

# Distributed Data Management of Daily Car Pooling Problems

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## INTRODUCTION

The increased human mobility, combined with high use of private cars, increases the load on the environment and raises issues about the quality of life. The use of private cars lends to high levels of air pollution in cities, parking problems, noise pollution, congestion, and the resulting low transfer velocity (and, thus, inefficiency in the use of public resources). Public transportation service is often incapable of effectively servicing non-urban areas, where cost-effective transportation systems cannot be set up. Based on investigations during the last years, problems related to traffic have been among those most commonly mentioned as distressing, while public transportation systems inherently are incapable of facing the different transportation needs arising in modern societies. A solution to the problem of the increased passenger and freight transportation demand could be obtained by increasing both the efficiency and the quality of public transportation systems, and by the development of systems that could provide alternative solutions in terms of flexibility and costs between the public and private ones. This is the rationale behind so-called Innovative Transport Systems (ITS) (Colorni et al., 1999), like car pooling, car sharing, dial-a-ride, park-and-ride, card car, park pricing, and road pricing, which are characterized by the exploitation of innovative organizational elements and by a large flexibility in their management (e.g., traffic restrictions and fares can vary according with the time of day).

Specifically, car pooling is a collective transportation system based on the idea that sets of car owners having the same travel destination can share their vehicles (private cars), with the objective of reducing the number of cars on the road. Until now, these systems have had a limited use due to lack of efficient information processing and communication support. This study presents an

integrated system for the organization of a car-pooling service and reports about a real-world case study.

## BACKGROUND

Car pooling can be operated in two main ways: Daily Car Pooling Problem (DCPP) or Long-Term Car Pooling Problem (LCPP). In the case of DCPP (Baldacci et al., 2004; Mingozi et al., 2004), each day a number of users (hereafter called servers) declare their availability for picking up and later bringing back colleagues (hereafter 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, each user is available both as a server and as a client, and the objective is to define crews or user pools, where each user, in turn, on different days, will pick up the remaining pool members (Hildmann, 2001; Maniezzo et al., 2004). The objective here becomes that of maximizing pool sizes and minimizing the total distance traveled by all users when acting as servers, again subject to car capacity and time window constraints.

Car pooling is most effective for daily commuters. It is an old idea but scarcely applied, at least in Europe, for many reasons. First of all, it is necessary to collect a lot of information about service users and to make them available to the service planner; it can be difficult to cluster people in such a way that everybody feels satisfied. Ultimately, it is important that all participants perceive a clear personal gain in order to continue using the service.

Moreover, past experience has shown already that the effectiveness and competitiveness of public transporta-

tion, compared to private transportation, can be improved through an integrated process, based on data management facilities. Usually, potential customers of a new transportation system face serious problems of knowledge retrieval, which is the reason for devoting substantial efforts to providing clients with an easy and powerful tool to find information. Current information systems give the possibility of real-time data management and include the possibility to react to unscheduled events, as they can be reached from almost anywhere.

Architectures for information browsing, like the World Wide Web (WWW), are an easy and powerful means through which to deploy databases and, thus, represent obvious options for setting up services, such as the one advocated in this work. The WWW is useful for providing access to central data storage, for collecting remote data, and for allowing GIS and optimization software to interact. All these elements have an important impact on the implementation of new transport services (Ridematching, 2004). Based on the way they use the WWW and on the services they provide, car-pooling systems range between two extremes (Carpoolmatch, 2004; Carpooltool, 2004; Ridepro, 2004; SAC, 2004, etc.), one where there is a WWW site collecting information about trips, which are open to every registered user, and another one where the users of the system are a restricted group and are granted more functionalities.

A main issue for the first type is to guarantee the reliability of the information. Their interface often is designed mainly to help set service-related geographical information (customer delivery points, customers pick up points, paths). Such systems only rarely will suggest a matching between clients and servers but operate as a post-it wall, where users can consult or leave information about travel routes.

As for the latter type, the idea is normally to set up a car-pooling service among the users, usually employees of the same organization. This system is more structured. Moreover, the spontaneous user matching often is substituted by a solution found by means of an algorithmic approach. An example of this type of system is reported in Dailey, et al. (1999) or in Lexington-Fayette County (2004). These systems use the WWW and react to unexpected events with e-mail messages.

## MAIN THRUST

This article describes an integrated ICT system that supports the management of a car-pooling service in a real-world prototypical setting. An approach similar to Dailey, et al. (1999) is suggested, and a complete system for supporting the operation of a car-pooling case as a prototype for a real-life application is described. The

service is supported by a database of potential users (e.g., employees of a company) that daily commute from their houses to their workplace. A subset of them offers 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 called servers. The employees asking for a lift are called clients. The set of servers and the set of clients need to be redefined once a day. The effectiveness of the proposed system is related strictly to the architecture and the techniques used to manage information.

The objective of this research is to prove that, at least in a particular site (the Joint Research Center [JRC] of the European Commission located in Ispra, northern Italy), it could be possible to reduce the number of transport vehicles without significantly changing either the number of commuters or their comfort-level. The users of the system are commuters normally using their own cars for traveling between home and a workplace poorly served by public transportation.

## System Architecture

The architecture of the system developed for this problem is shown in Figure 1 (interested readers can find a complete description of the whole system in Wolfler et al., 2004). The system consists of the following five main modules:

- **OPT:** An optimization module that generates a feasible solution using an algorithm that defines the paths for the servers. The algorithm makes use of a heuristic approach and is used to assign the clients to the servers and to define the path for each server. Each path minimizes the travel time, maximizes the number of requests picked up, and satisfies the time and capacity constraints.
- **{M-, S-, W-}CAR:** Three modules that permit to receive, decrypt, and send SMS (SCAR), EMAIL (MCAR) and Web pages (WCAR) to the users, respectively. The module Sms Car Pooling (SCAR) allows the server to send and receive Sms messages. The module Mail Car Pooling (MCAR) supports e-mail communication and uses POP3 and SMTP as protocols. The module (WCAR) is the gateway for the Web interaction. All modules filter the customer's access, allowing the entitled user to insert new data, to query, and to modify the database (e.g., the departure and the arrival time desired) and to access service data.
- **GUI:** A graphical user interface based on ESRI ArcView. It generates a view (a digital map) of the current problem instance and provides all relevant data management.

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