects which approach the idea of dynamic ridesharing. Hence the paper identifies the most important problems hindering the dynamic ridesharing systems from success. Innovative solutions are proposed notably concerning the problem of the critical mass, the price finding, security, ridesharing hubs and software calculating the potential reduction of traffic in function of number of hubs, number of users and maximal waiting time for a ride.

2. Contents

3. Terminology

Term	**Definition**
Passenger	The person who joins the driver in his car to share a ride.
Driver	The person who shares its car with a passenger.
User	The driver of the passenger which uses the ridesharing system to find another user.
Ridesharing	To share a ride, equivalent to liftsharing, carpooling and hitchhiking, not equivalent to carsharing.
Dynamic Ridesharing	To share a ride using localization technology and cell phones. The main difference to normal ridesharing is that the query in such a system can be done at any time, even some minutes before departure. Equivalent to instant, ad-hoc and real-time ridesharing, ridematching and flex-pool.
Query	The demand for a ride match done by a user in order to get a suitable user to share a ride.
Matching	The processing of the queries of the users using an algorithm by the dynamic ridesharing system.
Hub	A geographical point which is defined by the ridesharing system to serve as common changing point for passengers. Hubs are located ideally at already existing transportation hubs such as train stations.
Carsharing	To rent a car owned by an institution which is on the other hand partly property of the carsharer.

HOV	High-occupancy vehicle
SOV	Single-occupancy vehicle

4. Epilog

“Nothing is stronger than an idea whose time has come.” (Victor Hugo)

After goods trading[1], software development[2], banking[3], media[4] and even education[5] became peer-to-peer services, now information technologies are developed enough such that taxi services will join this list.

Joan just got a call from her professor to come to help out in the laboratory today. She lives in town A, the professor’s laboratory is in town B, 40 kilometers away from A. Joan clicks on two buttons of her cell phone: “Laboratory in A” and “Now”. Joan has already saved her normal preferences in the dynamic ridesharing system when she registered herself in the system. She desires for instant no more than one change per trip; she prefers her friends and friends of friends as drivers and she doesn’t want to pay more than 10 cents/kilometer, furthermore she recorded her normal itineraries on the system, such as from her home in town A to the laboratory in town B. Joan looks at her cell phone, the system proposes two drivers which are both going to the ridesharing hub on the expressway between A and B in the next five minutes. The system recommends Joan to choose her driver from the hub to the laboratory

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[1] I.e. Ebay
[2] Open source movement
[3] I.e. Zopa
[4] I.e. Twitter, Blogs, Wikipedia
[5] I.e. Livemocha

only when she has reached the hub because historical data show that sufficient trips are available on this route. Joan selects the cheaper offer of the drivers and walks into the direction of the crossing next to her home. On her cell phone's screen she can already see the car approaching as this one has activated the GPS function. She hops into the car and meets Agathe and Rakesh who is driving the car. Rakesh lives in town A and goes to work somewhere between A and B. He began to participate in the dynamic ridesharing system because he found it a reasonable idea to make something for the environment and to get some money in return at the same time. But actually he continued to participate mainly because he found it interesting to meet people he would have never met otherwise. Agathe is a woman in her eighties and takes the car only for a short distance from the park where she went to walk to the bus station. She didn't want to walk along the dangerous road, so she just pressed the two buttons which her son programmed for her and waited till Rakesh found her at the gate of the park himself using GPS. When theirs cell phone approached each others the two Bluetooth systems recognized each other and the ridesharing system was informed automatically that the users found each other. Rakesh drops out Agathe at the bus station and drives on the carpooling lane to the ridesharing hub. When leaving the car Joan confirms that the trip has finished, the money exchange between the users is done automatically between theirs accounts. She searches a ride for the laboratory and finds a friend of her who is going to the desired place in 4 minutes.

5. Introduction

Today most seats of cars are empty on the road. For instant in the U.S., responsible for 45% of the car produced CO_2 emissions, the seat occupancy is about 1.3 persons/car.[1] In Switzerland the average number of people in the cars is about 1.57 and for commuters only 1.1[2], in UK in 2004 the car occupancy was at 1.6 persons/car and 1.2 for commuters. In Germany the commuter occupancy is even only 1.05 persons/car.[3] In Delhi we counted a seat occupancy of 1.85.[4] However, there would be in average about five seats available per car. There have always existed solutions to confront this inefficient use of seats by pooling passengers together. We will call this general approach carpooling (often used terms are also ridesharing, liftsharing and hitchhiking) in the following. This solution stayed an exception for special cases so far or for special occasions for instant during war or the oil crises. Due to political incentives 12% of commuters are doing carpooling at least in the U.S.A..[5] We will come back to the reasons of the failure of a wide popularization of such solutions later in this report.

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[1] [46]
[2] [2]
[3] Data from Germany and the UK originate from [8]
[4] A non-representative counting has been done by the authors in May at Africa Avenue in Delhi, this included 100 vehicles (cars with five seats).
[5] According to Robin Chase in the video [11]

Compared to other measures to decrease green house gases (GHG) emissions the establishment of an efficient carpooling system and thus the decrease of total GHG emissions in a two digit percentage would be possible much faster. When we assume that such an efficient carpooling system could grow similar to the today's popular web 2.0 social networks it would take only a few years. On the other hand the replacement of the car fleet with more efficient machines would take much longer as the average life of a car is long (about 17 years in the US[1]). New renewable energy power plants, improvement of buildings and more efficient use of energy in industries involve all long investment cycles and thus need time in the magnitude of 10 or 20 years.[2] So when we consider for instant the IPCC's proposed reduction of GHG emissions of 50% by 2050 an efficient carpooling system that could reduce the emissions now by 10% would have the equal value of a technology that could reduce overall emissions by 20% in 2030. Dynamic ridesharing is anyway not a competing measure to reduce GHG emissions but an additional one. Beyond that carpooling doesn't involve any risk technology and the approach of using less energy instead of changing the production method is more elegant and cheaper obviously.

The recent popularization of cell phones eventually with integrated Global Positioning Systems (GPS) and the possibility to locate cell phone holders using triangulation led to a new approach for carpooling. The idea is to

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[1] [11]
[2] [11]

team people in real time. They would send their information about location, destination, desired time of departure and other important boundary parameters to a central system which proposes them other fellow passengers or a car which matches theirs search criteria. The GPS or the triangulation would update continuously the present location of the user. Such a system that enables 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 is called dynamic ridesharing[1] (also ad-hoc, instant, real-time ridesharing, ihitching, ridematching and flex-pool). We will present current projects which already are using this approach later in the report.

We can compare the relation of a conventional ridesharing system and a dynamic ridesharing system to the relation of the concept of flea market and the recently developed internet auction systems – lets take for instant Ebay[2] as the most popular example. 20 years ago it was very difficult for private individuals to find a buyer for used products. The problem was that the market was very small for highly specific products; even with considerable effort it was difficult to communicate the offer to a sufficient number of people who would be interested in the product. So the cost for the offer was often higher than the potential price the product would get in the end. Therefore most products were not offered at all and ended up at waste. With Ebay it was suddenly possible to address a huge market

[1] definition based on: [19]
[2] see [29]

with very low offering and transaction costs. Like this it became profitable to sell unused products.

The same issue can be observed concerning car rides: As each ride has very individual parameters and only very few persons are interested in a specific planned ride, it is extremely time-consuming to find corresponding buyers of rides using the usual web based databases; however, when the cost of offering and of transaction would be very low nobody could afford not to offer the next ride to the public anymore. For instant it is possible to offer a product on Ebay within less than a minute. If it would be possible to offer the next car ride within some seconds spontaneously – the ride may be in some days or within the next minutes – it would make even sense to offer the ride when the probability of a match would be low. Of course it would be even better when the offer could be published automatically.

The objective of this report is to give an overview of current trends in dynamic ridesharing as the new approach leads to new developments every day at the moment and it is difficult to keep the overview. It can be observed that many dynamic ridesharing projects fail because of similar reasons. First they don’t aim for a sufficient size of the user pool and thus the main benefit of a dynamic ridesharing system that it creates a big market is not achieved and the project is not satisfactory for the users. Secondly the marketing effort is too weak. The third main reason for failure is the user interface which is normally too complicated for the users. But the biggest mistake seems to be that most project teams maintain that they are pioneers working on a carpooling matching system with real-time character; however, the dynamic ridesharing is already mentioned for instant as “smart traveling” in papers from U.S. authorities dating 1992[1] and till today roughly 50[2] dynamic ridesharing systems have been realized or proposed. But it seems that the new projects didn’t review their project evaluations and thus didn’t learn from theirs faults. This paper shall therefore serve for future dynamic ridesharing projects to avoid mistakes and to focus on the main challenges.

We will analyze and compare the current projects and papers, we will synthesize the issues which have to be solved in order to get a successful dynamic ridesharing system and finally we will propose some solutions of identified bottleneck problems, particularly we present a software developed in order to calculate the potential of traffic reduction in function of the number of ridesharing hubs, the number of users and the maximal waiting time for a ride.

It shall be mentioned that the topic of this paper doesn’t include only civil engineering, physics, environmental engineering, but also computer science, psychology, information technology and many other areas.

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[1] The paper of J.Glazer et al. on “Part-time carpooling: a new marketing concept for ridesharing.” was published already 1986 and the paper “Transportation efficiency and the feasibility of dynamic ridesharing.” by A.L. Kornhauser et al. was even published already 1977.

[2] Estimation by the author.

The projects and studies presented in this paper focus mainly on the U.S.A. and Europe; however, most issues discussed are not bound to a particular geographical area.

6. The Reasons for and against Dynamic Ridesharing

Why should the average number of people in the cars be increased? What would this change? What advantages and disadvantages would result for individuals and society?

- Supposed the same amount of people travel in fewer cars, so noise emissions, green house gas emissions and air pollution affecting the local environment(PM10, SO_2, NO_x and so on) decrease. For instant if the average number of people occupying a car could be raised to 3, so the local air pollution would go down by roughly 50% and the overall CO_2-emissions would go down by about 20%. [1] However, as former users of public transportation may change to carpooling, emissions could down less significantly or even increase theoretically.

- In areas with little public transport an efficient ridesharing service can increase the speed of traveling. The same for areas with carpooling lanes.

[1] Based on the source [5], the traffic in Switzerland produces between 30 and 35% of total CO_2-emissions. Assumed that the average seat occupation would go up from 1.1 to 3 and that the people would make the same average distances as before, two third of the original emissions, that is more than 20% of the total emissions, would be economized.

- As fewer cars would use the infrastructure such as roads, the public expenses for the renewal and maintenance of such infrastructure would go down.

- Congestion would be less frequent and so the macroeconomical costs of congestion would go down, which are a 3 digit billion $ amount worldwide at the moment.[1]

- As people travel together there's an increasing of social capital. On the one hand it gives people the possibility to learn to know people who they would never have met otherwise. In case the ridesharing is limited to a certain group it gives the possibility to look after the existing contacts.

- The amount spent on foreign originating oil decreases, the money spent for somebody else's services increases, so the local added value would increase.

- As less cars are on the road the risk for external people involved, for instant pedestrians of cyclists, in an accident goes down. It is also favorable for the accident rate that congestions decrease because these cause more accidents. A rating system implemented into the dynamic ridesharing system would select automatically the best and most careful drivers and high risk groups would have difficulties to drive other people. Also safe cars will be selected by the passengers

[1] [16]

in case the information about the car model is available. Furthermore the cashflow for the driver may lead to more investments in new and safer cars. All this factors are favorable for a decreasing traffic accident rate. However, the overall significance for traffic accidents would have to be studied accurately. A major negative point of ridesharing is that more people are sitting on the normally less safe back seats.

- The financial advantage due to ridesharing decreases the foreign trade deficit and increases the local GDP.

- The ameliorated connectivity, especially in rural areas, leads to economical growth as the markets become bigger like this.

- About 10% of all car rides in Canada[1] are done for the only reason to bring a friend or a family member somewhere. After the person who actually had a reason to move is placed somewhere the car would drive back creating an additional ride. So when this person would use dynamic ridesharing instead two rides at one time are eliminated increasing the efficiency by 67%.

- Ridesharing leads to load removal from public transportation; however, this competition could be harmful for the public transport depending on the specific situation

[1] [45]

- Because of ridesharing less people will buy new cars, the used cars will drive more kilometers per year and thus lead to a higher replacement rate resulting in more fuel-efficient and safer cars.
- It allows to have a higher mobility for people who were restricted before as old, handicapped or minor persons.
- Higher propagation of diseases may occur because of the closer contact between people.

7. Paper Summaries

The aim of the following reviews is to describe all solutions, challenges, mistakes and observations concerning dynamic ridesharing made which haven't been mentioned so far. If the paper would describe an issue – even as the first one chronologically – and it has already been mentioned in another summary in this paper, so it won't be described again. On the other side the summaries limit themselves to issues which could concern other dynamic ridesharing projects independently of the geographic area.

7.1. Nokia Research Paper[1]

It is maintained that the market of empty seats worldwide has the value of about 500 billion €. A major part of the crude oil consumption in the US is consumed by light cars (43%), congestion, the need of new infrastructure and environmental impacts causes economical costs in the

[1] [16]

magnitude of a 3 digit billion $ amount each year. The car occupancy for instant in UK and Germany is very low (for commuters 1.2 and 1.05 persons/car respectively). The carpooling services which have been provided till now don't have success and don't allow arranging trips ad-hoc. Technologically a system could be established using existing solutions. The critical mass, a major problem, can be attained by extending existing dynamic ridesharing networks, by starting with taxi networks, by connecting public transportation in addition and by introducing other incentives. Till now the technology was always the problem, with the present emerging widely available technologies a dynamic ridesharing service can be established.

7.2. Smart Jitney[1]

The paper illustrates the trend that cars seat occupancy decreases and promotes ridesharing as a measure as a huge possibility to reduce global GHG emissions. Other measures such as hydrogen fuel cell car or the electric car have failed so far despite of promises over the last thirty years. The newest innovation, the hybrid car, shows only a low reduction in GHG emissions as the electric motor is mainly used for a faster acceleration instead of less energy requirement. In addition only about 1 pro mille of the new bought cars are hybrids at the moment. And for both, electric plug-in cars and hybrid cars, the GHG emissions produced by the local electric energy mix is equal or higher than if the energy would have

[1] [46]

produced directly by carbon-hydrogen fuel, this is true for the majority of countries.

Regarding mass transit a high population density is needed, ideally on a corridor, thus it is not suitable for many regions. Because of the urban sprawl which was created in the U.S. due to the availability of cheap individual mobility, the construction of efficient mass transit gets nearly impossible. But even the mass transit would be built; it would require about the same amount of energy per distance. Thus private cars are the solution after all.

Figure 6: Mass Transit Over-rated (Btu per passenger mile)

Private Car	3,549
Light Truck (SUV)	7,004
Bus Transit	4,160
Airplane	3,587
Amtrak Train	2,935
Rail Transit	3,228

Mass transit offers only a small improvement over private vehicles for personal travel, and is hardly applicable.

Figure 7-1: Rail transit requires nearly the same amount of energy per kilometer as private cars do in the U.S.. Source: [46]

Here the paper introduces the idea of Smart Jitney: This is an unlicensed car or van driving on a defined route according to a schedule with seat occupancy between 3 and 6. Any good driver could be a jitney driver. Benefits would be the higher speed of travel and fast implementation.

In addition it is proposed to install an Auto Event Recorder AER, this would enforce safe and environmentally friendly driving.

The jitneys would be controlled by a central which would handle pick-up requests of passengers optimally.

They also propose to inspect each vehicle which somebody wants to use for jitney trips.

The paper mentions that the criminal rate is very different depending on the country. Thus measures to ensure safety will vary according to the country.

Country	Population (millions)	Murders per 100 K	Rapes per 100 K	Assaults per 100 K
US	300	4.3	30	764
Japan	130	0.5	2	34

Figure 7-2: Crime rates in U.S. and Japan. Source: [46]

The paper emphasizes that the investment required for such a system would be very low; however, the challenges are to convince the users, to change theirs habits and to change the legal system accordingly.

7.1. Interactive System for Real Time Dynamic Multi-hop Carpooling[1]

This paper describes a system where users are not matched according to same destinations, instead the passengers hop in the direction of their destination and change vehicles with a minimal waiting time. The route is optimized using historical, current and external data for the costs, the number of hops, hop waiting time, overall travel time, overall travel distance, personal preferences and social network.

As only project this one responds to the problem of punctuality: In normal systems no-shows or delays can cause considerable inconveniences.

An algorithm is proposed that optimizes the route similar as shipping and train companies, airlines and data networks are optimized.

The author proposes to make ridesharing mandatory, to obligate car producers to equip cars accordingly for instant with sensors counting the free seats.

Concerning the payment the paper proposes as a new possibility of financing that companies interested in customers could sponsor trips which stop at theirs hubs to change vehicle.

In addition to normal passenger pickup the paper proposes to pickup packages or objects.

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[1] [14]

Furthermore the paper mentions the possibility to combine dating with a shared ride and the possibility to bind the commitment of a shared ride with conditions such as: “I only travel with this user when he doesn’t take more passengers.”

Finally the paper mentions that a once established network could be used for numerous other functions.

7.2. Organized Dynamic Ride Sharing: The Potential Environmental Benefits and the Opportunity for Advancing the Concept[1]

The paper starts with the observation that the U.S. suburbs, towns and rural areas have been planned assuming high individual mobility. Thus only 11% of the suburban population lives within a quarter of a mile of a transit stop with non-rush hour service frequency of 15 minutes or less. A solution to decrease the use of cars is therefore the organized dynamic ridesharing system which uses GPS and wireless communication technology and integrates an incentive system for driver and passengers in order to realize an instant ride matching. The paper examines the failure of such systems in the past (before 2001).

Several dynamic ridesharing systems are presented which took all place in the U.S.A. before 2001. Usually the investment was in the dimension of 1

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[1] [44]

million $, between 50'000 and only 1 successful ride matches were achieved, the programs ran in the order of several months up to one year.

They failed due to lack of advertisement, too short project time,

The following conditions are necessary but not forcibly sufficient for successful ridesharing systems[1]:

- *Corridor oriented approach enabled gradual growth and high successful match rates;*
- *HOV facilities provide time and money saving incentives to drivers;*
- *Pick up locations provide easy access to both drivers and riders;*
- *Employment densities provide a critical mass of participants;*
- *Good public transit service is available for passengers to make return trips and for back-up service for incoming trips;*
- *Personal security is not an issue because users have become familiar with each other and system etiquette allows "no-questions asked" rejection of rides. This removes much of the uneasiness of participating. In addition, HOV-3 lane restrictions provide commuters with a sense of security because they are not alone with an unknown driver; and*

[1] citation

- *Casual carpooling evolved over time. This allowed commuters to overcome their initial fears of riding with unknown people and of using an unconventional means of commuting.*

7.3. Casual Carpooling—Enhanced[1]

The paper presents technology that enables ridesharing in areas without high-occupancy lanes (HOV). It addressed as well the problems of personal safety and of the "free rider" (a driver who fulfills only the minimum amount of passengers for the HOV). Finally it compares the measures of monetary incentives and of the construction of new HOV's.

The paper proposes to distribute RFID chips to both, the potential passengers and drivers in order to get data of the behavior of them, mainly the common transit corridors. Devices with RFID readers would be installed at common pick-up points. When the passengers joins a rider, both would hold there RFID chips to the reader, so the system would collect historical data.

The author mentions that it is common in the U.S. that passengers use to join drivers either randomly or at least in a pair to improve personal security. The RFID approach could improve personal safety by allowing the passenger and driver to evaluate each other anonymously as the system knows the identity of both while they don't.

[1] [42]

For HOV the author proposes to change the number of minimum passengers in the cars dynamically: More in peak hours, less otherwise. This would confront the problem that drivers tend to take the minimum amount of passengers only to get on the HOV.

Another problem of HOV is the "first mile" and the "last mile", the distance between the final destination and the pick-up or drop-off point. The author sees a solution in the creation of hubs.

The author calculates in an example of Santa Barbara that it is cheaper to pay the passengers 4 $/day and the drivers 10 $/day for the participation of a ridesharing program than to spend the annual costs for the maintenance of a new HOV lane. Thus it would reduce the traffic amount and avoid the construction of an additional HOV lane. In this calculation not even the huge capital costs of the HOV lane is included.

The author concludes that the proposed RFID application would both, enhance the capacity of HOV lanes and make it possible to make incentives in areas without such lanes.

7.4. Machbarkeitsstudie (feasibility study): Ride Message Service (RMS)[1]

RMS is a dynamic ridematching system that allows the users to find drivers or passengers using short messages of mobile phones. The localization is done by mobile phone antennas. The matching is done using

[1] [2]

a central system and by sending the match per SMS to the users. The study investigates on the theoretical possibility of such a system.

First it is mentioned that because of the density of the mobile phone antennas it is only possible to use this kind of localization in cities and agglomeration, in rural areas, the density is to low to allow precise localization.[1]

As the localization affects the privacy of the users it is necessary that they accept in advance this issue and are informed well.

The control of cell phones from outside is not possible technically, thus this type of localization doesn't allow to inform the users about the location of the other users, they have to find themselves by normal communication.

Further it is not possible using this method to vectorize the route of a user. It is technically possible to actualize continuously the location of the users, but as this uses a lot of resources of the networks it is not probable that the providers of the network would allow such a method. Therefore the matching by RMS is only possible by using the location data of the start and end points.

The seat occupation in Switzerland is 1.57 in average and 1.1 for commuters.

[1] This statement is true mainly for Switzerland where the study has been done.

The main costs of ridesharing are according to different sources the loss of privacy and the additional distance for the pick-up or the drop-off. The main motivation of the users is also according to several surveys the economical incentive or the incentive to be able to use an HOV lane.

Ridesharing projects have huge marketing problems. People normally have never heard of ridesharing or have negative prejudgments. When the people are addressed they often don’t understand the function of the ridesharing systems as those can be quite complex. As most projects run only for a small time as test the users obviously are not ready to spend much time to get into it.

The study mentions the importance that the used technology is spread widely in the user community. Furthermore it is necessary for a further project to work together with public and private partners in order to increase the user number right in the beginning. It is necessary that the project has sufficient financial means even when the user number stays low over the first several years.

The study develops that no additional insurance for passenger or drivers are required in Switzerland.

In the following legal issues concerning privacy and contract partners are discussed; however, these are specifically for Switzerland.

The localization by triangulation by cell phone and three near antennas has in cities roughly the precision of 150 m. In rural areas antennas are spaced up to 30 km from each other, thus it is hardly or in other cases not at all possible to triangulate.

The reason the paper doesn't propose GPS for localization is that the authors don't see it as realistic that GPS enabled phones will be wide spread beyond the users within the next five years.

In order to improve the traffic safety it is proposed to program a specific ringing tone for successful matches, like this the driver doesn't have to look on his phone while driving. For instant this specific ringing tone can be started as soon as the potential passenger is in a radius of 100 m and thus the driver would know that he has to stop the car at the next occasion.

The ridesharing system does work only when enough users use it and at the same time only many users will register when the system works well. In order to solve this chicken-egg problem the paper proposes to start the project only when a certain amount of people registered for the system.

The paper expects a slow growth of the ridesharing system, similar to the carsharing system Mobility which is today one of the biggest carsharing systems in Europe but grew slow.

Year	Number of users of the carsharing program
1987	28
1988	58
1989	170
1990	550
1991	1070
1992	1800

1997	17400
2002	52000
2006	73600

Table 1: The increase of the users of the carsharing system Mobility.

7.5. Market Analysis for RidePartner[1]

The paper develops some interesting issues about the market potential of dynamical ridesharing systems in the Bay area of the U.S.A.. It concludes that the market is not interesting because the market potential is not big enough locally, because such a ridesharing system's success bases on the change of the behavior of the users and finally because the authors predict that in the long run carpooling will be less interesting as the pressure on transport costs will decrease with emerging new "green" individual transport solutions.

7.6. RideNow! Evaluation Report[2]

This paper evaluates the dynamic ridesharing pilot project RideNow which took place in the area of Dublin, California.

The project's personalized marketing strategy achieved best results, instead of just spreading information using different media they spread face-to-face information and showed the functioning of the system directly to the user. As the technology used was quite complicated to understand this marketing strategy was very successful according to the paper.

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[1] [10]
[2] [37]

The surveys made after the participation of the users showed that people used RideNow mainly because of the incentive that ridesharing cars could use parking spaces with priority, furthermore because of higher mobility, the fact that the car could be left at home for other familiy members, that the RideNow participation led to free public transportation tickets and because they had the desire to improve the air quality of the city.

The typical user had an age between 25 and 59, was a man and had a high income.

The paper identifies three major reason of failure: Too complicated rules and user interface, too weak marketing efforts and thus too few users.

At the beginning of the project the following lessons had been learned from other already realized dynamic ridesharing projects and accordingly solutions had been implemented[1]:

- *People have complex and erratic schedules requiring flexible carpooling and dynamic ridesharing arrangements*
- *Targeted marketing is important including printed instructions to explain program requirements and procedures*
- *Financial incentives effectively attract dynamic ridesharing participants*

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[1] The list is a citation.

- *Participants have concerns about sharing rides with strangers. To overcome this issue, one suggestion was to pre-screen participants, while others felt this could inhibit participation.*

- *A guaranteed ride home program was a necessary element to ensure participants if no ride matches, they could still get a ride home.*

- *There needs to be a certain "volume level" for matching to be effective. When this doesn't occur, people get discouraged further inhibiting the chance for successful matches.*

- *Participants were more willing to offer rides and less willing to be a rideshare passenger.*

In general it could be observed, that only few people addressed by marketing actually even considered using RideNow, of those who considered to use RideNow only few actually registered and of those who registered only half actually used the systems whereas the others failed to understand all rules and thus didn't even try. On the other those who once understood the system were satisfied and continued to use it.

The overall ratio of matched rides per matches requested was only 12%.

Please see also the presentation of RideNow as project below.

7.7. Dynamic Ridesharing: Theory and Practice[1]

The paper develops a formula to calculate the likelihood of a user to find a ride matching given the total users and the probability that a user will offer a ride.

A successful matching depends on the following five factors:

1) Someone must be driving between the desired origin and destination at the designated time (within bounds), and must have space for an extra passenger.

2) The driver must be registered in the dynamic ridesharing database.

3) The driver must be reachable by phone or other means prior to the trip to make the ride request.

4) Once reached, the driver must be willing to offer a ride.

5) The ride must be successfully consummated (passenger and driver must meet at appointed time and complete trip).

The probability of finding a match is:

$$P = 1 - \sum_{n=0}^{\infty} f(n)(1-p)^n$$

whereas

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[1] [15]

f(n) = probability that n drivers travel between the desired origin and destination at designated time(within tolerance)

p_1 = probability that the traveler is registered

p_2 = probability that a person is reachable, given registered

p_3 = probability that person is willing to share a ride, given registered and reachable

p_4 = probability that the trip is completed, given that a ride was offered

$p = p_1 p_2 p_3 p_4$ (product of conditional probabilities)

Assuming that f(n) follows a Poisson distribution P can be expressed as

$$P = 1 - e^{-p\mu}$$

whereas μ is the mean value of n.

	p		
μ (1)	0.02 (2)	0.1 (3)	0.25 (4)
5	0.095	0.39	0.71
20	0.33	0.86	0.99
80	0.80	1.0	1.0

Table 2: P values for Poisson distribution. Source: [15].

The assumption of a p to be 0.25 is rather optimistic, thus μ should exceed 20 to ensure a chance of success for a matching.

In the following the paper develops an equation to calculate the μ in function of several parameters of a geographical area. However, as it is assumed that it is not possible to change car during a trip and especially because it is assumed that origins and destinations are distributed randomly over an area the equation seems not appropriate for a modern dynamic ridesharing system. Since the publication of the paper telecommunication services evolved fundamentally and allow very spontaneous communication on the other hand origins and destinations are obviously clustered normally.

7.8. Seattle Smart Traveler: Dynamic Ridematching on the World Wide Web[1]

The paper develops among other things a model to calculate the probability of a successful ride matching. Every individual trip has the following attributes:

1. The range of time for departure d_i
2. The range of times for arrival a_i
3. The spatial region of the departure r_{di}
4. The spatial region of the arrival r_{ai}

For a match two trips must intersect all four attributes, they have to be in the same range of time for departure, the same spatial region of the arrival and so on.

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[1] [12]

For M trips in the database, there are

$$n = \sum_{i=1}^{M} M(M-i) = \frac{M(M-1)}{2}$$

pairs of trips.

The probability for a pair of trips matching, $P_m(M)$, is estimated on the ratio of the number of observed matches N to the total number of pairs of trips in the database at the time:

$$P_m(M) \approx \frac{N}{\sum_{i=1}^{M} M(M-i)}$$

It is assumed that this probability is constant across the population of rideshare trips:

$$P_m = P_m(M)$$

The number of matching trips, T_m, can be estimated by

$$T_m(M) = \frac{M(M-1)}{2} P_m$$

It shall be mentioned that the number of matching trips increases quadratic in M.

A linear relationship is assumed between the number of users U and the number of trips:

$$M = \alpha U$$

Thus we can express the number of matching in function of the number of users U:

$$T_m(U) = \frac{(\alpha^2 U^2 - \alpha U)}{2} P_m$$

Furthermore a linear relationship between matches and actual carpools C_p is assumed:

$$C_p = \beta T_m(U)$$

So the number of carpools increases quadratic in dependence of the user number. This is good news.

The assumptions that the probability of trips matching is approximately constant across the population of trips, that the relationship between the number of users and the number of trips is linear and that the relationship between matches and actual carpools is linear are verified empirically in the paper.

The conclusion is that because of the quadratic increase of the ride matching in function of the number of users it can be expected that the future dynamic ridesharing systems with a high number of users will have considerably more success than the systems established so far which had only few users.

8. Carpooling Projects Using Dynamic Ridesharing

This list of different ridesharing projects of who most started after 2000 serves to give an overview of the varieties of solutions. We are interested here most of all in the reasons of theirs failures as with some exception as for instant Ecolane, all these projects failed or run with only a few users. Of course this list is not complete; moreover the availability of usable information is limited concerning the projects of commercial companies.

8.1. Ecolane Dynamic Carpool™ and Ecolane DRT™[1]

The Finnland based company Ecolane, founded in 2002, offers applications for normal Java-enabled cell phones. Up to only 15 minutes in advance it is possible for drivers of private cars or commercial taxi drivers and for passengers to enter their location and destination. The system proposes a pick-up or a fellow passenger to the user and extends the route for instant not more than 10 minutes. This system is very successful in the area of Helsinki. Up to 1 million trips have been organized each year like this. The system can show a fairly impressive performance, for instant 96% of all demanded pick-ups took place within 10 minutes after the promised pick-up time by the system. [2]

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[1] [31]
[2] See the factsheet on performance: [30]

8.2. Covoiturage[1]

This service uses mainly in the region of Paris by students allows to enter desired routes using internet or mobile phones. Concerning money exchange it is encouraged to share the costs of the ride equally between all participants.

8.3. Carticipate[2]

The US-based company Carticipate is doing an experiment in social transportation using an interface for iPhone and another for Facebook, both applications have been released in 2008. This project uses the GPS function of iPhones.

8.4. Avego/Eirlift[3]

The Irish company Avego offers an iPhone application using GPS. The users record theirs usual routes automatically using the GPS of the iPhone. The user then adds pick-up points on the map. Avego itself charges 30 cents/mile of whom 85% go to the driver, the rest to the company.

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1 [1]
2 [27] , see also this article in the New York Times: [35]
3 [22]

Figure 8-1: Avego Operation Center. Source: http://blog.avego.com/blog/?p=409

8.5. Carriva/M21/eNotions[1]

The company eNotions offers a platform called Carriva for people in the region of Frankfurt am Main, Germany, to find fellow passengers in real-time. At the moment there are about 1000 registered users and roughly 30 organized rides per day. A special feature of this platform is that once a ride has been demanded, the user gets a guarantee to get back. If now return trip can be found, so the platform supplier pays the costs for public transports and cabs. In this system the users record on the website theirs normal trips and give them a number. When they want make the trip they call either the service number for the driver or the service number for the passenger and enter the two digit code for their trip. The system finds

[1] [26]

matching users and establishes directly a voice call between driver and passenger who can arrange the details. The driver will be compensated with 0.075 €/km, the passenger has to pay 0.1 €/km and the rest goes to the service supplier.

8.6. Carlos[1]

This project ran pilot tests between 2002 and 2005 in an agglomeration area in Switzerland (near Burgdorf in Bern). The system wasn't based on any internet application, instead there were put several pick-up point stations similar to bus stops. A pick-up took place when a passenger entered a desired destination into the device. The name of the destination was presented on a screen to the bypassing cars. Both, the driver and the passenger were recorded by a video camera for security reasons. The passenger paid a predefined amount of money to both, the driver and the service supplier. The scientific analysis of the project[2] found essentially four reasons of the failure of the project. First the place of the stations weren't located optimally; they should have been placed there where the demand is the highest. Secondly it was very difficult to gain attention from people. There have been a lot of marketing efforts, however, only a minority of the population ever tried to use the system and so it didn't have the possibility to prove its quality to the people with critical attitude towards the project. In fact this critical attitude was the third reason: Most

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[1] [4]
[2] [3]

people doubted the usability of the system, however, as surveys before and after the use of the service showed, the people's prejudgments turned out to be false, so the people who used the system at least once changed their attitude. The forth and last reason identified was the uncertainty of the system: People didn't like to risk to go somewhere without knowing if they will be able to come back. However, as the evaluation showed, the average waiting time for a ride was short with only 6 minutes.

8.7. Ride Now![1]

This project launched in California matches passengers and drivers automatically using a web and cell phone based systems. The three pilot tests all failed, a successful project would require according to the innovators: "*(1) an institutional sponsor committed to the project; (2) sufficient incentives (for example, scarce parking spaces provided to project participants); and (3) sufficient marketing (including start-up incentives to create "critical mass"). This world does not seem to offer a reasonable chance for these factors to coincide.*"[2]

See also the summary of the evaluation report above.

8.8. Goose Express[3]

This US-based company provides services for limited communities. The users enter their intended trips into the system by SMS or internet. The

[1] [37]
[2] Citation from: [38]
[3] [33]

system was used for instant from 2007 to 2008 by a Microsoft employee community in Seattle. To encourage people to participate it was paid to them a certain amount of money when they registered in the system and when they used it the first time.

It is maintained that if someone can figure out how to broker the rental of some of those unused seats, she or he will be rich, and the driver and rider will save money by the oil barrel.

Up to now, the biggest obstacle to such a market has been information. How can drivers and riders find each other? How can they know whether to trust each other? How can they ensure payment?

Goose has built a real-time ridesharing system that links riders with drivers by combining text-messaging mobile phones, mapping software, a database, and a billing system for splitting the cost of fuel.

Some 200 Microsoft employees who lived in central Seattle were testing the system. It functions like this: a goose member sends a text message about her impending departure and location to the central computer, which instantly looks for matches with others going the same way. The service is free for both rider and driver (except for the cost of the text message). Goose's costs are paid by the employer. (The phone company also makes money on the text messaging. In fact, cell phone companies might do well to underwrite digital hitchhiking just for the texting it generates.)

At some time in the future, Goose Networks believes it can move beyond commute trips, once text-hikers are commonplace and text-hiking is ubiquitous. For now, though, Goose's whole business plan pivots on employers and commuters. The company aims to grow by adding one large employer after another, capitalizing on the trust among these firms' employees; their similar commute schedules; and these firms' obligation under state laws in California, Oregon, and Washington to plan for reduced solo-driving commuters. Compared to the cost of vanpools, employee transit passes, and showering facilities for cyclists, paying for a corporate Goose program is likely to be a good alternative.

8.9. Zypsy[1]

This project ran between 2006 and 2007 in San Francisco. The users had to record their intended route my SMS, indicating the time and roughly the area of departure and destination. The project failed because of the following reasons according to the initiators: The number of users didn't reach the critical mass: *"Ride sharers do not sign-up due to the lack of riders, and riders do not sign-up due to the lack of sharers."*[2] Furthermore people didn't trust anonymous riders. The riders are not motivated to share their own car and loose their privacy. Moreover the initiator emphasizes the importance of marketing.

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[1] [28]
[2] [28]

8.10. Piggyback[1]

A French-Canadian team developed an application for the mobile phone operating system Android. The driver needs a GPS enabled cell phone whereas it is optional for passengers. The cost of the trip is calculated by the system, shared by the participants and the settlement is done by Paypal. The team intends to release the application as well for other platforms such as iPhone, Symbian, Blackberry, Facebook and Windows Mobile.

8.11. Aktalita[2]

Tom Kessler is developing a system in Guadalajara, Mexico. The user use SMS, Java-enabled phones or a website to enter their location, the exact intended route – otherwise a route is assumed - , the detour distance tolerance and the time tolerance. The system integrates public transportation, for instant if a potential passenger goes to town A using a train and a driver would be available already at some train station before town A, so the system proposes the passenger to get out at this train station and to join the driver to the intended destination.

8.12. GoLoco[3]

This company was founded by Robin Chase who is founder of the biggest carsharing company of the world, zipcar.com, at the same time. A main

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[1] [36]
[2] [21] and [32]
[3] [32]

difference to usual carpooling sites is that you can limit the users with whom you want to drive to friends and friends of friends. There's also a GoLoco application for Facebook available.

8.13. Carpool4Cash[1]

A small project in the US that promotes casual carpooling using a internet application, where people make the queue at certain places such as bus stations to join cars which can use than carpooling lanes and don't have to pay tolls for the use of the lanes.

8.14. RideGrid[2]

RideGrid is a service that uses mobile internet and location technology to enable individuals to obtain rides to and from any location, spontaneously. Using the service, rider and driver can evaluate the safety, convenience and value of riding together before they meet. They may use HOV lanes and get faster to theirs destinations. RideGrid works by dynamically combining routes. They evaluate the change required in a driver's route such that it passes through the desired source and destination of a compatible passenger. RideGrid is not yet in production.

8.15. Pooll[3]- Combining Ridesharing and Social Network

For instant in the Netherlands 52% of the population takes part in a web based social network. This could be a good database in order to give the

[1] [24]
[2] [54]
[3] [52]

potential users of a ridesharing system the possibility the identity of the other users.

Pooll provides software for PDA's and smart phones with GPS devices.

According to the study designed for the project 80% of the carpooling driver use a ridesharing system because of the payment, 30% of the passengers do it because of the low costs and 24% of all users do it because of social aspects.

A survey of the study showed that female users tend not to accept strangers for a rideshare and males do much more. Furthermore it was showed that a match is more probable with increasing age of the users. The income was proportional to the age in this survey.

Finally the survey revealed that people are ready to spend 17% more time to pick up a friend of the social network rather than a stranger.

9. Comparison of Problems and Propositions of Appropriate Solutions

9.1. Security

Security refers to the risk passengers or drivers face when they decide to travel not on their own, but with somebody else. Such risks are physical or psychical violence, especially against women, robbery and so on. The user forums of normal carpooling sites and the scientific research on the project Carlos show that these issues are not frequent at all; however, typical problems concerned more reliability, politeness and customs, so for instant that somebody drove somewhere else than he/she declared in advance or that somebody in the car makes the cloth of somebody else dirty.[1]

So the major issue is not that ridesharing is dangerous but that people think that it is dangerous. So measures have to be taken that people feel safe while ridesharing.

To make a dynamic ridesharing trip more secure the project groups proposed a rating system similar to those on online auction sites such as Ebay. Always after the trip driver and passenger give a rating eventually with comments to the other user. This rating can be used to confirm the security to join this driver/passenger and gives the possibility to select *a priori* only users with a certain quality of rating. This system turned out to be very efficient in several social network projects. The rating system should include apart of subjective ratings from other users also objective ratings such as the rate of confirmed trip-requests, the rate of cancelled trips and time accuracy.

Another often proposed security measure is the registration of the identities of both, driver and passengers as well as the identification of the car.

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[1] [16]

Some projects proposed to use Bluetooth, RFID, finger print sensors or voice signature of cell phones to identify each other, other projects proposed to create for each ride a code which both users would have to say for identification. Another possibility would be to send the photo of the other user for identification as soon as a trip as been scheduled or to send a photo of the opposite user to the system's central as soon as these meet.

The fact that both parties have a cell phone with them ensures already that they could call for assistance in emergency. Some project groups go further and propose a special button for emergency call. Another project group proposes to offer the option to call automatically emergency in the case that the user doesn't confirm his safe arrival at the destination till a fixed time. As the central has the information about the car, the identity of the driver, maybe the geographical location of driver and passenger the investigation will be quite easy.[1]

Another possibility is to give the option to drive only with a certain group of people, for instant only with women of only with people from the church community X or to travel only when other fellow passengers join the car.[2]

Finally the system could check permanently if the vehicle is on the planned route and give a warn signal otherwise.

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[1] [48]
[2] [46]

9.2. Safety

To improve transportation safety the study Smart Jitney proposes the integration of auto event recorders (AER) which record the trip similar to Black Boxes in airplanes. On the other hand they propose not to allow groups of high risk to drive, for instant to young new-drivers.

The rating system can also be used for the improvement of the transportation safety as users with dangerous driving styles will be selected.

Other possibilities are to measure speed of the vehicles using GPS or triangulation in order to warn or control the users.

9.3. Protection of Privacy

To protect the privacy of the users some projects avoid exchanging actual personal data between the users and use instead pseudonyms.

A major issue that hinders the people to participate in ridesharing is the loss of privacy in the car; many people don’t like strangers in their own car or don’t trust in strangers. One measure to confront this problem is allowing people to use their existing social networks, friends and friends of friends as discussed in the Security section.

Furthermore a code of behavior for rideshares seems appropriate which should be designed specifically for each geographical area. Such a code could propose rules about the behavior inside the car, how to contact the other users, how to behave of a non-show of a user and so on.

9.4. Localization

As the study of the University of Zurich showed, the triangulation by antennas is complex regarding the technology, the legal issues and the coordination with the respective telecommunication companies. It is not possible to update the location of the users continuously and in addition the precision is highly variable and reaches 100 m in the best case.[1] The continuous updating is possible for GPS, there's no special agreement needed with other companies, no special legal agreements and the precision is higher. Thus it makes sense to use GPS for the localization.

9.5. The Dependence of the Passenger on the Driver

Humans naturally avoid risks, so it was shown in the study on the Carlos project that people were afraid of using the system because their feared that there will be no car driving back of because afraid of waiting at a station and finding no car at all. However, the average waiting time for a ride was only 6 minutes.

To motivate people to use the system several project groups proposed to promise the passengers a free taxi of public transport ride in case that they go somewhere and don't find a car to go back. As long as the system is enough stable and only a few percent don't find a car this solution is financially possible.

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[1] [2]

9.6. Behavior of Users – Adaptation to People

A critic of the paper "Market Analysis of RidePartner" is that a dynamic ridesharing bases on changing the behavior of people and thus has to fail.

We agree that such a system shouldn't work only if people change strongly the behavior, that's why it is necessary to adapt the system to the users and not the other way round.

As the approach and the attitude towards ridesharing depend on the culture, gender, origin – in brief on the people – it is necessary to adapt the system specifically to the conditions.

System entities that should be adapted include for instant:

- Technology used: Java applications, website, smartphones, SMS or phone call.
- Payment method: Auction or fixed price.

9.7. Payment

There are already some projects which use established online payment systems which don't have any transaction costs and work in real time, such that when somebody makes a payment the receiver registers it immediately. An example for such a system is Paypal.

9.8. Simplicity of the System - Usability

A ridesharing system should be similar simple and intuitive like Twitter: Instead of "What are you doing?"[1] Where are you going now? So the user would have to enter only the destination, the location is given by the localization system. The user could choose from a list of destinations he uses normally. Other parameters such as free seats, precise route, preferences and so on are proposed to be as last time but can be modified easily. So beyond the simple use it should be possible for advanced users to modify parameters very detailed.

9.9. Marketing

Most projects failed because they didn't get a critical mass which would be needed to have a stable network. This is also due to a lack of marketing.

Ridesharing and especially dynamical ridesharing is not part of common knowledge, hardly anyone reflected advantages or disadvantages of such a system for himself.

Furthermore the marketing has to confront negative prejudgments of people: Ridesharing is associated with unreliability, problems with passengers, crime and adventure.

So the difficult part is to get people to try the system at all at least once.

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[1] [41]

Several projects spent money in the order of 1 million $ on marketing; however, calculated on the active users this resulted in 10-100 $ per user. As the probability increases strong after a user has used the first time the system that he will use it again, this money would have been probably spent more efficiently by paying it directly (for instant 5 $) to every user when he gets active in the system.

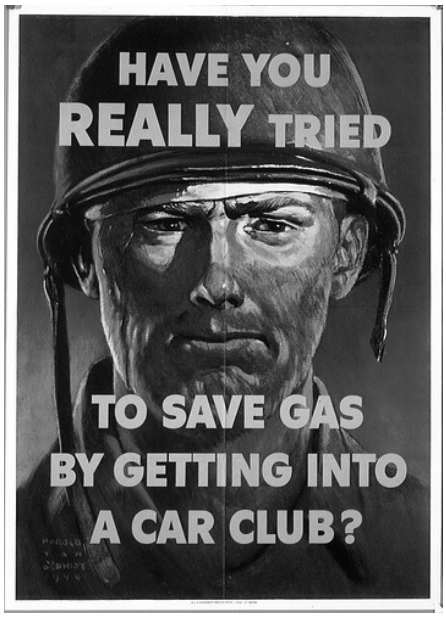

Figure 9-1: Marketing for Carsharing or Ridesharing in 1943. Source: http://www.archives.gov/exhibits/powers_of_persuasion/use_it_up/images_html/ride_with_hitler.html and http://farm3.static.flickr.com/2189/2108368143_30d63237bf.jpg

Figure 9-2: Marketing for Ridesharing today, book cover by Bill Maher. Source: http://www.marketoracle.co.uk/images/when-you-ride-alone.jpg

9.10. Legal Issues, Insurance

A problem is that in a sudden private persons offer services similar to commercial taxi drivers. This is a phenomenon similar to other web 2.0 social networks such as Ebay. As commercial taxi drivers need special permits in many countries, this may lead to legal problems for dynamic ridesharing projects.

The pick up of passengers is another legal issue: Where is it allowed to stop for cars? Is it necessary to include the legal pick up points into the matching algorithm?

Geo-localization by GPS or by cell phone triangulation signifies a major impact on the privacy of individuals in many legal systems, thus a contract has to be signed by the users to accept this impact.

Taxes are another issue that has to be cleared up in advance according to every country.

If a special insurance is required for dynamic ridesharing, a grey area between casual and commercial transportation, has to cleared up specifically for each country. For instant in Switzerland it was found that no special insurance is needed.[1]

9.11. Integration of Public Transport Possibilities

In order to give the passengers an alternative transport possibility many of the presented systems integrate public transport facilities: When a passenger makes a query they propose him public transports or a combination as well. This is a good solution to get more interest of people for the platform even if they might not find a suitable car driver.

It would also be possible to integrate systems such as bicycle rent systems in small towns. For instant there are established systems including stations with publicly available bicycles. When bicycles are available the ridesharing system could propose in function of known parameters of the user the use of the bicycles.

9.12. Combining Carsharing and Ridesharing

Carsharing means in the following the renting of cars which belong to a community or company which is owned on the other hand by the

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[1] see [2]

carsharers. Carsharing users have already proven that they are ready to change their behavior and to make experiments. Thus they are suitable to build a base for a ridesharing system.

Furthermore it is possible to place cars of carsharing institutions at ridesharing hubs in order to give passengers without a car who don't find a ride anymore the possibility to use the carsharing cars.

9.13. The Economical Incentive

The maximal amount of money which somebody wants to spend for a ride and the minimal amount of money for which a driver is ready to participate in carpooling depend on many different individual parameters. For example a businessman who is going with his car somewhere might have already high costs because he has to spend five minutes to wait for somebody. Somebody without car might be in a hurry and would be ready to spend very much money whereas some idealist might be ready to drive somebody somewhere for free. Or imagine an interruption of a train connection, so suddenly many people would require a ride, such a shortage of drivers could only be solved when the passengers are able to propose their maximal desired amount to spend, like this it would be even interesting for drivers to come across who are far away from the passengers.

So a system that dictates the participants a fixed price as it is done in the majority of the projects presented in this report would inhibit a lot of possible rides. Therefore I propose a system with prices fixed by the two user parties, driver and passenger. The offers could be matched similar to the system in stock markets by taking the average of the maximum amount offered by the passenger and the minimal amount demanded by the driver. Alternatively it would be possible to fix the price in an auction similar to an Ebay auction. In such a system either the driver or the passenger would post first the offer, the other type of user (passenger or driver respectively) would bid. The auction would last for a determined time.

In order not to discourage people who would prefer a very simple fixing of the price an option can be offered which fixes the price automatically.

Except a group of three Italian IT-specialists which developed a system for auctions of ridesharings[1], almost all projects dictated the price automatically to the users. But on the one hand this is often not enough as financial incentive, an on the other hand an auction system as the play and fun factor, and normally people like to play. The amount of people who sold their old stuff which they didn't use anymore on a flea market in the time before Ebay was negligible; however, today almost everybody in Europe or America uses Ebay to sell the old items, because it is fun and because the time spent for the selling is equal to the time spent for the disposal; however in the first case the cashflow is positive.

[1] [8]

As a dynamic ridesharing system probably shouldn't provide private people the possibility to work as taxi drivers and compete with commercial taxi drivers the system could limit the maximal allowed amount of payment for private people such that they are not able to make too much profit.

It could be observed that people don't even try to use the system but in that in case they try that the probability of further use is high. Assuming the probability that a user will use the system regularly once he used it ten times would be 1/3, the following economical incentive system could be established. To every user 10 $ could be paid under condition that he uses the system at least ten times. If he would still desire to use the system after ten times use he would have to pay 60 $. This amount would be low for somebody who has understood the usefulness of the system; in addition he would have the interest that more people join the system. This 60 $ would fund the incentives for another six people to start using the system. In average 2 more people of those 6 would use the systems more than ten times, so a snowball effect would have been created resulting in a fast and sustainable growth of users.

Another possibility would be that the dynamic ridesharing system would use its own "currency" or points, this has already been done in many peer-to-peer social networks. When a passenger would pay for a ride he would do this using these points which he would have to buy by regular currency. The rider would get these points and would be able to use them to pay when he figures as passenger. The advantage is that the system could create like this as much of these points as necessary without costs. For instant for each new user it would be possible to promise him a particular amount of points to get started, another amount could be given when he uses the system at least 10 times and so on. When the project would be in the beginning phase it could be prohibited to sell points for the users. After some time when the system would get stable users would also be able to sell points for real currency, thus people who figure only as drivers could exchange theirs earned points.

9.14. Political Incentives to be provided

Measures already taken by the political institution in order to make ridesharing more attractive include carpooling/high-occupancy vehicle lanes in the United States of America, parking places provided for carpooling cars only, this was done for instant within the project of Carriva in Frankfurt am Rhein.

Other possible instruments are road pricing, pay-as-you-drive insurance, “cash-out” parking, congestion pricing, tolls, subsidies or any monetary measures which result in a benefit for the ridesharing people compared to single-occupancy vehicle users.

Regarding infrastructure the political institutions should provide solutions for ridesharing hubs.

Finally it is necessary to adapt laws in order to enable dynamic ridesharing.

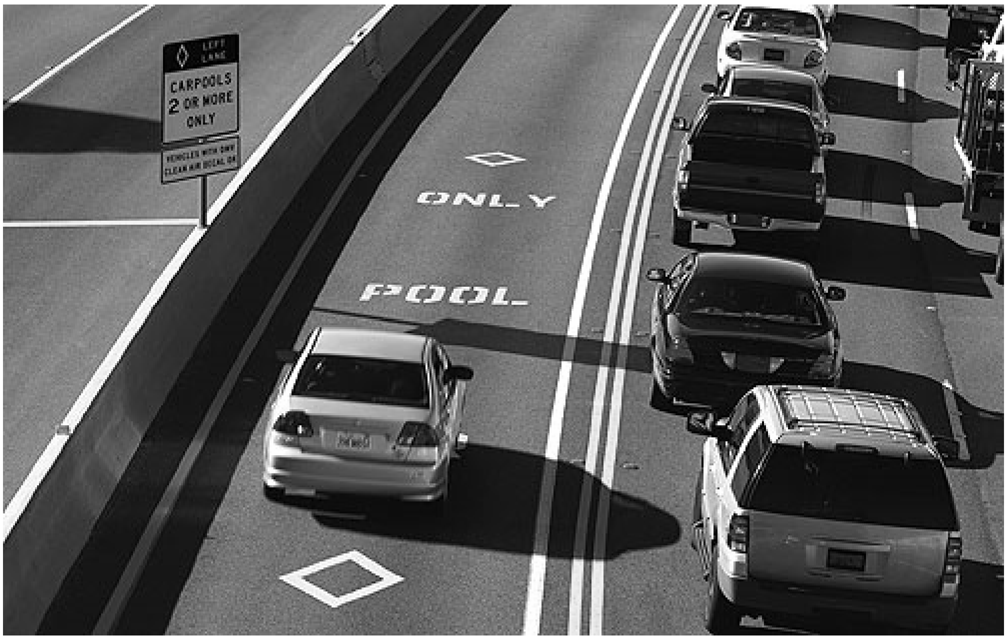

Figure 9-3: HOV lane in the US. Source:

http://www.mwcog.org/commuter2/images/spotlight%20pics/05_gx_carpool_lane_500.jpg

9.15. Chicken-Egg Dilemma or the Critical Mass

Similar to online auction platforms and stock exchanges a dynamic ridesharing platform has the problem with the chicken and the egg: Passengers only participate in the network if sufficient car drivers participate. Those participate only if sufficient passengers participate. So it is difficult to attain a critical mass which is needed for a sustainable growth of the community.

A solution to get fast a critical mass is to implement the system first for an existing taxi network, similar to the Ecolane project in Finnland. So the efficiency of the taxis could be increased and after some time privates could participate as well in the system with their private cars.

Our proposition is to allow drivers to enter automatically their current trips in the system, for instant they can only pull one button “driving to”, they would have to enter their standard destination and the system would automatically locate them, so the time requirement would be very low.

In the ridesharing project rideshare[1] only one third of all queries were successful; however 95% matches would be necessary to have a stable system according to the same source. [2] Therefore it is necessary to ensure a big user community right at the beginning of a project. More incentives should be offered and more consequent marketing applied at the beginning. The start of the project should be announced in advance. It should be stated that the project is not provisional but will endure. Furthermore it is necessary to make the system attractive even if no matches are created for a query. Such an attraction could be: Money in case of no match or information about public transportation possibilities

It is more frustrating for passengers who don’t find a driver than for drivers that don’t find a passenger. That’s because the plans of the driver are not strongly affected by a failure of matching, in case of a match he

1 [53]
2 [2]

has only to spend some minutes more for a pick-up. The main difference between match and non-match for the driver is the cost of the ride. For the passenger in the contrary it is much more complex: If he doesn't find a ride he might leave his location a long time before he would leave in case of a match or he would even have to stay at his present location. Thus it should be the aim to have much more drivers than passengers who are continuously active in the system in order to increase the matching probability for the passengers. Once this probability increased it will be also more interesting for the drivers to go for passenger, so the matching probability for passengers will decrease again; however the relation of the number of passengers to the number of drivers will find an equilibrium once. The increase of the number of drivers could be done by a high automatisation of match queries for drivers and a very low time requirement for starting the service. The system should give people the possibility to show always the location of their car, so they would only have to enter the destination when they start their journey. The precise itinerary of the driver would be based on the data already confirmed by him in advance or calculated automatically. When a passenger would request a pick-up the driver would get a short message indicating the requested place and time of pick-up along with eventual parameters of the passenger. So he would be able to confirm the trip or refuse.

Considerably more resources should be invested in the start-up time of a dynamic ridesharing system than it was done in the past. Most projects failed because they didn't reach a critical mass. Instead of an initial investment in the dimension of 1 million $ the tenfold would be appropriate in order to get more users and thus a higher matching rate as it was demonstrated in the paper [12].

9.16. Survey

In order to implement a dynamical ridesharing service successful we propose to make a extensive survey in the concerned area. Important information needed from the population includes the following (it shall be mentioned that those questions ask the information needed; however, for an actual survey it would be necessary to design the questions such that we get actually also the necessary information, so for instant rhetoric questions should be avoided):

Knowledge about Ridesharing

- According to your knowledge, how much more time do you have to spend for a trip by ridesharing compared to use just your own car?
- What average waiting time do you expect for a ride, supposed you enter a query to go right now?
- Did you ever hitchhike, carpool or share a ride?
- What technologies did you use to find the ride?
- Do you think that ridesharing could have a big influence on the total GHG emissions caused by humans?

Personal Attitude towards Dynamic Ridesharing in General

- Why would you participate?
- Why would you not participate?
- What are your associations toward ridesharing?
- What factors determine mostly your decision to participate? Security, safety, uncertainty of matching, contact with strangers, not having privacy?
- What is according to you the most appropriate method of payment and price finding? Auction or fixed price by the system?

Personal Attitude towards Strangers/Friends

- Are you ready to travel with complete strangers? In what conditions and for what kind of trips?
- Would you be ready more probably to share a ride in case you can travel with a friend, a friend of friend or people whose identity or specific parameters you know? Which parameters?

Mobility Behavior

- List your routes done in the last X weeks with car, public transport or other means. This includes the location and time of departure, destination and eventually if you have passed ridesharing hubs defined by the ridesharing system. Furthermore you did you have other passengers on board (car) during your ride? How were you related to this person? How did you find the person? Could you imagine making this route by ridesharing? How much more time would you maximal be ready to spend for the trip? Do you have absolutely to be on time at the destination or what is the importance to be on time? Would you be ready to make the trips normally done as driver as passenger? Do you prefer driving or being a normal passenger in a car? What does the specific trip cost? How much would you be ready to spend on the correspondent ridesharing trip? How much time in advance did you know about your trip?

- Do you own a car? Do you have a subscription of public transports?

Questions Related to the Usability

- Do you dispose of the respective technical equipment for the system?
- How much time are you ready to spend for the registration for the ridesharing system?
- How much time are you ready to spend per query?
- Would you be ready to provide your location found by GPS continuously to the ridesharing system?

9.17. Creating Carpooling Hubs – Trip Chaining

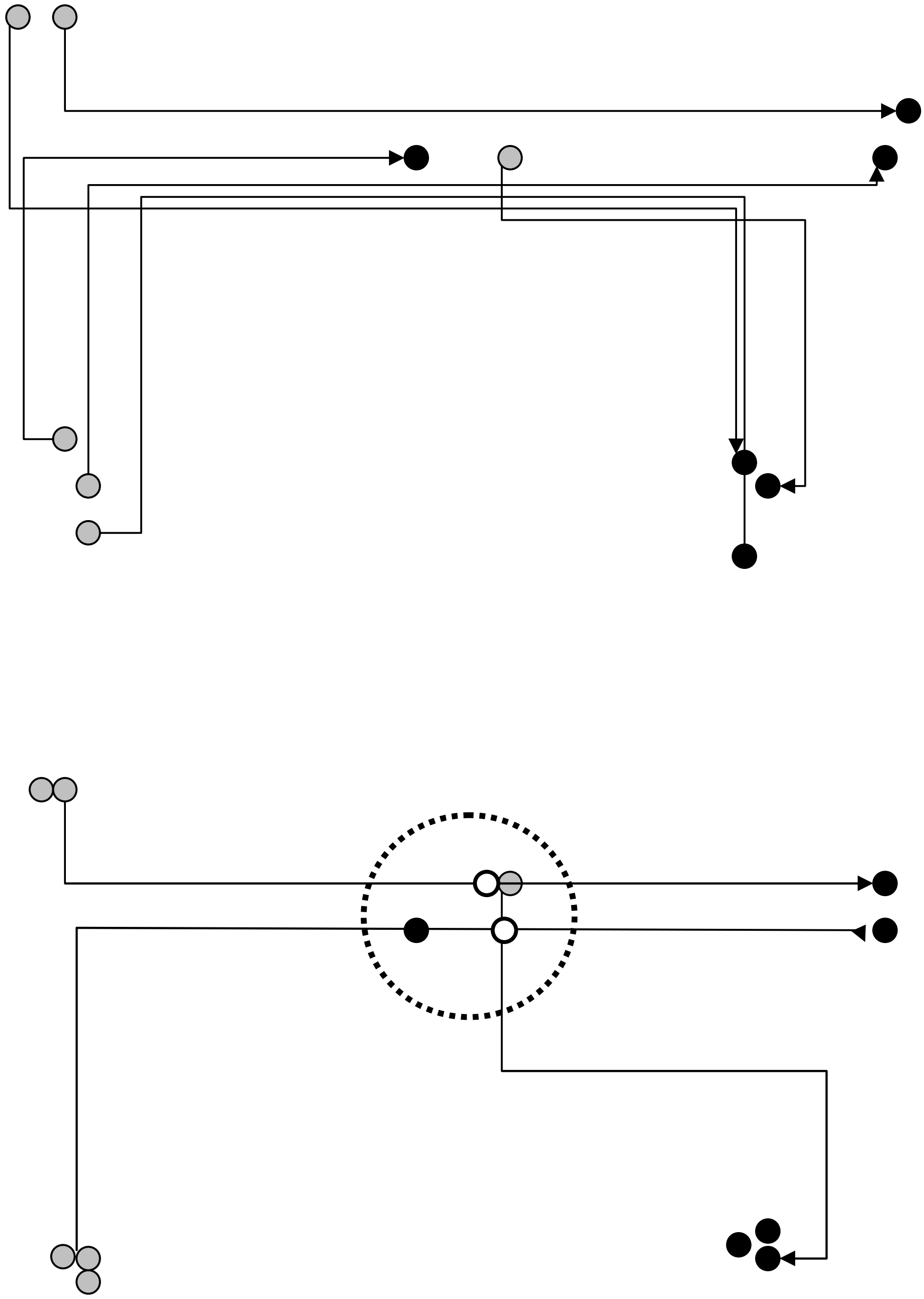

Figure 9-4: Ridesharing hubs: The grey circles are the starting points, the black circles the destinations and the dotted circle figures the hub. Above 6 cars are

driven while with a ridesharing hub the number is reduced to three. Two changes of cars are required in total (white circles).

A dynamic ridesharing system that integrates one or two hubs per passenger ride can increase the probability of matching and decrease the average waiting time and the average overall travel time. This is obvious if we consider the following example: A passenger is located at a fuel station on a highway 100 kilometer from his destination which is in the agglomeration of a major city. Every second car is driving to this major city; however, only very few cars are driving to his specific destination in the agglomeration. Thus the passenger is faster when he takes any ride in the direction of the major town. When he approaches the town the probability increases that a car is driving to his specific destination, so when the system signs him that such a car is near to him he can stop at a hub next to the town and change car.

The software developed in the section 9.19 will demonstrate the potential of hubs.

Such hubs should be located on highways, near public transportation hubs as train stations or at any point with very high traffic frequency.

Beyond the traffic condition hubs should provide ideally shelter against weather, communication possibilities, internet access, they should be safe and secure, have enough parking space and they could include commercial devices (fuel station, shops, restaurants and so on).

9.18. Further Ideas

Goods Delivery Service

Once a dynamic ridesharing system works it would be possible to extend its function. For instant it would be possible to enable transport of parcels or other goods with the network. Such as system would have a similar speed as express mail services but much lower costs and GHG emissions.

Environmental Awareness

By increasing the awareness for the positive environmental impact of dynamic ridesharing the motivation to use such a system will increase. This can be achieved by calculating for instant GHG emissions for each shared ride and by comparing it to a single occupied car.

Status Symbol

As dynamic ridesharing is – next to the practical and economical benefit – a social and environmental commitment, users should be motivated to show this commitment outside of their cars in the form of some publicity or even on some display showing the current status “ridesharing” or “seats available”.

Long-term Reliability

It is important that the user can rely on the system. If the users use the system only as alternative or parallel to other transportation so the fix cost of those would stay and thus the financial incentive to use the ridesharing system would be low. If the reliability of the system is high so the users can change their strategy on the long term, for instant selling the car or not buying anymore the public transportation subscription.

Economics of the System Provider

The economical nature of a ridesharing system is a monopoly: The most successful system gets all users. When the providing institution is a private company the problem will occur that the company will try to optimize its profit instead of the efficiency of the system. Thus it would make sense for the society to create a public institution charged for the system. A dynamic ridesharing system has the potential to create huge macroeconomical savings; however, it has been already mentioned that it is difficult to transform this macroeconomical benefit in actual cashflow for a private system providing company. This was also the reason why the dynamic ridesharing project of Google, Google Ridefinder, has been selected for the non-profitable projects and has been stopped therefore recently. This fact is another reason for a public institution instead of a private one.

Open Standard

To integrate several dynamic ridesharing systems it would be useful to develop an open standard for ridematching software.[1]

---

[1] This idea has been developed by [17]

9.19. Software Calculating the Potential of a Dynamic Ridesharing System in a Specific Region

The success of carpooling seems to be inhibited mainly not by the lack of technical solutions but by the lack of consciousness of the huge potential. To calculate this potential for individual regions we develop here a program that is able to calculate the number of rides which could be avoided in the best case given a certain number of users and their normal routes. This data of their routes would be gathered by surveys and include:

- A list of driven routes by car of a period, for instant a week, time of departure and arrival and time when they drove by a predefined hub.
- A list of done routes by other vehicles during a period, time of departure, time of arrival and when they passed a predefined ridesharing hub.

Beyond the calculation of the potential reduction of cars the algorithm could also be implemented for the real-time ridematching software for the actual system; however, in this case it should be defined if the user is a driver or passenger because we assume for the software that each user can be either driver or passenger.

We are going to describe how the ridesharing system would work: First, every user should posses a smartphone with a GPS device connected to the ridesharing network. It is crucial to know in real time the position in terms of latitude and longitude of each user. Ideally, the user would send a request to the network with his destination and the time at which he would like to reach this destination. The software would then send this request to all the cars going to this destination in the appropriate time. The drivers would have the choice to accept or refuse the request. When the user found a driver, the two users have to manage to find an appropriate location for a pick-up. A more accurate algorithm would also take into account the hubs (check point is used as synonym for hub in the following). It is possible to imagine that a person X wants to go from place A to place C. Let's suppose that there is a driver who is going from A to B and another from B to C. Then, person X would travel in the first car until B and in the second car until its destination. More than one check point is imaginable. But two or three would be a maximum. It is not very convenient to change car and we can imagine that a lot of people would not accept to reach their destination after five stops; they would prefer to take their own car. It is very important to keep in mind that the comfort of the users (drivers and passengers) is essential. If the trip takes too much time or if they have to change car too often so they won't use the ridesharing system anymore. Two stops is the maximum we are arbitrarily fixing.

The update of the system is a major issue. Because people are constantly sending information to the system, the configurations keep on changing. The system is designed to choose the configuration. But, if the data are not the same, then the best configuration will be different at every time. How to insure that cancellations would not occur to often and how to deal with people left out at a check point without any car going to their final destination? Therefore, it is important to make the users responsible and to develop rating system as mentioned already in several other sections of this paper. A driver would be awarded good points if he is in time, comes at the right place to pick up the passenger or to leave the passenger at the right place. In the contrary, if a driver cancels his trip whereas he accepted to pick up someone at a check point, he would be awarded negative points. It is possible to imagine a remuneration system based on these points.

In real life, people will not have location A or B; they will have longitude and latitude. And people will be considered having the same location if there is less than a certain distance between them. The way to consider this distance is also crucial. One could imagine a simple radius but this induces lots of problems. Imagine that a driver is on a highway. And a passenger is located on the road next to the highway. The distance between the two is small enough so that the two persons are located at the same place. But we can easily imagine that the distance needed to go out of the highway is much larger. By calculating the distance, it is essential to use the GPS software. The GPS is able to calculate the actual distance by road from a point to another. And it is this distance that we have to consider in order to be relevant.

What we have done is a simple algorithm. First we add to generate a list of users. We assigned them randomly a location, a destination and a specific time. (Kindly find the C++ program in the appendix). We limited ourselves to 10 different locations.

The data given are the followings: for each person, its location, its destination, its arrival time and its arrival time at a hypothetic check point common for everybody.

Example: X, Y, Z are located at A, A and B respectively. X is going to C whereas Y and Z are going to D. Let's say they all arrive at the same time at the check point.

First, we have to check the total number of cars required.

We designed the algorithm according to these recommendations:

1) If the person X is the only one coming from location A, then this person takes his car. In the same way, if the person Y is the only one to go to B, then this person takes his car.

2) Two persons can travel together if the passenger has a possibility of arriving at his destination by changing car at the check point.

In our example, X is taking his car (condition 1.1) as well as Z (condition 1.2). X and Y are going to travel together to the check point. Then, Y will change car and travel with Z to his destination.

In case of a high number of users, the probability of 1) will be reduced dramatically. The role of the algorithm is also to calculate the best arrangement possible. Different configuration will give a different number of cars required. The role of the algorithm is to check all possible configurations, to pick the best one (the one involving the less number of car) and to transmit this configuration to the users.

Since we generated the list randomly, we have done at least 10 simulations each time in order to have a mean number.

We inserted different variables: number of check-points and time gap between the change of car and the number of users. The time gap is the maximum time that a user has to wait at a check point before someone else picks him up.

First we set the number of user at 10’000, the number of check point at 1, the time gap at 0. The result of the simulation was a little disappointing since the number of car used was 9110. The general tendency is the same if we increase the number of users.

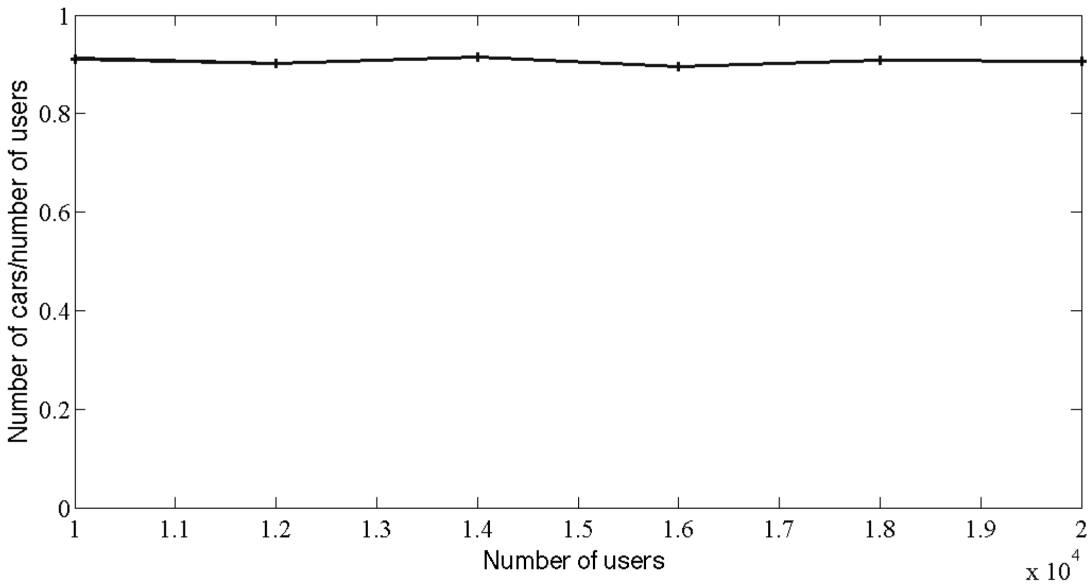

Figure 9-5: Number of cars/user in function of the number of users.

We see that as when we increase the number of users the average number of car used per user is the same.

We can now increase the number of check points from 1 to 5. We can see on the next figure that as we increase the number of check points, the number of car decreases. Obviously, the more check points there are, the more possibilities of matching situations there are.

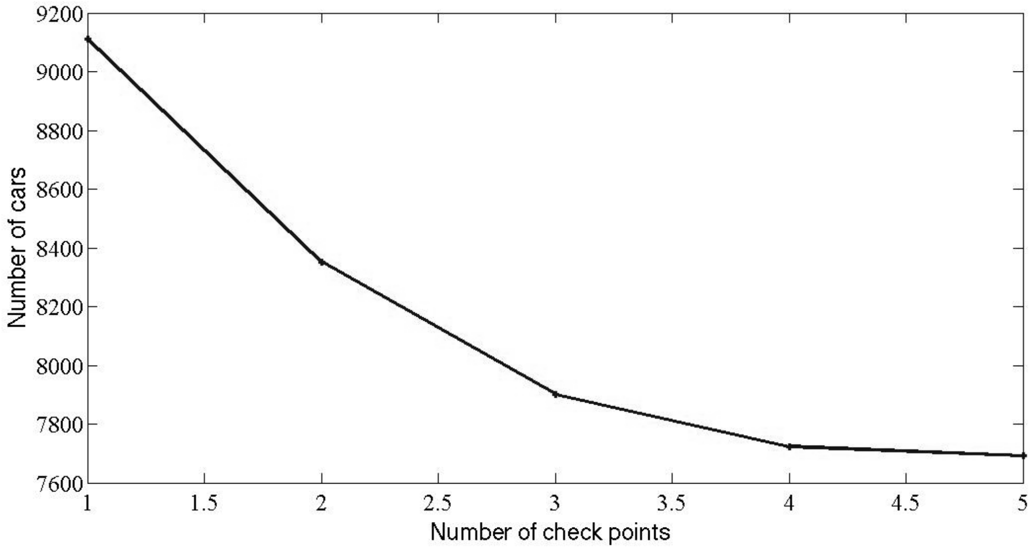

Figure 9-6: Number of cars in function of the number of check points.

This curve has the shape of an exponential which means that saturation occurs. We can see that the difference between 4 and 5 checkpoints is negligible compared to the difference between 1 and 2. We note that the simulation has been done for 10000 users. There is still one more parameter that we can change. It is the time gap. We ran the simulation for 10000 users and 3 checkpoints.

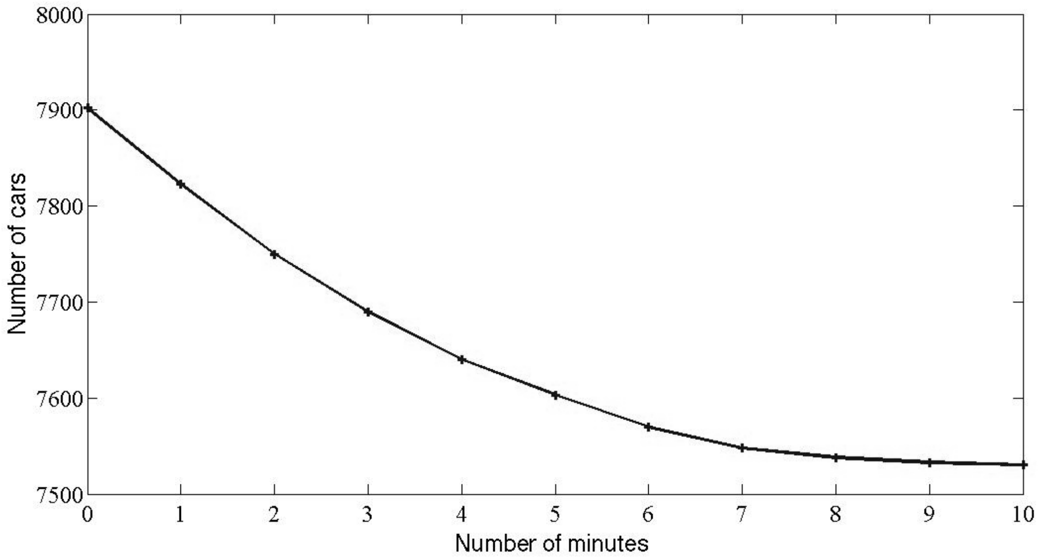

Figure 9-7: Number of cars in number of waiting minutes.

Surprisingly, the number of minutes does not reduce so much the number of cars. The principal factor is therefore the number of check points.

10. Conclusion

The major improvements for future dynamic ridesharing systems recommended by this paper are:

- A dynamic ridesharing system needs a lot of drivers first in order to get a critical mass! This is particularly interesting as the matching rate increases quadratic in function of the number of users.
- Nobody knows better how much they are ready to pay than the users themselves, so the ride price should be fixed by auction!
- Ridesharing hubs increase the matching probability!

- A ride query shouldn't take more than some seconds to enter!
- The system has to adapt to the behavior of the users!
- Carsharing communities should be integrated in the ridesharing system!
- Considerably more resources should be invested in the start-up time of a dynamic ridesharing system than it was done in the past!

Concerning further research we propose particularly the following topics about which we found little literature:

- What impact does ridesharing have on traffic safety?
- Given a particular established dynamic ridesharing system: What transport modes did the users have before and what impact did the change to the ridesharing have on environmental, social and economical parameters?
- What measures could be taken in order to improve the situation about the two major hindrances privacy and security?
- How is it possible to combine the requirement of a simple user interface with the requirement of a complex system in order to ensure a high efficiency?

11. Appendices

11.1. Index of Figures

11.2. Index of Tables

11.3. Source Code in C++

```
/*
 *  generateur.cpp
 *
 *
 *  Created by Yann Stempfel on 26.04.09.
 *  Copyright 2009 Yann Stempfel. All rights reserved.
 *
 */

#include <iostream>
#include <fstream>
#include <string>
#include <vector>
#include <cmath>
#include <complex>
#include <sstream>
using namespace std;

string gener_lettre()
{
int A( rand() % 100 +1);
if (A < 10)
{ return "a";}
if (A > 10 && A < 20)
{ return "b";}
if (A > 20 && A < 30)
{ return "c";}
if (A > 30 && A < 40)
{ return "d";}
if (A > 40 && A < 50)
```

```
{ return "e";}
if (A > 50 && A < 60)
{ return "f";}
if (A > 60 && A < 70)
{ return "g";}
if (A > 70 && A < 80)
{ return "h";}
if (A < 80 && A < 90)
{ return "i";}
else{ return "j";}
}


int main()
{
std::ostringstream oss;
      oss << "generation.dat";

      std::ofstream ofs(oss.str().c_str());
      ofs.precision(15);

      for( int i(1) ; i < 10000 ; i++)
      {//cout << rand() % 100 +1 << endl;
      int A(rand() % 100 +1);
      int B( rand() % 100 +1);
      ofs << i << " " << gener_lettre() << " " <<  A*10 << " " << B*10 << "
" << gener_lettre() << endl;
      }
ofs.close();
}
/*
 *  carsharing.cpp
 *
 *
 *  Created by Yann Stempfel on 28.03.09.
 *  Copyright 2009 __Yann Stempfel__. All rights reserved.
 *
 */

#include <iostream>
#include <fstream>
#include <string>
#include <vector>
#include <cmath>
#include <complex>
#include <sstream>
using namespace std;

void readData(const string& fileName, vector<double>& num, vector<string>&
loc, vector<double>& tdep, vector<double>& tarr, vector<string>& dest)
{
    //Open file to read it
    ifstream file(fileName.c_str());

    //Temporary variables
    string buffer;
    double num1;
    string loc1;
    double tdep1;
    double tarr1;
    string dest1;
```

```
    //Read the whole file
    while(getline(file,buffer))
    {
    //cout << buffer << endl;
        //If the line is not empty
        if(buffer != "")
        {
            istringstream stream(buffer);

            //Read the first value
            stream >> num1;
            stream >> loc1;
            stream >> tdep1;
            stream >> tarr1;
            stream >> dest1;

            //Store the value in the array
            num.push_back(num1);
            loc.push_back(loc1);
            tdep.push_back(tdep1);
            tarr.push_back(tarr1);
            dest.push_back(dest1);
        }
    }
}


int main()
{

     //array to be filled
     vector<double> numero;
     vector<string> location;
     vector<double> Tdepart;
     vector<double> Tarrive;
     vector<string> destination;
     vector<int> memoire;
int A(0);
int B(0);

     //Read the values in the array
     readData("generation.dat",   numero,   location,   Tdepart,   Tarrive,
destination);
    vector<bool> voiture1 (numero.size());
     vector<bool> voiture2 (numero.size());
     vector<bool> voiture (numero.size());

     for( int i(0) ; i < numero.size() ; i=i+1)
     {
     voiture1[i] = true;
     voiture2[i] = true;
     }


for (int k=0 ; k < numero.size() ; k++)
{
for (int j(0) ; j < numero.size() ; j=j+1)
{

if( k != j)
{
```

```
if (location[k] == location[j])
{

voiture1[k] = false;
}
}
}
}

for (int i(0) ; i < numero.size() ; i++)
{
for (int j(0) ; j < numero.size() ; j++)
{
if( i != j)
{
if (destination[i] == destination[j])
{
voiture2[i] = false;
}

}}}

for( int i(0); i < numero.size() ; i++)
{
if( voiture1[i] == true || voiture2[i] == true)
{voiture[i] = true;}
}

std::ostringstream oss;
      oss << "result.dat";

      std::ofstream ofs(oss.str().c_str());
      ofs.precision(15);


for (int H(0); H <= 15 ; H= H +5)
{
for(int i(0); i < numero.size(); i++)
{
//if(voiture[i] == false)

for(int j(i); j < location.size(); j++)
{
for( int z(0); z < memoire.size() ; z++)
{if( i == memoire[z]){break;}}

if( location[i] == location[j] && Tdepart[i] >= Tdepart[j] && Tdepart[i] <=
Tdepart[j]+ H)
{
for(int k(0); k < destination.size() ; k++)
if(  destination[i]  ==  destination[k]  &&  Tarrive[i]  >=  Tarrive[k]  &&
Tarrive[i] <= Tarrive[k] + H)
{
if( i != j && i != k && j != k)
{
voiture[j] = true;
voiture[k] = true;
memoire.push_back(j);
memoire.push_back(k);
}
}}}
```

```
int K(0);
for( int i(0) ; i < numero.size() ; i++)
{
if( voiture[i] == true )
{
K = K+1;
}
}


ofs << H << " " << K << endl;

}
ofs.close();
}

//Assignation of cars
for( int i(0); i<numero.size(); i++)
{
A=0;
B=0;
for (int j(0) ; j < numero.size()-1; j++)
{
if(i =! j)
{

if( location[i] == location[j])
{

A = A+1;
}
```

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