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PoliUniPool: a carpooling system for universities

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Abstract

Carpooling is a transport system based on a shared use of private cars. The mobility managers of the Università Statale and Politecnico di Milano universities are interested in promoting the use of such system among their students and employees. The paper presents an ongoing project to design, implement and test PoliUniPool, a car pooling service for such universities. The main characteristics of the PoliUniPool service are the following: (1) the use of the system is restricted to employees, faculty and students of the two universities; (2) besides suggesting a matching between the users, the system provides the expected schedule for their trips; (3) in addition to the campus premises, users can select – as destination of their car pooling trips – the main railway and subway stations, in order to encourage the most environmental friendly means; (4) users are informed immediately in case of delay or changes, to improve the reliability of the service; (5) the system estimates the costs for each user, in order to let the users know how to share them; (6) the system has some social network functionalities, e.g. drivers are able to set partial pre-arranged crews; and users may indicate other users they would prefer to car-pool with (“friends”) or they don’t want to (“I don’t like him/her”). A web-based software tool has been implemented to manage the matching of the users. In order to solve the carpooling problem, we use an heuristics, based on a guided Monte Carlo method. The algorithm minimizes an objective function, subject to user time windows and car capacity constraints. The objective function is a weighted sum of different terms in order to maximize the number of served users, minimizing the total route length, and maximizing the satisfied user preferences (e.g. friends). The result is a matching between drivers and passengers, their schedules and the routes to be driven by each driver. The trial of the proposed service will start on September 2011 and will take into account how to introduce and promote the service, identifying regulation, incentives, modalities, and marketing actions.

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1. Introduction

Increasing vehicle occupancy offers a potentially low-cost measure to a number of transport problems, including traffic congestion, energy consumption, air pollution, and climate-change emissions. Increased vehicle occupancy could be achieved through carpooling, vanpooling, and public transport usage. Carpooling is a transport system based on a shared use of private cars, which can be casual or be organized by a service. In *casual* carpooling, usually

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the driver decides to pick up passengers in order to be able to use a high occupancy vehicle (HOV) lane or to share the trip cost, and the crews are formed on the spot (Burris and Winn, 2006). Examples of *organized* carpooling are RideSearch (www.ridesearch.com), eRideShare (www.erideshare.com), Carpoolworld (www.carpoolworld.com). The car pooling service of NuRide (www.nuride.com) is included in a point-based reward system. Users earn points every time they participate in a green trip, including carpooling, taking public transportation, biking. Those points can be redeemed for rewards, such as local restaurants coupons, discounts at locally participating businesses, promotion ticket. Such services do not suggest a matching between the users, but operate as a sophisticated post-it board, where everybody can consult or add information about travel routes or origins and destinations. Therefore, the single users have to find themselves the companion for the trip. Moreover, there are two other main issues for this type of services. The first is related to the reliability of the system, because is difficult to guarantee the correctness of the data provided by the users and to manage possible *no-shows*. The second issue concerns the safety for both passengers and drivers: some services do not require a reliable identification of the users. More structured services to improve the effectiveness of the service have been designed, such as the system described in Correia and Viegas (2006). The idea is to set up a carpooling service that suggests a possible matching, using an appropriate algorithm. Another example is presented in Dailey et al. (1999), which describes the Seattle Smart Traveler, a dynamic ridematching test program that operated in Seattle (WA) from 1995 through 1997 (www.its.washington.edu/sst). Another example is represented by car2gether (www.car2gether.com), a pilot project in Germany that builds on a social network of drivers and passengers. The system matches up users according to their destinations and profiles and suggests a possible rate for the cost of gas.

In Italy, carpooling was promoted in the national legislation in 1998 with a law on sustainable mobility (Ministero dell'ambiente, 1998), which instituted the figure of the mobility manager. The objective of such figure is to rationalize the commuting trips, promote the use of collective public transport and endorse the introduction of innovative transport systems, such as demand responsive services. Moreover, the mobility manager, whose institution is compulsory for companies with more than 300 employees, designs the company transport plan for the home-to-work trips. As regards car pooling, Jungo (www.jungo.it) is an example of a casual service, while Autostrade car pooling (www.autostradecarpooling.it) is an example of an advanced post-it board service, organized by the concessionaire of the highways between Milano, Como and Varese, which proposes a fare discount for carpoolers.

The mobility managers of the Politecnico di Milano and Università Statale universities are interested in promoting the use of such system among their students and employees. In particular, they target students, because the likelihood of choosing carpooling and other car-use reduction measures increase if we consider young people (Gärling et al., 2000). The paper presents an ongoing project to design, implement and test PoliUniPool, a car pooling service for such universities.

The paper is organized as follows. In order to describe the framework of the carpooling software, Section 2 briefly outlines the objectives of the project and the carpooling software functionalities. Section 3 presents the algorithm developed to solve the matching problem. Section 4 shows some numerical results. Section 5 concludes the paper.

2. The PoliUniPool car pooling

Three web-based surveys, financed by Fondazione Cariplo, have been carried out in 2007, 2008, and 2010, in order to estimate the mobility patterns of students and employees of Politecnico di Milano and Università Statale. In the following, we report the main results regarding the Politecnico di Milano 2007 survey (Luè and Colorni, 2009). The fraction of students living in Milan is 38%, while 17% live in municipalities that are directly served by rapid transit (subways and railways), and 45% live in municipalities that are not served by rapid transit. That is, a large number of students live in areas not well connected to Milan by public transport, or not connected at all. Thus, many students have to use their own cars or to carpool. The car is used by 40% of the students, either to go directly to the university or to park&ride. Among those students, 78% travel alone, resulting in an average vehicle occupancy rate of 1,3. As regards the attitude toward carpooling, 46% of the students who use the car stated to be interested in participating in carpooling with other students. A percentage of 33% of the students would have be interested in participating at the following conditions:

- reserved parking spots;

- traveling with known students or at least trusted students, “certified” by Politecnico di Milano;
- possibility of traveling always with the same crew;
- reliable compatibility of departure and arrival times among the crew members.

We designed the car pooling service in strict collaboration with the mobility managers of Politecnico di Milano and Università Statale, and we considered also feedback of students and employees, and the results of the surveys among students and employees. We developed a web-based software tool for the management of the PoliUniPool service whose main characteristics are the following:

- (1) the use of the system is restricted to employees, faculty and students of the two universities;
- (2) the system, besides suggesting a matching between the users, provides the expected schedule for their trips;
- (3) in addition to the campus premises, users can select – as destination of their car pooling trips – the main railway and subway stations, in order to encourage the most environmental friendly means;
- (4) users are informed immediately in case of delay or changes, to improve the reliability of the service;
- (5) the system estimates the costs for each user, in order to let the users know how to share them;
- (6) the system has some social network functionalities, e.g. drivers are able to set partial pre-arranged crews; and users may indicate other users they would prefer to car-pool with (*friends*) or they don't want to (*I don't like him/her*).

We consider the third characteristic very important, because the mobility managers of the two universities do not want to encourage the use of the car if there are most environmental friendly means, i.e. the ideal way of car pooling is the following: the drivers pick-up the passengers towards the most convenient stations, from which all the car poolers reach the campus using public transport.

Communication between the system and the users is done using a website, an e-mail service, and a Short Message Service (SMS), to communicate unexpected events (e.g. delays, cancellations) to the users' mobile phones. Employees and students are univocally identified by their email accounts, which are validated by the university administrative offices. The fact that the system is restricted to persons belonging to Politecnico di Milano and Università Statale creates a sort of club of users. The objective is to provide a common minimum level of trust between its members and improve the psychological acceptance of the service (Correia and Viegas, 2010).

Figure 1 represents the web page where the users can set their general preferences when they subscribe to the carpooling service, e.g. phone numbers, *I don't like him/her* persons and *friends*, addresses of origin and usual destination - which will be used by the software as default addresses for the origin and destination of the carpooling trips.

The users define their carpooling requests with the following information: origin and destination of the trip, set of days when they are willing to carpool, earliest departure time and latest arrival time, maximum travel time, availability and capacity of the car, and - for those who have a car - whether they are available just as drivers of their own car or also as possible passengers in another car. Moreover, the driver is able to set partial pre-arranged crews. In this way, people that already carpool to the university put at disposition of the system their available seats. The origin and destination addresses are validated with the road database through the Google Maps service, in order to univocally identify their locations. The users have to state their requests and preferences in advance, e.g. by Wednesday of the week before the requested trip. Afterwards - on Wednesday night - using the algorithm described in Section 3, the system computes a solution, which consists in a matching between drivers and passengers, their schedules and the routes to be driven by each driver. The algorithm finds the solution subject to a detour constraint, i.e. the path of each user does not deviates too much from his/her shortest path. In order to maximize the possibility to be inserted in a pool, each user can extend such constraints, letting the path to be longer. The schedule and the routes are available, from Thursday morning, on the PoliUniPool web site and are sent via email to students and employees.

In order to let the users perceive a clear financial benefit, the system calculates and shows in a transparent way the costs and benefits of all the carpoolers. In general, car pooling consents a saving in the travel costs and in the total kilometers traveled by the carpoolers. On the other hand, the carpool driver takes a little more time. Such account of the trade-off between the monetary saving and the increasing in travel time helps the users to decide whether to carpool or not. We developed an accounting system associated with the users' trips, which takes into account how much the passengers owe to the driver. The system can be used on a single trip (i.e. each passenger

pays the driver at the end of the trip), or for an entire period of time, for instance a year, taking into account credits and debits of each user.

Figure 1. The on-line form used by students and employees to set their general preferences when they subscribe to the carpooling service.

In case of significant changes of the scheduling, such as delays and cancellations, the system notifies passengers and drivers in real time, sending them a short message. By default, short messages are used only for alerts, not for ordinary communication between the system and the users, because of the costs of short messages. However, this software setting can be modified by the mobility managers depending on the available resources.

The mobility managers are able to monitor the alert messages and the state of the system (schedules, routes, and crews' composition), and they can manage a black-list of the users who do not show up for the appointments. Considering a specific time-period, the system calculates a set of indicators:

- number of total requests;
- number of fulfilled requests (users successfully matched by the software);
- number of formed crews;
- average vehicle occupancy rate;
- vehicle-km traveled by users whose requests were not fulfilled;
- vehicle-km traveled by the carpool crews;
- vehicle-km saved thanks to carpooling.

3. The algorithm

We developed a suitable algorithm to group together the users in crews taking into account their time windows, their origins and destinations, and their preferences. Such algorithm tries to maximize at the same time the number of served users, the total preferences satisfied, the level of service (i.e. the average path lengthening of all the served users respect their minimum path) and to minimize the total route length.

3.1. Literature on algorithms for the carpooling problem

From the point of view of algorithm, the carpooling problem was first proposed and studied in Fagin and Williams (1983) and later studied in Ajtai et al. (1998). The carpool problem here considered consists of defining

the subsets of users that will share each car and the paths the drivers should follow, so that sharing is maximized and the sum of the path costs is minimized. Ajtai et al. (1998) and Fagin and Williams (1983), for the most part, deal with online schemes, i.e. when the schedule of future arrivals of participants is not known. Fagin and Williams (1983) discuss a few elementary schemes for choosing a driver each day, highlights their flaws in terms of fairness and/or robustness and then propose a scheduling algorithm which is fair.

Literature also distinguishes two main ways of operating the car pooling considering the Daily Car Pooling Problem (DCPP) and the Long-term Car Pooling Problem (LCPP). In the case of DCPP Baldacci et al. (2004), each day a number of users (*servers*) declare their availability for picking up and later bringing back colleagues (*clients*) on that particular day. The problem is to assign clients to servers and to identify the routes to be driven by the servers in order to minimize service costs and a penalty due to unassigned clients, subject to user time window and car capacity constraints. In the case of LCPP (see Hildmann (2001) and Maniezzo et al. (2004)), each user is available both as a server and as a client and the objective is to define pools where each user will in turn, on different days, pick up the remaining pool members. The objective here becomes that of maximizing pool sizes and minimizing the total distance travelled by all users when acting as servers, again subject to car capacity and time window constraints. As for the latter type, the idea is normally to set up a car pooling service among the employees of the same organization but, the spontaneous user matching is substituted by a solution found by means of an algorithmic approach. An example of this type of system is reported in Baldacci et al. (2004), where the system uses the www and reacts to unexpected event with email messages. Baldacci et al. (2004) propose both an exact and a heuristic method for the carpool problem, based on two integer programming formulations of the problem. The exact method is based on a bounding procedure that combines three lower bounds derived from different relaxations of the problem. A valid upper bound is obtained by the heuristic method, which transforms the solution of a Lagrangean lower bound into a feasible solution. The computational results show the effectiveness of the proposed methods. Wolfler Calvo et al. (2008) describe a complete system for supporting the operation of a DCPP case as a prototype for a real-life application. The service is supported by a database of potential users (employees of a company) that daily commute from their house to their workplace. A subset of them offer seats in their cars. Moreover, they specify the departure time (when they leave their house) and the mandatory arrival time at the office. The employees that offer seats in their cars are named servers. The employees asking for a lift are named clients. The set of servers and the set of clients needs to be redefined once a day. Instead of an exact approach like Baldacci et al. (2004), Wolfler Calvo et al. (2008) propose a constructive heuristic based on the computation of a *regret* for each client i given by the difference of the length paths between the two servers which have the least and the second least extramile when pick up client i . The construction algorithm tries to assign each client to its closest server, considering clients in order of decreasing regrets and the solution found is improved by way of a local search algorithm. Finally Teodorovic and Dell’Orco (2008) propose a bee colony optimization metaheuristic and test it in a real case with 97 traveler in Trani, a small attractive city in the south-east of Italy, to Bari, the regional capital of Puglia.

At the best of our knowledge no work in literature faces the problem of designing a carpooling service for university students taking into account the needs of this particular class of users (e.g. friend/enemy list, possible multiple destinations, imposition of partial pools). For these reason we have put right a tailored matching algorithm to form the pools meeting all these needs.

3.2. The matching matrix

The Matching Matrix (MM) is the basic tool used by our matching algorithm: it is the mathematical representation of the links, the first potential and then definitive, among all participants in the carpooling on a certain day of the week. The MM is a dynamic data structure originally built by associating a row to each driver’s journey, a column to each passenger’s journey, both a row and a column to every mixed user’s journey. If a user has more than one possible destination, it will be replicated for each of them giving rise to so many rows or columns as are its destinations; we will call *clones* these rows/columns to highlight the fact that they refer to the same user. The MM element a_{dp} indicate whether and how the passenger (or mixed user) related to the trip p can be inserted in the pool of a driver (or mixed user) who makes the journey d . In particular, element $a_{dp} = N$ if such users are tagged as “I don’t like him/her”; $a_{dp} = \infty$ if the time windows of such users are incompatible.

The time window $[T_p^{\min}, T_p^{\max}]$ of a passenger p , with origin O_p and destination D_p , is compatible with that one $[T_d^{\min}, T_d^{\max}]$ of a driver d , with origin O_d and destination D_d , if the following inequalities are satisfied:

$$T_d^{\min} + t_1 + t_2 \leq \min\{T_p^{\max}, T_d^{\max} - t_3\} \tag{1}$$

$$t_1 + t_2 + t_3 \leq \text{MaxLos}_d t_d \tag{2}$$

$$\max\{T_p^{\min}, T_d^{\min} + t_1\} + t_2 + t_3 \leq T_d^{\max} \tag{3}$$

where (see Fig. 2) t_d is the duration of the shortest path from O_d to D_d , t_1 is the sum of the duration of the shortest path from O_d to O_p with the maximum driver waiting time (possibly also equal to 0), t_2 is the duration of the shortest path from O_p to D_p and t_3 is the duration of the shortest path from D_p to D_d . Moreover MaxLos_d represents the maximum relative travel time (with respect to t_d) accepted by driver d .

Finally if the time windows of users d and p are compatible the MM element a_{dp} is given by

$$a_{dp} = t_1 + t_2 + t_3 - t_d \tag{4}$$

and so it represents the extra travel time of driver d to satisfy the journey request of passenger p . Once established, according to some strategy to match driver/mixed user d with passenger/mixed user p , MM is updated with the following operations:

1. both row d and column p and all their clones are deleted from MM;
2. if d is a mixed user also the column corresponding to d and all their clones are deleted from MM;
3. if p is a mixed user also the row corresponding to p and all their clones are deleted from MM;
4. if p does not saturates the vehicle capacity, a row is added to MM, corresponding to the fact that the passenger p has now become a "virtual driver" because the driver (true) is at this time at the origin of passenger p . This row inherits all the incompatibility (N, ∞) of the driver (initially true and after virtual) which was matched in the previous iteration. The elements of such row are computed according to (4) taking into account the origin of virtual driver p and the corresponding time window.

Users who subscribe to the service requiring to be part of a specific pool, are considered in MM entering the last passenger of such a pool as a virtual driver row.

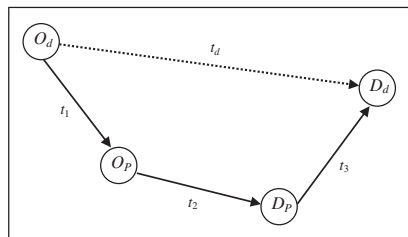


Figure 2. Detour of a driver d satisfying the request of a passenger p .

In the follow we consider two matching matrices, one for the outward journey and one for the return journey, calling them MM^A and MM^R respectively. Moreover we call $MM^{A,0}$ and $MM^{R,0}$ their initialization as previously described.

3.3. The objective function

Evaluation and comparison of the various alternatives leading to the final choice will follow the approach of multi criteria analysis. It allows a choice between alternatives through the calculation of an overall objective function which is a measure of performance for all criteria considered. Each criterion is measured by calculating some indicators associated with it. Each indicator is usually expressed according to their own units, so you must

perform a normalization which associates to each of them an *utility function* which relates the indicator values with dimensionless values expressed in a scale (between two extremes, usually 0 and 1) representing the corresponding level of satisfaction. The lower and upper bounds respectively show the maximum "dissatisfaction" and maximum "satisfaction" for the alternative with respect to that indicator.

We used the following five utility functions.

1. *Kilometer Benefit (KB)* is the saving obtained on the total length covered by the carpooling users respect to total length covered without carpooling.
2. *Matching Coefficient (MC)* is the ratio between the total served users and the total users requiring the carpooling service.
3. *Level of service (LOS)* measures the average path lengthening of all the served users respect their minimum path.
4. *User preferences (PREF)* measures the friendship preferences of the users.
5. *Pool Historicity (HIST)* measures how many times users matched in the current pool was in the same pool also over a certain period.

For instance the *Kilometer Benefit* utility function is given by:

$$KB = \frac{1}{N} \sum_{i=1, \dots, N} \frac{n_i}{n_i - 1} \left(1 - \frac{KMCP_i}{KMA_i} \right) \quad (5)$$

where N is the total number of pools formed, n_i is the vehicle capacity used in the i -th pool, KMA_i is the total length covered by the users of i -th pool before using the carpooling whereas $KMCP_i$ is the total length covered by the same users using the carpooling service.

More details on the other utility functions can be found in Bruglieri et al. (2008). The overall objective function *OBJ*, is given by (6) and consists in the weighted sum of the five utility functions with non negative weights λ_i with sum equal to 1.

$$OBJ = \lambda_1 KB + \lambda_2 MC + \lambda_3 LOS + \lambda_4 PREF + \lambda_5 HIST \quad (6)$$

3.4. Guided Monte Carlo method

The method consists in generating several random feasible pools taking into account the path lengthening, the user preferences and the pool historicity; finally the algorithm selects the best solution with respect to the objective function (6). This is the detailed description of the guided Monte Carlo algorithm:

1. Compute $MM^{A,0}$ and $MM^{R,0}$ starting matching matrices for the outward journey and return journey respectively, as described in section 3.2;
2. while the CPU time < Max_CPU_Time :
 - 2.1 choose randomly coefficients $\gamma_{dev}, \gamma_{prefs}, \gamma_{hist}$ in [0,1] interval with Gaussian probability distributions around the average values $\frac{\lambda_1}{\lambda_1 + \lambda_4 + \lambda_5}$, $\frac{\lambda_4}{\lambda_1 + \lambda_4 + \lambda_5}$, $\frac{\lambda_5}{\lambda_1 + \lambda_4 + \lambda_5}$, respectively;
 - 2.2 for $k=1, \dots, max_num_iterat$
 - 2.2.0 initialize MM^A and MM^R with $MM^{A,0}$ and $MM^{R,0}$ respectively; (*Phase I*)
 - 2.2.1 while MM^A has elements different from N and ∞ :
 - 2.2.1.1 in the outward journey choose to potentially couple driver d (true or virtual) with passenger p with probability $\frac{\pi_{dp}^A}{\Pi^A}$ where

$$\pi_{dp}^A = \begin{cases} 0, & \text{if } MM_{dp}^A = \infty, N \\ \gamma_{dev} \left(1 - \frac{MM_{dp}^A}{\mu^A} \right) + \gamma_{pref} PM_{dp} + \gamma_{hist} HM_{dp}^A, & \text{otherwise} \end{cases}$$

μ^A is the maximum element of MM^A , PM is the user preference matrix, HM^A is the history matrix for the outward journey and $\Pi^A = \sum_{dp} \pi_{dp}^A$;

2.2.1.2 if passenger p has the outward journey and the return constrained:

2.2.1.2.0 if passenger p is compatible with driver d also in the return

(i.e. $MM_{dp}^R \neq N, \infty$) couple d and p also in the return;

2.2.1.2.1 otherwise in the return journey choose to couple passenger

p with driver d'' (true or virtual) with probability $\frac{\pi_{d''p}^R}{\Pi^R}$

where $\pi_{d''p}^R$ and Π^R are defined in the analogous way of

π_{dp}^A and Π^A but considering MM^R and HM^R instead of MM^A and HM^A ;

2.2.1.2.2 if column p of MM^R contains just N or ∞ elements:

2.2.1.2.2.1 execute Phase 2 for passenger p on MM^R ;

2.2.1.2.2.2 if passenger p cannot be coupled with any

driver, eliminate column p both in MM^A and MM^R and go back to 2.2.1.1

2.2.1.2.2.3 otherwise match driver d with passenger p in the outward journey;

2.2.1.3 otherwise match driver d with passenger p in the outward journey and update MM^A ;

2.2.1.4 if d is a true driver and also a mixed user delete its column from MM^R ;

(Phase 2)

2.2.2 try in exhaustive way to insert every passenger not coupled in all positions of all formed pools and insert it to the first feasible pool (this operation has not to be done for the MM^A rows where such a passenger has an N element but just where has an ∞ element);

(Phase 3)

2.2.3 Eliminate from MM^R passengers having constrained outward journey and return, which are not coupled in the outward journey

2.2.4 while MM^R has elements different from N and ∞ :

2.2.4.1 in the return journey match driver d with passenger p with probability $\frac{\pi_{dp}^R}{\Pi^R}$;

2.2.5 Execute Phase 2 on MM^R

2.2.6 Evaluate the objective function (6) in the current solution and if it is better of the best found solution, update the latter.

4. Some numerical results

For testing the performance of the guided Monte Carlo method described in section 3.4, we created five likely instances of the university car pooling problem. They have been built considering users with origins spread in the Cremona and Bergamo provinces of Lombardia region and common destination in the main location site of Politecnico di Milano. Note that the maximum time required by the farthest origin-destination pair is 70 minutes. Concerning the time windows $[T_u^{\min}, T_u^{\max}]$ of each user u , T_u^{\min} have been chosen between 7 a.m. and 8.40 a.m. with increasing values for users having the origins nearer to the destination, whereas $T_u^{\max} = 9$ a.m. for all users u . Every car has capacity 4 (including the driver). The parameter MaxLos_u , discussed in section 3.2, has been chosen equal to 1.9 for the long travels (i.e. lasting more than 40 minutes), 2.5 for the short travels (i.e. lasting less than 10 minutes) and has been set with intermediate linear values for medium length travels. Table 1 summarize the features

of all the instances generated: rows 1 and 2 indicate the number of user requests for the outward journey and return journey, respectively; row 3 indicates the percentage of users requiring that the satisfaction of both ways trips is mandatory; rows 4, 5 and 6 indicate the number of the drivers, mixed users and passengers, respectively; finally the last two rows indicate the number of user pairs that are enemy or friends, respectively.

Table 1. Features of the five instances generated for the university carpooling problem.

	Instance 1	Instance 2	Instance 3	Instance 4	Instance 5
Outward journey requests	122	122	122	122	122
Return journey requests	0	0	0	122	122
Outward-return constrained	0	0	0	0	100%
Drivers	0	0	0	0	0
Mixed users	47	47	47	94	94
Passengers	75	75	75	150	150
Enemy pairs	28	28	28	28	28
Friend pairs	10	10	10	10	10

In the runs of the Monte Carlo method, the first 4 weights λ_i of the objective function (6) have been set in uniform way (i.e. $\lambda_i = 0.25$ for $i=1,\dots,4$) and $\lambda_5=0$. Moreover we have chosen $\text{Max_CPU_Time} = 4$ minutes and $\text{max_num_iterat}=10$. Table 2 summarize the results on the five instances: row 1 indicates the percentage of travel requests satisfied; row 2 indicates the number of pools formed; row 3 indicates the average occupancy rate of cars weighted on the traveled distance with each different number of occupants during the journey; row 4 indicates the average maximum number of occupants of the cars used in the carpooling solution; row 5 indicates the total traveled distance; row 6 the saving between the distance traveled by the users accepted and the one they would have traveled without carpooling; row 7 represents the average over all users accepted of their Level of Service (i.e. for each user, the ratio between the travel time in carpooling and his minimum travel time); finally row 8 represents the maximum value of Level of Service over all users accepted.

Table 2. Results on the five instances of the university carpooling problem

	Instance 1	Instance 2	Instance 3	Instance 4	Instance 5
Satisfied requests	94.30%	94.30%	94.30%	92.20%	82.80%
Pools formed	36	36	36	67	74
Weighted occupancy rate	1.86	1.86	1.86	1.96	1.7
Maximum occupancy rate	3.19	3.19	3.19	3.36	2.73
CP traveled distance (Km)	1,904.30	1,904.30	1,904.30	3,529.30	3,544.50
Traveled distance saving	35.50%	35.50%	35.50%	37.70%	29.60%
LoS	1.31	1.31	1.31	1.35	1.26
Max LoS	2.1	2.1	2.1	2.39	2.25

The results show that a high percentage of users requests is accepted: often greater than 90% and this percentage decreases only for the instance 5, having the mandatory satisfaction of both outward and return journeys. From row 4 we deduce that very often the maximum car capacity (four) is achieved in the pools formed by the guided Monte Carlo method. Also the saving on the total distance traveled by the carpoolers is substantial being often greater than 35%. Finally we note that the average Level of Service is near enough to the ideal one (value 1) being often less than 1.31: this means that in average for each user the journey is 1.31 times less long of the direct journey from his origin to his destination.

5. Conclusions

We presented an ongoing project to design, implement and test PoliUniPool, a car pooling service for the Università Statale and Politecnico di Milano universities. We described the designed characteristics of PoliUniPool, the functionalities of the software tool to manage the car pooling service, and the algorithm on which the software tool is based.

In designing the system, we tried to overcome some limitations of existing services. In particular, we focused some social network functionalities, in order to let the incentive the user to use the system. Moreover, as regards the algorithm, since in literature no work faces the problem of designing a carpooling service for university students taking into account the needs of this particular class of users (e.g. friend list, possible multiple destinations, imposition of partial pools) we have put right a tailored matching algorithm based on a Monte Carlo method. Preliminary computational results show that such algorithm is able to find very good quality solutions (*Level of Service* very close to the optimum) and with short CPU time (4 minutes).

A trial will start on September 2011, with the aim to arrive to a full exploitation of the service in December 2011. The success of the service will depend not only on the provided features, but also on the communication programs promoted by the two universities and by the local administration. The objective of the mobility managers is not only to implement a successful service for their students and employees – i.e. good statistics, such as fulfilled requests and average vehicle occupancy rate – but to have a long-term effect. Moreover, promoting the use of sustainable mobility services (such as carpooling) among young people has an educational effect. What you learn doing as a young person will influence your attitude when you grow older. Because the universities are major trip generators (Tolley, 1996), a success in a carpooling service would be certainly useful to alleviate traffic congestion in the urban area of Milan.

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