Collaborative Car Pooling System

João Ferreira, Paulo Trigo and Porfírio Filipe

Abstract- This paper describes the architecture for a collaborative Car Pooling System based on a credits mechanism to motivate the cooperation among users. Users can spend the accumulated credits on parking facilities. For this, we propose a business model to support the collaboration between a car pooling system and parking facilities. The Portuguese Lisbon's Metropolitan area is used as application scenario.

Keywords— Car Pooling; Collaboration; Sustainable Mobility.

I. INTRODUCTION

In the European Union, over 60% of the population lives in urban areas (information from Eurostat). Air and noise pollution is getting worse each year. Urban traffic is responsible for 40% of CO_2 emissions and 70% of emissions of other pollutants arising from road transport [1]. Increasing traffic in town and city centers is responsible for chronic congestion, with the many adverse consequences that this entails in terms of delays and pollution. Every year nearly 100 billion euros, or 1% of the EU's GDP [1], are spent by the European economy to deal with this phenomenon. Several solutions have been proposed to these problems, such as a diversity of intelligent transportation systems and solutions. Despite all current efforts, the occupancy rate has reached only 1,06 persons per car [3]. It is clear that additional efforts are needed to utilize the free capacity in these vehicles. Against this background, is proposed a collaborative Car Pooling system, to raise vehicle occupancy based on a user collaborative environment motivated on a credits mechanism that can be converted into parking licenses in facilities of big cities. The Car Pooling happens whenever at least two people ride the same car. Each person would have made the trip independently if the carpool had not been there. Driver and passengers know beforehand the trips that they will be sharing the ride. This idea is not new and several initiatives have been tried in the past [4,5,6,7,8,9] without big success. Most of these systems allow convenient trip arrangements over the internet, support trust building between registered users, and they implement billing systems to charge passengers and compensate drivers. Yet, these services have not become popular and did not significantly increase the average car occupancy. The main technical reason for this is that existing ride sharing services do not allow truly ad-hoc trip arrangements. Today's mobile computing with current advances on geographic location systems, mobile

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communications (e.g GPRS, Wimax) and new mobile devices (e.g PDA, mobile phone) and navigations platforms overcame this limitation and enable for the first time truly ad-hoc ride sharing services.

On top of this technology advances is proposed a new collaboration approach based on market share principals and on user profit, which is defined as credits that can be spent for advanced park booking and reduce the payment fees in metropolitan areas.

This paper is organized as follows: section one, introduces the problem; section two describes the main approach guidelines taken and the definition of the main system modules; section three describes credits mechanisms and payments; section four describes a proposed application scenario for Lisbon Metropolitan Area (LMA); section five is dedicated to work conclusions and future work.

II. SYSTEM CONCEPTS AND MAIN MODULES

Capturing requirements efficiently is crucial to the development of any system. It is proposed a software engineering requirement approaches to try to identify patterns that can be later reused for similar systems developments. Based on these a generic workflow of the several activities that compose the requirements, namely: (1) stakeholder analysis, where it is identified the main stakeholders that are likely to be affected by the activities and outcomes of the project, to assess how those stakeholders are likely to be impacted by the project and the relations between then; (2) problem domain analysis it is performed in LMA main transportation infrastructure (e.g roads, parking places and public transportation); then we perform (3) requirement elicitation; then the (4) requirement analysis; (5) requirement specification; and (6) requirement refinement. The main output of the system's specification, that meets user carpooling needs and the flow list of requirements, aiming to increase the average rate of car occupancy, is:

- Real time traffic information;
- Best route search based on traffic information, based on dynamic route matching algorithms;
- Integration with public transportation information and parking facilities;
- Pre-booked parking place;
- Ad-hoc trip arrangements;
- Use of past-experience data to estimate time-to-pickup;
- User Profiles and credit mechanisms.

System main modules are illustrated on Figure 1. External information sources feed the system with public transportation time table and information, weather information, car parking

facilities with available places and road information (routes and traffic). Car Pool Driver profile, illustrated on figure 2 and Car passenger profile, showed in Figure 3 are used in a Matching function to identify car pooling.

The car pooling design follows the use-case analyses (Figure 2 and 3) for Car Pooling system with two main profiles: Driver profile and passenger profile.

Driver profile is illustrated on Figure 2: user login, password, mail, cellular phone number, window travel time, start and ends points, credits, number of available seats, parking location, inform system about delay on schedule start trip, parking number and parking timing slot wanted (date, start hour, end hour).

The passenger profile is illustrated on Figure 3: user login, password, mail, cellular phone number, window travel time, start and ends points, credits, user results preference like driving distance to picking point, waiting time and if wants a daily updated information or relay on pre-defined information. Results visualization can use a graph visualization tool or a map using google maps interface and can receive notification about delays of scheduled ride based on driver start hour delay (only possible if the driver alerts the system) or road traffic conditions.
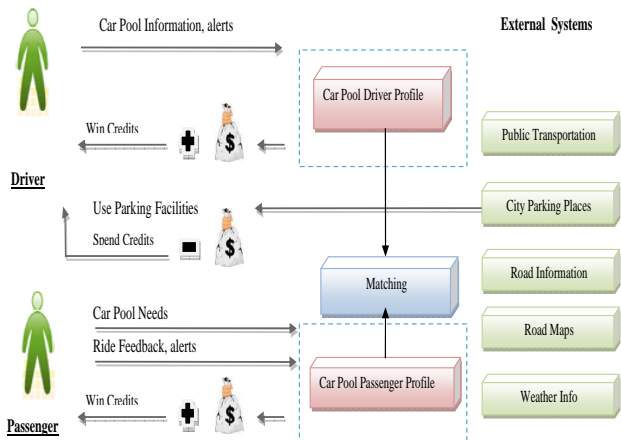
Profile matching is illustrated on Figure 4. First it is

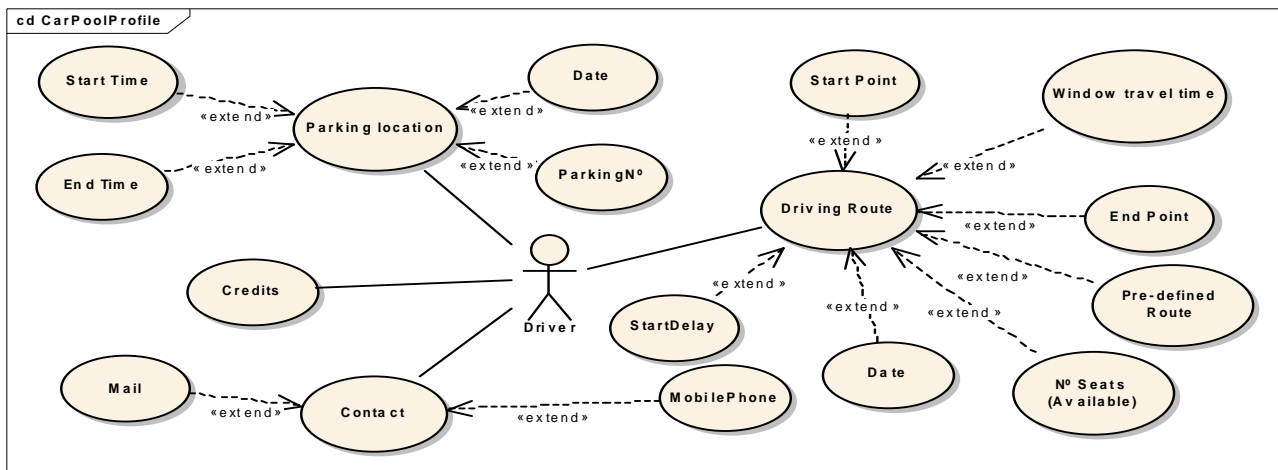Figure 1: System main modules

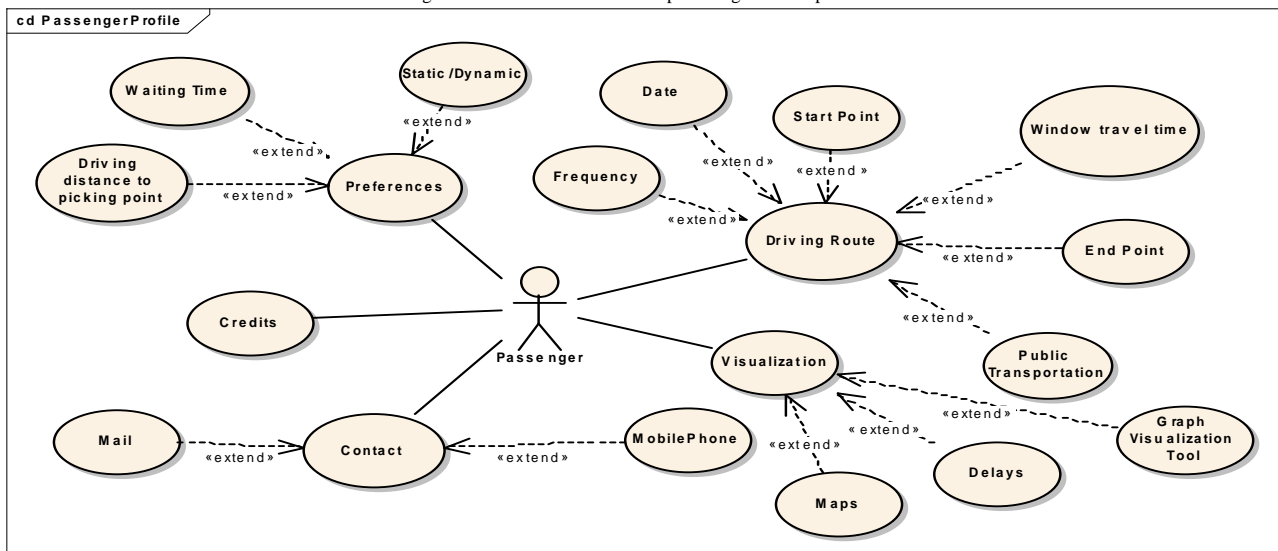Figure 2: Use Case for car pooling driver profile.

Figure 3: Use Case for car pooling passenger profile.

transformed the users routing plan in a nodes graph by defining the nearest node of GPS coordinates of start and end points. All node information comes from a GIS (Geographic Information System) application (like GoogleMaps or ArcGis). Nodes distances are calculated based on node GPS coordinates. Then system checks the travel time window based on matching nodes. If the user accepts public transportation we will add graph information related with an alternative routing path. Return trip is independent and matching start with end points matching (user location car), time window and start point. A list of possibilities is always presented to the users based on pre-defined user's criteria chosen, like trip distance for picking point, waiting time and end point. Results can be shown in google maps using public available API. Passenger's chosen trips are stored in a database associated to the user unless we ask for a new one.

Best routing path, is based on graph optimization based on Dijkstra algorithm, since it stop point is a node in the graph network (for detailed implementation see [11]). Graph nodes correspond to road intersection or stop points and graph arc measures the time travel. This time is calculated based on node distance divided by road maximum speed. Traffic condition can perform a modification of road speed. When road information is available from sensors the system can use real information about the traffic speed. In the case study identifies a problem with heterogeneous data formats. When the information is missing our heuristics determines the traffic speed, for details see [11]. To receive updated information in real time is important to look for communications and end-users devices. End-user device will determinate the communication interfaces and protocol. Users with mobile phone will receive and send SMS messages. If a user have a GPS and a GPRS (or even wireless) device communication (e.g smart phone, PDA) the system will be able to communicate and exchange information during the user ride.

Also we will try in a near future after negotiations with Portuguese authority a public transportation tickets selling at lower prices by the system.

III. CREDITS MECHANISMS AND PAYMENTS

The user does not pay his ride and can win credits giving alerts and feedback to the system or as driver rides. Credits can be mainly used in passenger ride or parking facilities so we need some government incentives to cover some parking expenses related with credits. This amount can be compensated by less CO_2 emissions and less traffic during peak hours.

Users are handled by the following modules: User registration, user credits, user communication interface, user profile.

User registration module is the responsible for detecting if the user is a registered user or not. If so, it shows its information, the number of credits that he has, allows him to change its personal data, driver profile, making suggestions and allows buying more credits. If it detects that it is not a registered user, it asks for the registration.

User communication interface formats the information for the end-user device (e.g PDA, Mobile Phone). The size of information to be transmitted dependents or the communication bandwidth and the visualization capacities of the end-user device.

User profile handles all issues related with the creation and change of driver or passenger profile.

Users Credits: An important research issue that addresses the system is: how can we determine the ride price (e.g credit cost)? In the current research we propose a dynamic value determination, based on the stock exchange metaphor, following the listed main guidelines and illustrated in Figure 5:

- New user recommend action to the system gives 5 credits;
- New user in the registration process receives 50 credits;
- Ride given is equal to a predefined value. Trip expenses (Km=1€ plus toll and parking) is divided by four. For example a trip of 25Km, 5€ toll and 10€ parking, is converted in 10 credits. So the driver wins 10 credits per passenger (or less if the trip is shorter) and the passenger spends only half of trip credits (5).
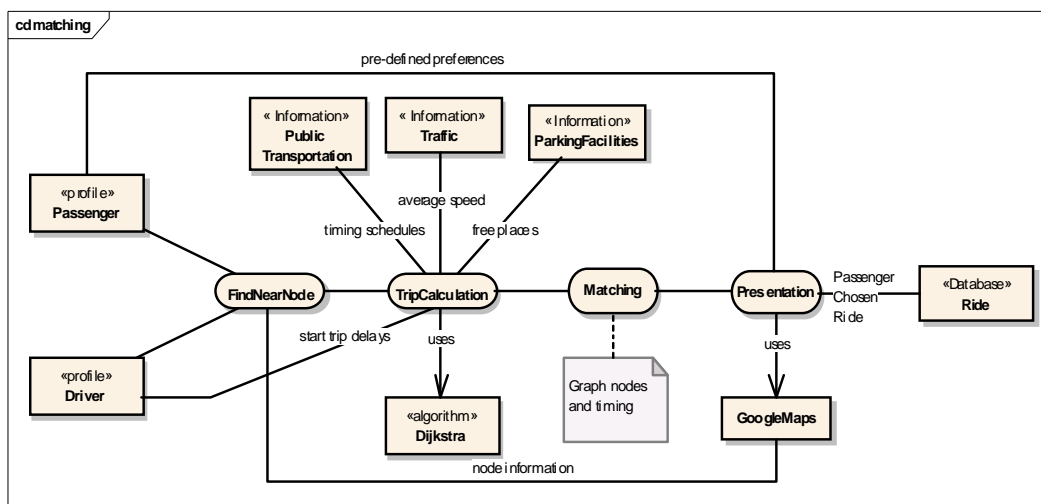

Figure 4: Profile matching based graph algorithms.

Based on agent simulation tasks we want to optimize this credit values in order to maximize car occupancy.

- Feedback of updated information over the ride gives one credit.
- By the end of each month the average occupancy rate of each poll car is calculated. This number multiplied by the number of rides performed by the car, gives additional credits.
- User feedback (e.g rate driver punctuality, flexibility) can act over ride credits. A positive feedback is used to increase by 1% the ride credit and negative feedback is used to decrease by 1% the ride credit.
- Each hour in a parking place is one credit.
- If ride car is fully booked (e.g number of passenger rider's equal car seats) and a user wants to take that trip he can initiate a process of increase the ride credits until one of the booked riders give up.
- Also in a monthly basis through ride statistics of car occupancy the system can raise or decrease the ride credits by 5%. If average ride occupancy is less than 2,5 (our target) then the system decreases 5% de ride credits, but if it is bigger then 2,5 we have an increase of 5%.
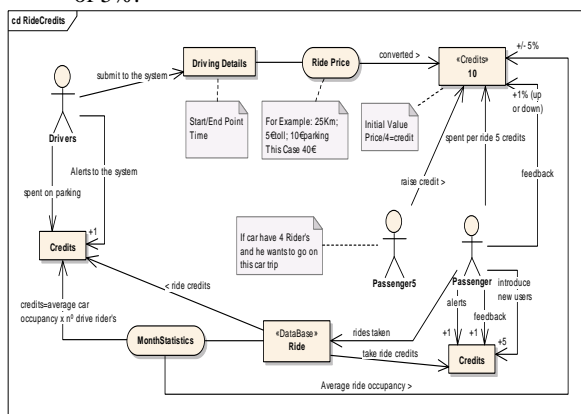

Figure 5: Credits mechanism.

Payments: The system uses a credits mechanism. Users can by credits (1credit is equal to one euro) through bank account transference. Based on monthly reports (from historical data) the system proposes ways of maximizing credits wins by increasing car occupancy or even propose more rides as driver. We are currently working in an optimization algorithm based on ride request (will use mainly time window and location) that can make suggestions to the driver to make small changes in order to increase car occupancy. If user wants to participate only as passenger perhaps we will need to buy credits that he will use to cover parking expenses.

IV. APPLICATION SCENARIO

Lisbon is the largest city and the capital of Portugal. Being the capital, it contains the main universities (both public and private), the main Seaport and the Airport. This results in a concentration of most economic activities which creates a synergy without parallel in Portugal. The Lisbon Metropolitan Area (LMA) was created by law nr.44/91, but the structures created were not given the necessary means to induce or co-ordinate action by all the municipalities involved (18). On the north side of the river, besides Lisbon, there are 8 Municipalities: Amadora, Azambuja, Cascais, Loures, Mafra, Oeiras, Sintra and Vila Franca de Xira. On the south there are 9: Armada, Alcochete, Barreiro, Moita, Montijo, Palmela, Seixal, Sesimbra and Setubal. Lisbon is not only the head of the LMA (there are only two Metropolitan Areas), but also a district capital (comprising 15 municipalities) and the capital of Portugal. LMA, is the largest population concentration in Portugal. Preliminary data from the 2001 Portuguese census puts the population of the metropolitan area at 2,641,006 (about ¼ of the Portuguese population), of which 20.8% lives in the city of Lisbon. About 27% of the population of continental Portugal lives in the 2,957.4 km² of LMA. From 2001 census performed by INE (National Statistics Institute, www.ine.pt) we have the following facts: average daily trip home to work is around 35 minutes and is distributed as shown in Figure 5. From this data we can check that car pooling is around 12,5% of car travels. This value reflects mainly family trip (husband, wife and kids). There is no car pool system implemented and supported locally. Due to a bad transportation system outside Lisbon area, a growing number of persons living outside Lisbon city area and the continuous fuel increases this system has a great potential combined with limited parking facilities in Lisbon area.
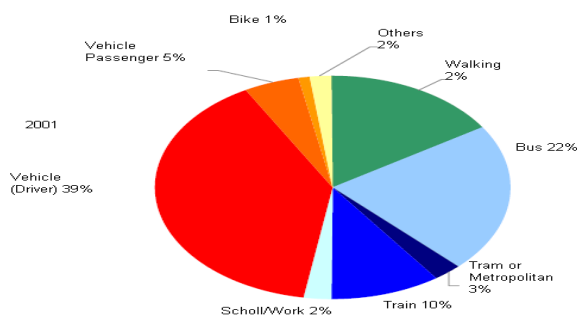

Figure 5: LMA traffic distribution from 2001 census.

In Figure 6, it is possible to see the potential of car pooling system in LMA because there is a major movement into Lisboa city from distant places, without good transportation infrastructure supports. For instance, a person that lives in Santa Cruz (village in a cost north of Lisbon) at around 70 Km distance. By car takes around 45 minutes (costs approximately 15/20€), but on public transportation the trip takes 2 hours. To avoid car cost or delays of 4 hours several persons organize car pooling ride among neighbor or friends. Let's check the system behavior based on the following scenario shown in Figure 7. A user starts his daily journey from home to work. Starting point is near node A0. He takes 5 minutes to reach node A0, but our system will assume starting point in A0. By

car the trip takes around 30 minutes (without traffic delays) and free parking place is always a nightmare, sometimes drivers wait more than 30 minutes without success. Pre-paid parking is cheaper, however daily prices are prohibitive (upper than 10 € for a 8 hour time slot in Lisbon). Based on the drivers profile the system will find the driver's node routes within a waiting time previously defined (this case 5 minutes). Also public transportation routes with starting time of pre-defined 5 minutes are shown to the user. In our system as shown in Figure 7, the information is in a graph visualization interface (is possible to represents the same view in a map using google maps interface). Based on the system information the user chooses the color node option and stores this information. The system notifies the drivers and in this case the trip time is only more 2 minutes then own car trip, but this time in average should be higher. Another advantage of this system is the parking booking. Credits can be converted in periods of parking, but the rate changes from park to park. Also relevant is an saving for this trip of 30 km, and motorway tool we can reach an amount of 25€/day which gives 600€/month and around 6600€/year. It is considered a delay report of user ride (for example 10minutes) and the system can advise users to take ride of drivers which start trip in C0 and catch public transportation at node A3. Also the driver that starts on node B0, can be considered in other day a passenger and catches a ride of driver A (starts in A0). 2001 census.

V. CONCLUSIONS

A novel approach for car pooling system collaboration is proposed. The proposed business model includes a credits mechanism, real time traffic information and parking book facilities. Additionally, the integration with public transportation is also proposed. The implemented prototype shows promising results that can be applied in the LMA described scenario. Based on simulations results obtained from the current version of our prototype, will be possible to double the car occupancy (to reach 2,5 person per car) then we will have half of the cars. This type of initiatives should have better incentives from governments, employers because it fits well to zones without big public transportation infrastructure. The future work should explore other kinds of collaboration

models, with car pooling system namely with public transportation. This collaboration models should also consider the available statistics analysis and real time traffic information systems.
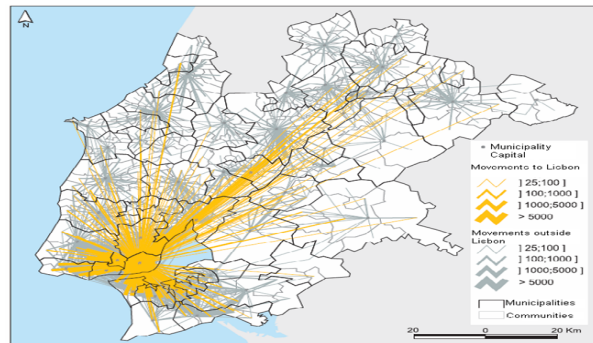

Figure 6: LMA people movements from 2001 census.

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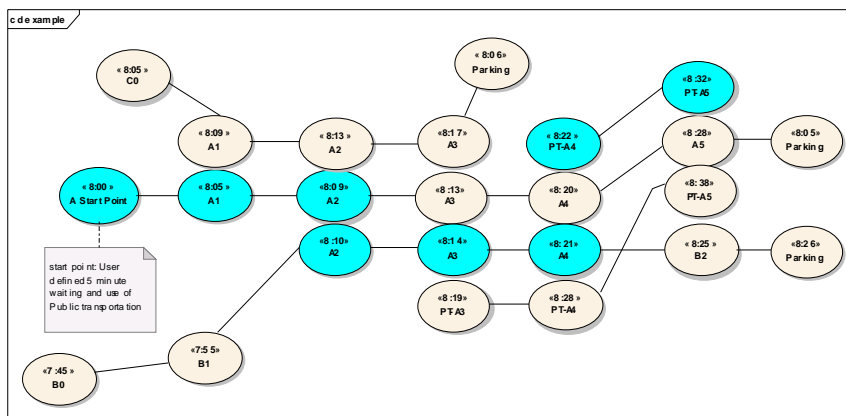[11] www.deetc.isel.ipl.pt/matematica/jf/bpath.pdf

Figure 7: User match ride, within user preference on a graph tool visualization in a java prototype.