

# Chapter 2

## Intelligent Carpooling System

### A Case Study for Bacău Metropolitan Area

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**Abstract** Mobility is one of the most basic features of our modern society. People and goods move around the entire Earth in a continuous and broad attempt to fulfill economic, safety and environmental goals. The Mobility Management or Transportation Demand Management is a collection of strategies for encouraging more efficient traffic patterns towards achieving specific planning objectives. For example, people can choose to switch from peak hours to non-peak time, or to cycle instead of using the car. Administrative regulations could introduce incentives or reimbursements when alternative commuting modes are used. Governmental policies could include fuel tax increases or pay-as-you-drive freeway taxes or car insurances. The goal of this chapter is to present several alternative travel modes, their social impact and their utility. As an example, we present two applications for shared-use mobility in the metropolitan area of Bacău, Romania. The applications integrate diverse computing languages with platforms, standards and technologies. The experimental results are encouraging, allowing us to consider that seamless integration of hybrid management systems for transportation could have tremendous economic and social impact at global scale.

**Keywords** Traffic management • Carpooling • Transportation on demand • GPS data sets

## 2.1 Introduction

Gathering people into common trips leads to individual and social efficiency. At a personal level, it reduces the total travelling cost and the driving stress as well. Although it is less comfortable than using the personal car and people usually need more time for performing the travel, the broad acceptance of the shared-use

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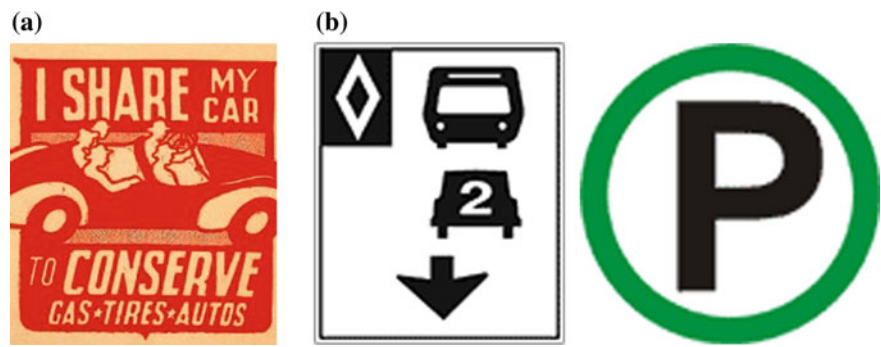
mobility shows its viability, with practical developments not entirely explored. From the social point of view, less fuel consumption, less CO<sub>2</sub> emission, less traffic congestion and more social interaction are the benefits of sharing cars or vans. By saving natural resources like oil, by producing less pollution and by cutting the travel expense, using a car for many persons is an advance to sustainable transportation systems. As an alternative to public transportation and taxi services, sharing a car combines the benefits of a shared cost with the flexibility of a taxi ride. The main idea of shared-use mobility is to share the transportation cost between multiple participants.

There are many ways people could use the same car or van. Car sharing means reserving and using a car for a short period of time (usually for several hours) and returning it before the reservation expires. It is a very convenient option for people needing rare and short rides: common vehicle costs show that this is the most efficient decision for less than 10.000 km/year. With an annual fee, and paying by hour when needing a ride, one could avoid buying a car and paying for its registration, insurance, maintenance, etc. Carpooling means using the same car for simultaneous transport of several people from a common starting point to a common end point. The most usual case is when neighbours work at the same facility and agree to travel using only one car. Modern systems use the internet and communication technologies in order to dynamically organise optimal trips. Such examples are the smartphone apps like *Lift*, *Sidecar* or *Uber*.

## 2.2 Shared-Use Mobility—Historical Evolution

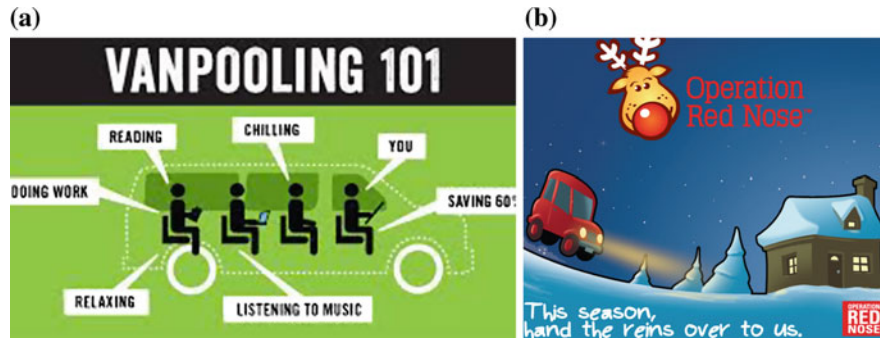
With more than 70 years of development, the shared-use mobility had different materializations, addressing specific needs, and using the available resources at that time:

- During the World War II, the American companies, churches and social associations were encouraged to “...organise state and local transportation committees and car sharing clubs” [1] in order to preserve resources for the war (Fig. 2.1a). After the war, the model of the modern family and the increasing quality of life brought less concern in sharing cars under institutional frameworks, but instead self-organised “fampools” (family and friends) became natural.
- The energy crises from the 70s spiked up the gasoline price, so people again turned to the idea of grouping for common travels. Governments supported such initiatives through High-Occupancy Vehicle (HOV) lanes, park-and-ride facilities (Fig. 2.1b), or by sponsoring ridesharing projects. A unique project still in use is the Morgantown Personal Rapid Transit (PRT) system from the West Virginia University, USA [2]. Small cars are dispatched only at request, but in crowded hours the system switches to a classic public transportation one. This is a hybrid system, but is worth mentioned as it is running for almost 40 years, with a reliability rate of 98.5 %.



**Fig. 2.1** **a** Car-sharing advertising (World War II). *Source* Ames Historical Society’s World War II Veterans Project. **b** HOV lane sign and free carpool parking sign in Ontario, Canada. *Source* <http://www.mto.gov.on.ca>

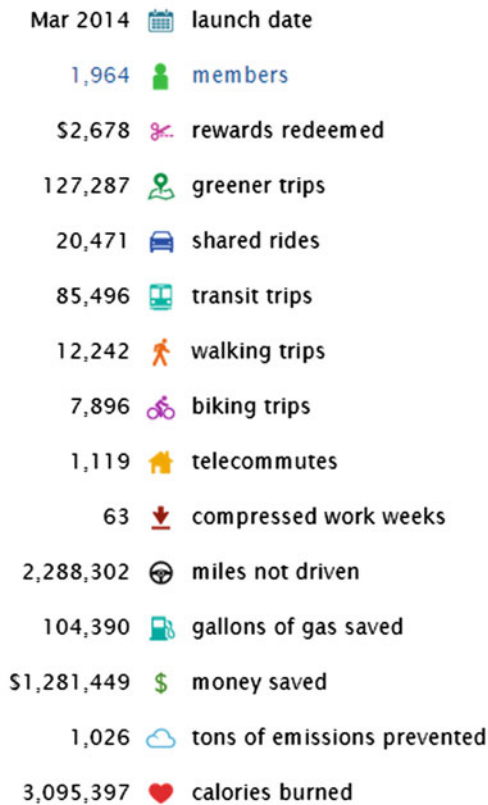
- Until the end of the last century, several early systems were organised either by large-scale employers, or by transportation associations, in order to mitigate the traffic congestion, to lower the air pollution and to reduce the parking lot strain. The matches were made by-hand, after collecting data on the employees’ addresses. Local transportation firms supplied vans for longer commutes when around ten employees came from the same residential area [3] (Fig. 2.2a). For one-time carpooling, telephone-based ride matching systems were set-up. The transition to the next systems is made by enhancing the systems through Personal Digital Assistants (PDAs) and Geographic Information Systems (GIS) capabilities.
- After 2000, the new communication technologies and the internet broad facilities had great impact on the reliability and on the responsiveness of the ridesharing systems. The clients manage to post online their commands, and connected services are now offered to the interested public. For example, the San Francisco 511 platform offers complex traffic information in the SF Bay



**Fig. 2.2** **a** Vanpool advertising in Vermont, USA. *Source* Vermont Agency of Transportation. **b** Red Nose 2014 advertising in Canada. *Source* <http://www.mto.gov.on.ca>

- area, including rideshare options [4]. *Ecolutis* offers aggregate services for firms and public in France [5]. There are special occasion ride offers, organised by the local authorities. An example is the *Red Nose* operation in Canada: the drivers are suggested to call for a volunteer who can safely drive them home during December (Fig. 2.2b).
- The current developments of mobile communications provide real-time or dynamic ridesharing today. The drivers post their trip while they are driving, and the potential riders warn just before the intentioned departure time. The mobile application notifies each part's smartphone about the available pairing, which can be accepted by a single tap on the smartphone screen. *Villefluide* is an online platform for ridesharing in France [6], *Ridefinder* works globally for Europe [7]. Successful smartphone apps are *Carma*, *Lift*, and *Sidecar*. Complimentary rewards are offered to people choosing to use these services. For example, *NuRide* computes and reports all its green activities in a specific area [8] (Fig. 2.3).

### Activity in Rhode Island



**Fig. 2.3** *NuRide* Rhode Island report on December 1st, 2014. Source [www.ripta.com](http://www.ripta.com)

Dynamic carpooling, also known as casual carpooling because it arranges shared rides on very short notice, arises supplementary challenges regarding the matching of drivers and travelers in real time. Adding this request to the flexibility required in routes leads to complicated algorithms, possibly leading to combinatorial explosion [9]. A review on the available automatic and heuristic data processing routines to support efficient matching in carpool schemes is presented in [10]. An application for dynamic carpooling also needs safety authentication of the rider and driver before making the match. Feedback or reputation systems may be useful in providing information about who to trust, as inter-personal constraints (such as punctuality, smoking versus non-smoking, male versus female preferences) could also interfere [11]. A state of the art on dynamic carpooling and an identification of the issues against the adoption of carpooling systems together with some suggestions to solve them are presented in [12].

For a comprehensive ridesharing classification scheme and for an evolution of the concept the reader can access the paper of Chan and Shaheen [13].

The following examples furthermore give some details on the functional vehicle sharing solutions, illustrating the potential of these initiatives, with implications in traffic flow improvement, public safety and optimisation of movement of people and goods.

- *Car2Go* [14] is the Smart division of Daimler AG, offering services in European and Nord-American cities. The company provides *Smart Fortwo* highly energy-efficient vehicles, available through booking online with applications for mobile devices. Moreover, the system is based on a “one-way” model, which makes it very flexible. The clients are charged per minute, hour or day. The rates include renting, fuel costs, insurance, maintenance and parking charges. Sometimes, a small annual fee may be applied. In May 2014, the company owned over 10,000 “car2gos” in eight countries, distributed in 26 cities and servicing more than 700,000 clients. According to [15] the service is providing electric cars exclusively in USA since November 2011.
- *Zipcar* [16] is the largest car sharing service, available in USA, Canada, Great Britain, Spain and Austria. The fleet is diverse, the cars may be driven by hour or day but they have to be returned to the same reserved parking spot. The driver pays a registration fee, an annual fee and reservation fees for the regular usage. The fuel costs, parking, and insurance are included, and facilities are provided for business and for universities.
- *CityCarClub* [17] is a UK car sharing network, available in 15 cities. The charge includes insurance, tax and fuel. The fleet is composed of low emission cars, experimenting alternative technologies such as biodiesel, hybrid vehicles and Stop-Start technology [18]. The network members use smart cards to access the vehicles.

## 2.3 Conceptual Models for Shared Mobility Systems

The current transportation domain encompasses many stakeholders with heterogeneous needs and goals. The Intelligent Transportation System (ITS) must operate with a large number of concepts, must balance the requests with the available resources, and are supposed to manage a wide variety of models and implementations. We expect that the ITSs will bring major social and economic benefits, due to the greater efficiency of the transport system and increase security. One direction in ITS research is to design specific ontologies, representing dictionaries of relevant concepts from traffic domains organised in a hierarchical structure of classes and taxonomy.

Examples of top-level ontologies that can derive transportation concepts are: Suggested Upper Merged Ontology (SUMO) [19], OpenCyc [20]. ISO 14825:2011 specifies the data model and physical encoding formats for geographic databases for ITS applications and services [21]. Semantic web for Earth and Environmental Terminology (SWEET) is a collection of dedicated top-level ontologies, maintained by NASA Jet Propulsion Laboratory [22].

By simultaneously treating Intelligent Vehicles and Intelligent Infrastructure, the low-level ontologies allow comprehensive and targeted approaches to Transportation problems. The Open Geospatial Consortium [23] offers geospatial and location standards, providing community-specific OGC Geography Markup Language (GML) application schemas (AIXM for aviation, GeoSciML for geosciences, etc.). Transportation simulations using ontologies are presented in [24, 25], and specific carpooling simulations based on ontologies are published in [26].

The complexity of the current transportation situations and the need of rapid actions when sensitive events occur (i.e. bottlenecks, accident, and sudden road closures) request decision support systems to assist traffic engineers. The knowledge-based systems are designed to enhance the dynamicity and responsiveness, to mitigate the effects of the traffic incidents, and to correctly predict them [27]. Data analysis or data mining can be used for real-time suggestions for human operators. One such example is the opening of new lanes when the sensors register heavy traffic. Another approach is to install mobile applications which can recommend to the driver new paths for completing his/her daily trip from home to work.

Conceptual models and simulations are used to get insights on the strengths and weaknesses of the carpooling systems for a given region. A simulation-based methodology which emphasizes the construction process of a logic flow diagram that translates the proposed methodology is presented in [28]. Multiple, heterogeneous models have been integrated using ontology techniques [26], especially for predicting the demand. User-centred research has also been developed. This approach is helpful for assessing the potential of the carpooling concept in general, as well as to improve the interaction of the users with the existing web-based platforms [29]. Statistical testing shows diverging requirements between different

groups; age, gender and individual economic situation (employment, for example) are factors that influence carpooling acceptance.

Culture-specificity is also very important. A case study for Switzerland is presented in [30] and an analysis on Vermont carpool data is available in [31]. The paper includes some considerations on the perceptions of carpooling, which have been found to play a larger role than cost or convenience. For Portugal, the work of [32] reveals the results of a *stated preference* experiment meant to assess the enhancement possibilities for carpooling and carpool clubs. For China, where the private car ownership had exceeded 88 million in 2012, a design of a commute carpooling system is given in [33] and an investigation of human mobility patterns, for predicting owners' driving trajectories and real-time position for carpooling, is presented in [34]. As taxicab systems play a prominent role in transportation models, recommendation systems for carpoolable taxicabs come from China, too. In [35, 36] the authors design such systems, based on a data driven approach.

## 2.4 Modelling a Carpooling System for Bacău, Romania

This section presents two implementations for carpooling services in the Bacău area, Romania. The models are based on multi-agent interactions, with specific characteristics and use multiple communication and representation technologies.

### 2.4.1 Country Context

Romania is located at the crossroads of many routes connecting Eastern to Western Europe and Northern to Southern Europe. Of the total National road network, 5,868 km (37.3 %) are classified as European roads [37]. Moreover, Romania's location on the transit axes connecting Europe to Asia generated numerous studies regarding the infrastructure and transport capabilities. The Romanian Government identified [38] several key transport-related issues:

- Domestic transport, although diversified, has insufficient capacity for transporting freight and passengers;
- The transport infrastructure is insufficiently developed and requires significant investment in order to meet European standards;
- Access to the West-European corridors, as well as to the Eastern and Southern Europe ones, is limited;
- The access roads from national roads to town centres and cities are inadequate and most towns located on National and European roads lack bypasses.

At the end of 2013, more than 5 million privately-owned vehicles have been recorded in Romania [39]. Nevertheless, the number of new cars has registered a significant decrease during the last 5 years. This is due mainly to the poor

purchasing power of the population and to the fluctuations of the pollution tax. Meanwhile, the market of the second-hand vehicles, imported from the Western Europe, has increased. Under these circumstances, the pollution could also increase.

Romanian law no 3/2001 ratifies the Kyoto Protocol of the United Nations Framework Convention on Climate Change. According to it, Romania is obliged to reduce its emissions of greenhouse gases with 8 %, considering the year 1989 as baseline. If we refer to the emissions from road transport, the average carbon dioxide emissions from new passenger cars was, in 2013, 132.1 gCO<sub>2</sub>/km (decreasing with 5.22 % compared to 2012) in Romania, while the EU Member States' average was 126.7 gCO<sub>2</sub>/km (decreasing with 4.1 % compared to 2012) [40]. The Romanian government encouraged the rolling stock renewal through national policies, in order to eliminate the vehicles with significant pollutant capacity. However, this initiative should be complemented with “soft” measures, such as intelligent traffic management and transport systems.

The following subsection presents an overview of the data which are relevant for Bacău, influencing the transportation conditions and the transit system as they stand at the moment of our study.

### 2.4.2 *City Context*

In order to implement a sharing mobility system that is functional and beneficial for a certain area, specific factors also have to be taken into account. This is the approach that we have considered for Bacău metropolitan area. Bacău, the 15th largest city in Romania, is the residence city of Bacău County, part of the historical region Moldavia and of the North-East Development Region (according to the EU regional policy [41]). The city is situated at about 300 km from Bucharest, the capital of Romania. Two European routes cross Bacău: E85 links the South area with the Northern cities Iași and Suceava, while E574 provides access to the South-Western part, with Brașov, Pitești and Craiova (the last two are important centres of the European automotive industry). There is no beltway for Bacău; therefore the transit through the city often faces congestion, consequently leading to increased travel time, vehicle operating costs, accidents and environmental damage.

Current data (June, 2014, [42]) show a population slightly over 170,000 inhabitants, distributed within the city limits of 43.1 km<sup>2</sup>, while the whole county has more than 706,000 inhabitants. Bacău metropolitan area [43] integrates Bacău and the neighbouring communities, with a population of around 250,000.

The transportation needs are high and have increased during the last 5 years, along with the development of SMEs around Bacău. Several divisions of important international companies are hosted in or in the vicinity of Bacău as well. The rolling stock has increased. Consequently, the traffic has reached in Bacău a level where the key performance indicators (especially the indices for traffic efficiency and for pollution reduction [44]) are alarming.



For Bacău County, the car ownership has been reported at 111,500 at the end of 2013 [42]. The public transport is based on three major median busways and seven secondary ones in the city. In addition there are regular buses for the neighbouring communities. This system is far from providing comfortable connections between the rural area and Bacău, where most of the employers are concentrated. Thus there is an important flow of vehicles to and from Bacău, especially during the working days. An important share of them uses E85 regularly, therefore generating agglomeration with all its consequences.

The development plan of Bacău [45] follows an integrated approach to the transport and land use. Key directions include improvement of infrastructure, management and control of land use citywide and traffic decongestion of the city centre, but important investments (which are not scheduled in the near future) are needed. In the central area of the city, roadside parking is limited in location and duration and is well enforced. The number of off-street parkings is very small.

As far as we know, no shared-use mobility study has been performed for the city of Bacău. The two implementations which are presented in Chap. 5 aim at encouraging the authorities to consider new policies regarding the local transportation means and to raise awareness among the local community towards the green solutions.

### 2.4.3 *Information Requirements for an Efficient Model*

In order to incentive the traveller's choice, a carpooling system has to provide several features [46], among which we mention:

- *Accessibility.* The stops need to be located near residential neighbourhoods and/or in the business area of the city.
- *Affordability.* The rates should be reasonable; it is important that the system is available for short trips.
- *Convenience.* If the vehicles are easy to check in and out at any time, this would highly encourage their use.
- *Reliability.* It is recommendable that the vehicles are available and have minimal failures.

Besides the above listed aspects, the targeted users in Bacău would certainly require to access the service on smart devices, hence the necessity of a modern, adequate implementation.

Considering these characteristics, the model we propose focuses mainly on fuel economy and reduction of transport-related greenhouse gas emissions through an improved degree of occupancy of the vehicles. The mobility of users in the metropolitan area and the connectivity to the public transportation systems have

been simulated through the flexibility of the implementations. Therefore, for the target area we have studied:

- the main transport routes and the most important congestion points
- the most important, necessary stops
- the zones with maximum passengers flow
- traffic monitoring (traffic volume, daily travel data)
- sample data on travel time and speed
- socioeconomic information (workplaces, schools, public institutions and number of their attendees)
- public transport and parking surveys
- consumers' satisfaction and perception data on the public transport systems
- environmental impact.

The corresponding data have been provided by the Committee for urbanism, territorial planning and environmental protection of Bacău County Council [47].

For an efficient carpooling system, the characteristics of the vehicle fleet are also essential. In order to score improvements resulting from its implementation, fuel consumption and emissions of CO<sub>2</sub> must be reduced. This can be done gradually, introducing alternative vehicles (such as hybrid electric or fully electric) and/or fuels (bio- and coal-based, compressed natural gas or liquefied petroleum gas). As these facilities are scarcely present in Bacău County, we only simulate their influence by means of two parameters: the average fuel consumption and the average CO<sub>2</sub> emission per car, for the system fleet. As a conclusion, our model strengthens the role of shifting from privately-owned vehicles to carpooling, and assesses the reliability of the solution considering the measures suggested in [48, 49].

According to these goals, the followings represent input data for the model:

- number of main stops
- number of secondary stops
- number of routes
- the set of routes
- number of clients in each main stop, on time intervals
- average fuel consumption
- average greenhouse gas emissions for the vehicles involved in the simulation.

For a given number of clients, the carpooling simulation algorithm allows us to load a car with 1, 2, 3, 4 or with a random number (between 1 and 4) of clients. For the chosen routes and stops, the calculations provide as output data:

- number of needed cars (for each of the five variants of loading)
- total fuel consumption
- total greenhouse gas emissions.

## 2.5 Applications and Experiments

The applications presented in this section integrate diverse computing languages with platforms, standards and technologies. They have been used to perform a preliminary experiment regarding the appropriateness of implementing a carpooling service in the metropolitan area of Bacău.

### 2.5.1 *SplitCar*

The *SplitCar* application implements the model with Microsoft solutions: the *Visual Studio 2013* suite, the *.NET Framework 4.5* package, *C#* and *XML*, the components *Windows Presentation Foundation* (WPF) for controlling the map delivered by *Bing*, and the *REST* service for locations and routes, offered by *Bing Maps*.

Given that the majority of the handled data represent locations, distances and routes, we have chosen as support the *Bing Maps* tool. In order to use maps, the *Map* control will be placed in a WPF window. Besides the *Map* control, an active Microsoft account and a *Bing* key are needed for the use of the map-related services: locations finding, distance calculator, route finding. After setting the Microsoft account and getting the key access to the *Bing* services, this key is assigned to the *Map* control *CredentialsProvider* attribute:

```
<WPF:Map CredentialsProvider='key' />
```

The map is initialized using the attributes *Mode* (*RoadMode*, *AerialMode*, *AerialModeWithLabels*), *ZoomLevel*, *AnimationLevel*, *Heading*, which can be modified at any time through the controller, using *C#*. For a complete control over the map, several functionalities have been implemented in the main window of the application, as Fig. 2.4 presents.

Several child controls may be added on the *Bing* map with the command

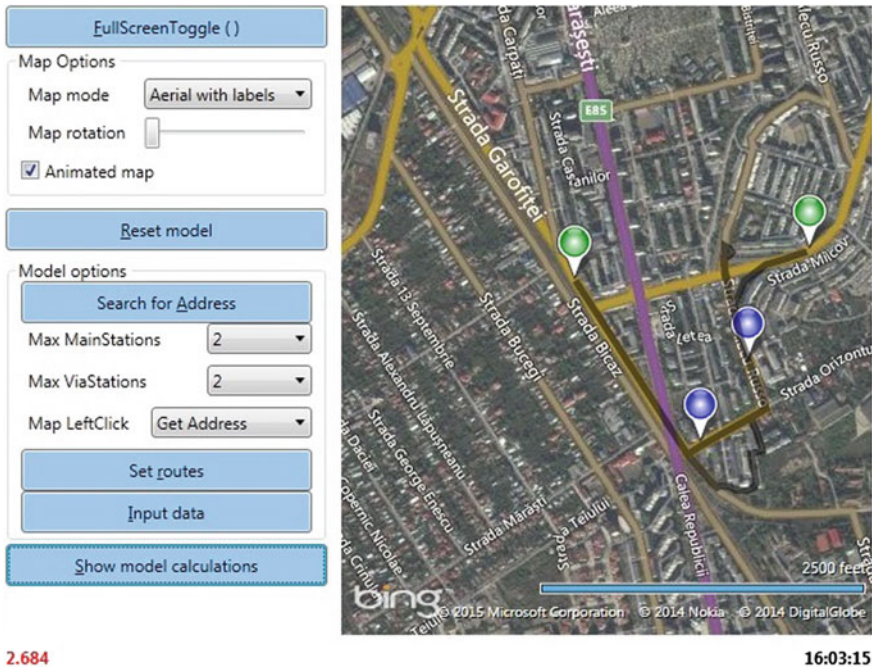
```
<map_name>.Children.Add(<control>);
```

These controls could represent locations, routes (*MapPolyline* objects), surfaces (*MapLayer* objects) or other objects. Only the first two are compulsory for our model implementation.

The locations are defined through *Pushpin* type controls, whose attributes allow the customization desired by the user. In Fig. 2.4, the main stops are coloured in green and the secondary ones appear in blue. Both types are created with a left-click of the mouse in the *Map* control. Right click on a location removes it from the map.

In the main window of the application, several items are designed to offer an improved control over the map. The user can set the maximum numbers of main stops (between 2 and 4) and secondary or via-stops (between 0 and 9).

Routes can be defined on the map between any two points, with a *MapPolyline* control, according to the following conventions: any route starts in a main stop and



**Fig. 2.4** The main window of *SplitCar*. Routes and stops

ends with a main stop (different from the origin); any route can pass through zero, one or more secondary stops; routes are displayed on the map with different colours, automatically computed according to the number of routes; the routes take into account the one-way roads; if a location (part of one or more routes) is deleted, the user implicitly agrees to delete all the routes that pass through that location/stop. Any number of routes can be created, and the definition of a route can be cancelled at any time.

The routes are created when activating the *Set routes* button (which opens the dialog window only if at least two main stop are already defined). For the accuracy of the implementation, we have used the services *REST* from *Bing Maps*. These services receive information on locations and routes, interpret them and display them on the map. The distance between two points on the map is computed in kilometres. In Fig. 2.4, the length of the routes appears in the low, right corner.

The implementation of a class that finds a certain location on the map is simple. The button *Search for address* opens a window where the user can introduce an address. After providing it, the class *LocationFromAddress* returns the corresponding location (latitude and longitude coordinates) on the map:

```

class LocationFromAddress
{
    private string BaseUrl =
        "http://dev.virtualearth.net/REST/v1/Locations?query=";
    private string BingAdditional =
        "&output=xml&include=queryParse";
    private string BingMapsKey = "&key=my_private_key";
    private string BingQuery = string.Empty;
    private Location point;
    public LocationFromAddress();
    public void SetQuery(string);
    public Location Run();
    private Uri AssembleLink();
    private string NormalizeQuery(string);
}

```

Conversely, the class *AddressFromLocation* returns an address if the location is given in latitude and longitude:

```

class AddressFromLocation
{
    private string BaseUrl
        "http://dev.virtualearth.net/REST/v1/Locations/";
    private string BingAdditional =
        "?output=xml&includeEntityTypes=
        Address&includeNeighborhood=1";
    private string BingMapsKey = "&key=my_private_key";
    private Location point;
    public AddressFromLocation();
    public void SetPoint(Location);
    public string Run();
    private Uri AssembleLink();
}

```

The next step is to compute the optimal routes and their lengths. The route between two main stops (with or without intermediary stops) is generated with the class *RouteBetweenTwoPoints*, whose components are as follows:

```

class RouteBetweenTwoPoints
{
    public enum MapOptions { Start = 0, End,
        ViaPoint, Optimize, TravelMode, Points, Tolerance };
    public enum OptimizeRoute { Time = 0, Distance,
        TimeAvoidClosure, TimeWithTraffic };
    public enum TravelMode { Driving = 0, Walking, Transit };
    private LocationCollection viaPoints;
    private Location Start, End;
    private List<string> Options = new List<string>();
    private string BaseUrl =
        "http://dev.virtualearth.net/REST/v1/Routes?o=xml";
    private string BingMapsKey = "&key=my_private_key";
    public RouteBetweenTwoPoints();
    public string SetRequestParameter(MapOptions, object);
    public MapPolyline Run();
    public string GetLink();
    private Uri AssembleLink();
}

```

We notice that the function *SetRequestParameter* receives as first parameter an object of *MapOptions* type and holds the information on what needs to be established, while the second parameter is an object which depends on the type of the first parameter. For example, if *RouteBetweenTwoPoints* is used to define a route, the function *SetRequestParameter* sets the following:

- the start and stop points (main stops)
- the intermediary points of the route (the secondary stops, if any)
- the optimisation type (there are four possibilities, to optimise upon: time, distance, traffic jams avoidance, time and traffic data)
- the travel type (with three options: driving, walking, transit)
- the type of the desired output, indicating if we need the points returned by the *REST* service to create the route)
- the tolerance allowed for the points to determine the route.

If all the data have been appropriately setup with *SetRequestParameter*, the route is received in a *MapPolyline* object, with the function *Run*. Afterwards, the computations are made with the class *DistanceBetweenTwoPoints*.

For each route and four time intervals (6:00–10:00, 10:00–14:00, 14:00–18:00, 18:00–22:00), a number of persons requiring the carpooling services can be introduced when activating the button *Input data*, as in Fig. 2.5. Moreover, the average fuel consumption and the average greenhouse gas emissions are required, per private, regular car and per carpooling vehicle.

When all the input data are available, the module *RouteData* performs the computations of the output information (total fuel consumption and greenhouse gas emissions) for a certain route. The data are presented in several formats: text, tables and histograms, according to the users’ choice, when activating the button *Show model calculations*. An example is given in Fig. 2.6, where the value “5” on the

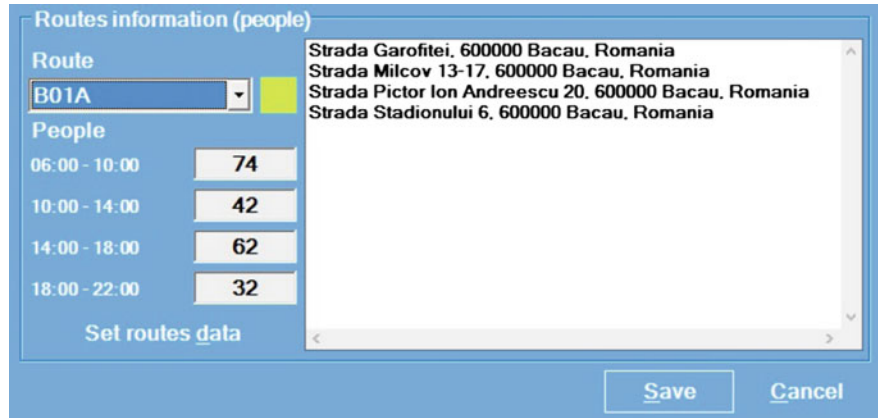


Fig. 2.5 Data acquisition window for *SplitCar*

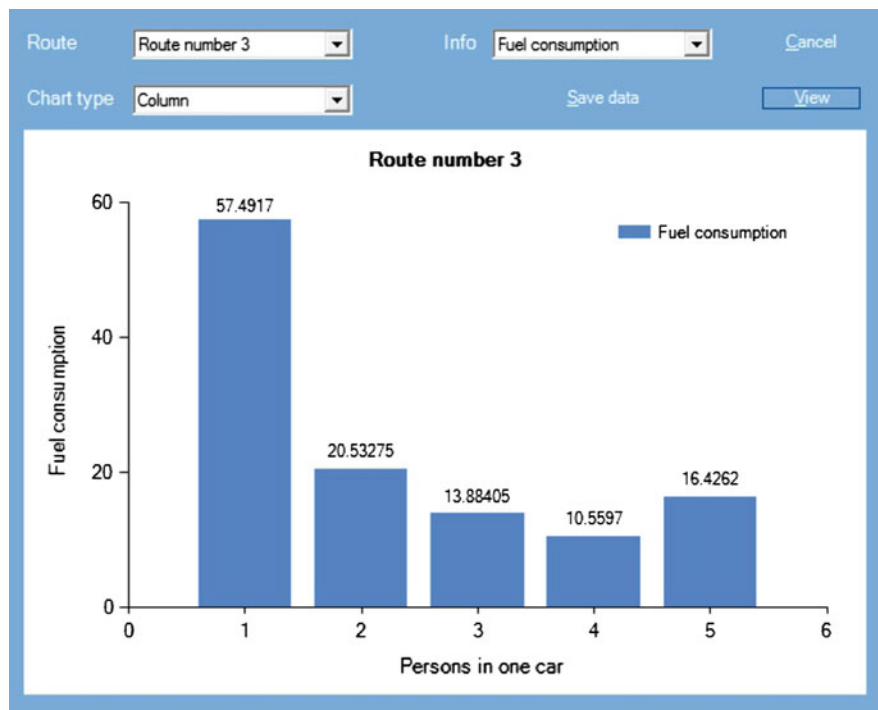
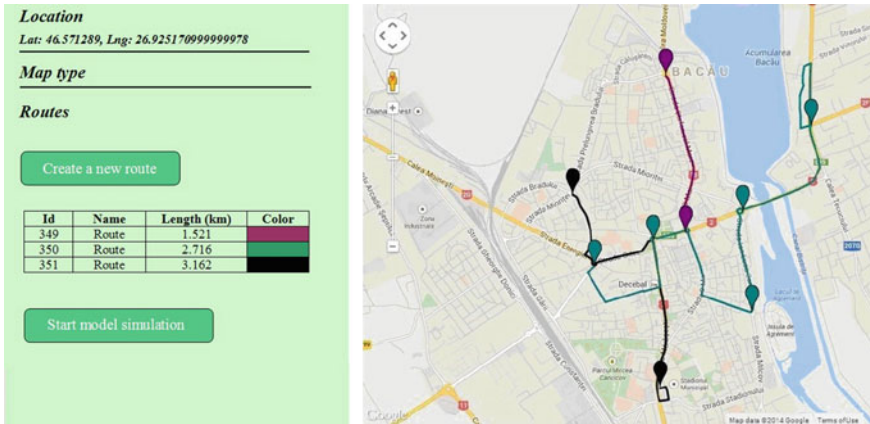


Fig. 2.6 A diagram for *SplitCar* output data

horizontal axis encodes what was denoted as “random setting” in Table 2.2, namely a *random* number (between 1 and 4) of occupants in a car. The total fuel consumption is measured in litres.

2.5.2 *Buddy*

The *Buddy* application is a web-based solution. We have chosen to use *ASP .NET* for the server-side, *JavaScript*, *JQuery*, *Ajax* as programming languages, *HTML*, *CSS* and other applications for improving the design of the web interface (*JQueryUI*, *Bootstrap*, *jChartFX*), all of them embedded in *Visual Studio*. We also used the API provided by Google for the well-known mapping service *Google Maps*. The API also allows the use of maps stored on sites of third parties, and includes a locator for organisations (as well as other objectives) placed on the territories of numerous countries all over the world.



**Fig. 2.7** The interface of *Buddy*

The interface of *Buddy* is simple (Fig. 2.7), with two main zones. For its dynamic configuration (resizing in accordance with the browser window or with the device display) we have used the *Bootstrap* style class collection. The right zone is a container that includes the *Google Maps* API. This API must be included in the header of the web page with:

```
<script
  type="text/javascript"
  src="https://maps.googleapis.com/maps/
    api/js?sensor=false">
</script>
```

and an object map is defined with:

```
var mapOptions =
{
  mapTypeControl: false,
  mapTypeId: google.maps.MapTypeId.ROADMAP,
  center: new
    google.maps.LatLng(46.571289, 26.925170999999978),
  zoom: 14 //zoom 14 times on Bacau
};
map = new google.maps.Map(
  document.getElementById("#map-canvas"),
  mapOptions);
geocoder = new google.maps.Geocoder();
```

The left zone of the interface uses the *accordion* widget from the *JQuery UI* package and offers access to three tabs: *Location*, *Map type*, and *Routes*.



The packages *jQuery* and *jQuery UI* have to be included in the header of the web page with:

```
<head runat="server">
  <script src="jquery-1.9.0.min.js" type="text/javascript">
  </script>
  <script src="jquery-ui-1.10.4.js" type="text/javascript">
  </script>
  <link href="jquery.ui.accordion.css"
    rel="stylesheet" type="text/css" />
</head>
```

As the widgets in *jQuery UI* use the *jQuery* classes, it is compulsory that the order of the lines in the above sequence code is maintained.

The user can search for a new location, either introducing its name or its coordinates. When searching for an address upon its name, the function *findAddress()* gets the input text and (if this is consistent) uses the *geocode* method, as follows:

```
geocoder.geocode(
{ 'address': address }, function (results, status)
{
  if (status == google.maps.GeocoderStatus.OK)
  {
    map.setCenter(results[0].geometry.location);
    $("#location-coordinates").html
      "Lat: " + map.getCenter().lat() + ", Lng: " +
      map.getCenter().lng();
  }
  else
    alert('Geocode was not successful
      for the following reason: ' + status);
});
```

If the corresponding search is successful and the function returns a list of locations, the map is centred in the first result, which is considered to be the most significant. When searching for an address upon its coordinates, the map is centred in the point defined by the specified coordinates (if they are correct) with

```
map.setCenter(new google.maps.LatLng(lat, lng));
```



**Fig. 2.8** A hybrid view over Bacău, with *Google Maps*

With *Map type*, the user changes the view, choosing among: *Roadmap* (as in Fig. 2.7), *Satellite*, *Hybrid* (as in Fig. 2.8) or *Terrain*.

The tab *Routes* is the most complex. It provides functionalities that allow to create and to modify routes on the *Google* map. When the web application is launched, an *Ajax* function calls an ASP.NET function from the server. It returns (if any) the routes previously saved in the database. The results provided by this function appear to the user as in Fig. 2.7, and are stored in a JavaScript object of JSON type. For the routes displayed in Fig. 2.7, the JSON object is as follows:

```
46.58299327827027-26.912510097026825/46.56989553861151-
26.91491335630417;
46.57880470562833-26.930191218852997/46.57160668424229-
26.92186564207077/46.56328646931478
26.922981441020966/46.56912845580439-
26.910965144634247/46.56706317894082-26.903841197490692;
46.57302276393836-
26.90118044614792/46.556971695640904-26.911823451519012;
```

The function *parseExistingRoutes* receives the above string and decomposes it in values representing the coordinates of the routes:

```
function parseExistingRoutes(string)
{
  string = string.substring(0, string.length - 1);
  var routes_strings = string.split(';');
  for (var i = 0; i < routes_strings.length; i++)
  {
    var route_string = routes_strings[i].split('/');
    var lcs = new Array();
    for (var j = 0; j < route_string.length; j++)
    {
      var locations_strings =
        route_string[j].split('-');
      lcs[j] = new Object();
      lcs[j].lat = locations_strings[0];
      lcs[j].lng = locations_strings[1];
    }
    r++;
    showRoute(lcs, function (distance) {});
  }
}
```

For each location, an object such as

```
{ lat: 46.57302276393836, lng: 26.90118044614792 }
```

is created. For each route, the application generates a vector of objects. This is further sent to the function *showRoute()* which recomposes the route. The first element of the vector always becomes the start point and the last one is seen as the destination. If the route is made of more than three locations, the intermediary ones become via-stops:

```
var start = new google.maps.LatLng(ls[0].lat, ls[0].lng);
var end = new google.maps.LatLng(ls[len - 1].lat,
ls[len - 1].lng);
var waypoints = [];
for (var i = 1; i < len-1; i++)
  waypoints.push({location: new google.maps.LatLng
ls[i].lat, ls[i].lng), stopover: true});
```

where the function *google.maps.LatLng(x,y)* creates *Google* objects of type *point*.

To display a route, the algorithm finds the shortest path that connects the starting point with the destination, preserving the position and the order of the intermediary locations. This is done with a *request* object, which is further used as a parameter for the functions in the *Google API*:

```
var request =
{
  origin: start,
  destination: end,
  waypoints: waypoints,
  optimizeWaypoints: true,
  travelMode: google.maps.TravelMode.DRIVING
};
```

Each point is identified with a *Marker* type object on the Google map. Ten images (for the marker objects) in ten different colours are stored in the resources file of the system, to enhance the routes readability on the map. The marker objects are initialised with

```
var icon = "Resources/marker" + r%10 + ".png";
for (var i = 0; i < len; i++)
{
  var marker = new google.maps.Marker({
    position: new google.maps.LatLng(ls[i].lat, ls[i].lng),
    map: map,
    icon: new google.maps.MarkerImage(icon)});
  newmarkers.push(marker);
}
```

where  $r$  is the index of the route.

The computations and the route display are done through a call of the *Google API*:

```
var directionsDisplay =
new google.maps.DirectionsRenderer({
  polylineOptions:
    {strokeColor: colors[(r - 1)%10] },
  suppressMarkers: true, preserveViewport: true });
directionsDisplay.setMap(map);
```

which specifies the desired colour for the route, cancels the standard markers display and indicates no zoom over the created route.

If the call is successful, the route is displayed (with the customized markers) and its length (in kilometres) is computed:

```
if (status == google.maps.DirectionsStatus.OK)
{
    directionsDisplay.setDirections(response);
    for (var i = 0; i < markers.length; i++)
    if (markers[i]) markers[i].setMap(null);
    var thisroute = response.routes[0];
    var distance = 0;
    for (var i = 0; i < thisroute.legs.length; i++)
    distance += thisroute.legs[i].distance.value;
    callback(distance / 1000);
    callback(response.routes[0].legs[0].distance.value/1000);
}
```

The application offers to the user the possibility of defining his/her own routes, when activating *Create new route*. This option calls the function *createRoute()*, whose main functionalities are to place markers in the desired locations and to reuse the already existing markers (both with right-click of the mouse). Instances of *Listener* type objects of the API are instantiated to activate these facilities:

```
listener1 = google.maps.event.addListener
map, 'rightclick', function (event)
{
    var marker=
    new google.maps.Marker
    ({position:event.latLng,map:map,title:'Marker-'+(l+1)});
    markers[l] = marker;
    var loc = new Object();
    loc.lat = event.latLng.lat().toString();
    loc.lng = event.latLng.lng().toString();
    locations.push(loc);
    ...

    for (var i = 0; i < newmarkers.length; i++)
    newmarkers_listeners[i]=
    google.maps.event.addListenerOnce
    newmarkers[i], 'rightclick',
    function ()
    {
        var marker =
        new google.maps.Marker
        ({ position: this.getPosition(), map: map, title:
        'Marker-' + (l + 1) });
        markers[l] = marker;
        var loc = new Object();
        loc.lat = this.getPosition().lat().toString();
        loc.lng = this.getPosition().lng().toString();
        locations.push(loc);
        ...
    }
}
```



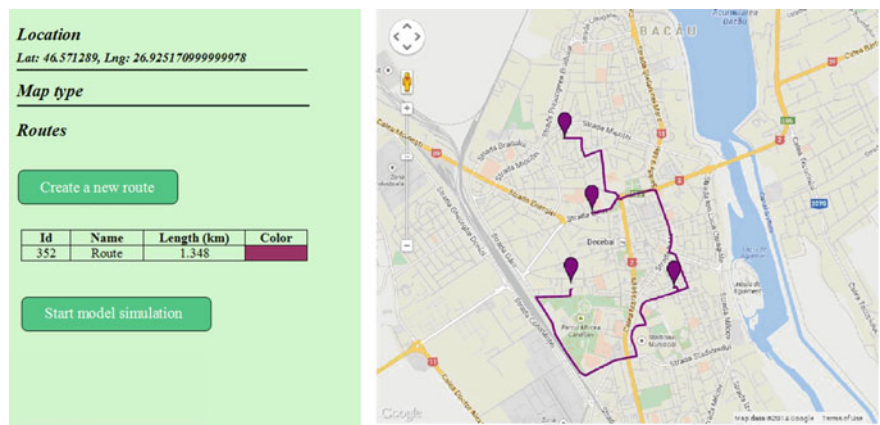


Fig. 2.10 The definition of the route is completed

The simulation starts when activating the button *Start model simulation*, which opens the windows where the user presents:

- the parameters (the same as in the first application: number of passengers, the average fuel consumption and the average greenhouse gas emissions per privately-owned car and per carpooling vehicle);
- data for each route: number of travellers on that route, per day and time intervals.

Both applications presented here are available at [50], where we have collected a series of applications designed to illustrate the role of Informatics in developing intelligent systems to support the sustainable development of our society. The results presented in the following Section were obtained on a desktop PC with a 2 GHz quad-core processor and 2 GB RAM capacity.

## 2.6 Results and Discussion

The application *Buddy* generates, for each route, a table (see Table 2.1) where the user can compare the figures related to each type of mobility setting, defined by the column *Persons per car* (4). The lines shadowed in grey correspond to the mean value of the vehicles loading, determined as the average of the sequence of random numbers (between 1 and 4) whose sum cover the travel request. The values in column (7), computed as the product between the route lengths, the number of cars and the quantity of CO<sub>2</sub> emissions per car and per kilometre, have been rounded to the nearest integer.

**Table 2.1** Comparison between five mobility choices

Route ID/Route name/Route length (km)	Time intervals	Travel request (number of persons)	Persons per car	Number of needed cars	Total fuel consumption (l)	Total CO <sub>2</sub> emissions (g)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
363/Route 363/1.614	6:00–10:00	250	1	250	28.25	64,561
			2	125	13.11	20,174
			3	84	8.11	13,556
			4	63	6.61	10,167
			2.58	97	10.18	15,654
	10:00–14:00	190	1	190	21.47	49,066
			2	95	9.97	15,332
			3	64	6.71	10,328
			4	48	5.04	7748
			2.79	68	7.13	10,976
	14:00–18:00	100	1	100	11.30	25,823
			2	50	5.25	8071
			3	34	3.57	5488
			4	25	2.62	4036
			2.56	39	4.09	6293
	18:00–22:00	80	1	80	9.04	20,670
			2	40	4.20	6457
			3	27	2.83	4358
			4	20	2.10	3229
			2.76	29	3.04	4681

The data in columns (6) and (7) can also be seen in charts, built with *jChartFX* support. The package *jChartFX* (which requires the presence of *jQuery* tools) must be included in the header of the web page:

```

<script src=
  "jchartfx.advanced.js" type="text/javascript"></script>
<script src=
  "jchartfx.system.js" type="text/javascript"></script>
<script src=
  "jchartfx.coreVector.js" type="text/javascript"></script>

```

The simulation has been run for a flow of 10,000 persons (which represents an estimation for the number of the commuters in a working day for Bacău city) and for an average route of 12 km length per car and per day. We used various routes



**Table 2.2** Sample output data

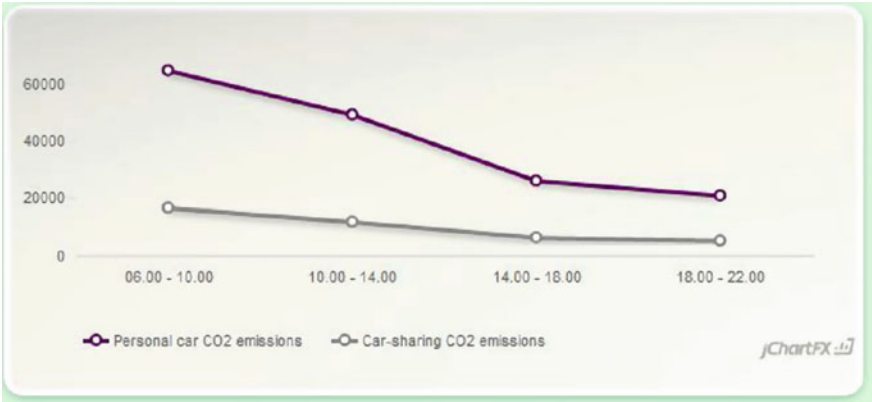
	Number of needed cars	Total fuel consumption (l)	Total CO <sub>2</sub> emissions (kg)	Fuel economy and CO <sub>2</sub> emissions decrease (%)
(a) Personal ownership (2 persons per car)	5,000	4,200	7,800	–
(b) Carpooling (1 to 4 persons per car; random setting) <i>Set 1 of parameters</i>	3,900	3,276	6,084	22.00
(c) Carpooling (1 to 4 persons per car; random setting) <i>Set 2 of parameters</i>	3,900	2,340	4,680	44.28

and two sets of parameters. *Set 1* models the case when the cars used for carpooling have the same characteristics as the regular ones. As most of the passenger cars used in Romania complies with the *Euro 4* emission standard, we have set the fuel consumption per 100 km at 7 L (of gasoline) and the CO<sub>2</sub> emissions at 130 g/km [39]. *Set 2* simulates a modern carpooling fleet, using vehicles with superior performances, for which the two parameters were set to 5 L/100 km and 100 g/km, respectively.

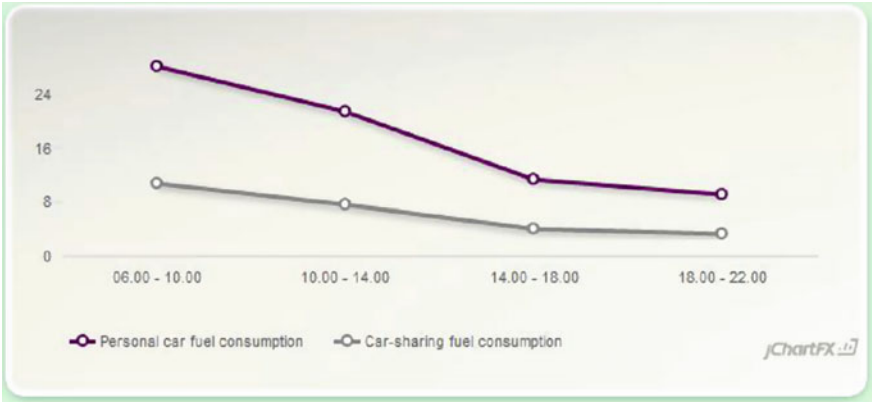
Table 2.2 presents a sample of output data, which display substantial fuel savings and important CO<sub>2</sub> emissions decrease. Although the applications allow the user to simulate a vehicle loading with any number (from 1 to 4) of passengers, the table includes only the lines for two persons per car and for the random loading, which is the most plausible situation to happen in real life. For the computation in the last column, the reference line is (a), for both (b) and (c).

If we consider an average price of 1.1 euros per gasoline litre in 2014 [40], we get a daily saving of 1,016 euros for case (b) and 2,046 euros for case (c). According to the SWOT analysis performed by Bacău County Council [45], the investments of the inhabitants in health-care and education decreased during the last years. The savings could be directed towards these domains, which could improve the quality of life, both at personal and community level. Moreover, the impact of the shared mobility services on the environment must not be disregarded. The results of the simulations are represented in Figs. 2.11 and 2.12.

Despite these encouraging results, we should question the attitude of the public in Bacău metropolitan area towards the carpooling option. A study on this issue is part of our future work, but preliminary research show that there are both psychological barriers and lack of involvement from the local stakeholders regarding this mobility solution.



**Fig. 2.11** The total CO<sub>2</sub> emissions for single-driver case (*indigo*) and for random number of passengers case (*grey*)



**Fig. 2.12** The total fuel consumption for single-driver case (*indigo*) and for random number of passengers' case (*grey*)

## 2.7 Conclusions and Further Work

Transportation activities have major adverse impact on most of the urban agglomerations, as the traffic is more and more busy and the pollution becomes difficult to mitigate.

The cars cannot be eliminated from our lives but the unwanted effects of their extensive use could be reduced through intelligent strategies. There are several solutions for that: ecological car design, efficient metropolitan networks, multi-modal planning etc. Among them, *car-sharing* and *carpooling* are two modern

concepts and should be put forth; specific solutions and facilities should be developed, as both are cost-effective and social rewarding.

Car-sharing and carpooling become more effective and more attractive when seen as an alternative means of transport that can be used together with the personal vehicles and/or with the public transport systems. Practically, all the shared-mobility companies started by manually managing their services: the users place a booking of a vehicle to a human operator, get the key and register the personal data in a form stored in the car. As the programmes have extended their fleet rapidly, the manual-operated systems became expensive and inconvenient, generating errors. Automated reservations, key management and billing offer make the share-used solutions more attractive and effective.

In Europe, car-sharing and carpooling have already proved to be effective in several countries, including: Austria, Germany, Switzerland and Netherlands. In Romania, the participation of several municipalities in European projects (such as Bucharest in the *CIVITAS TELLUS—Transport and Environment Alliance for Urban Sustainability* [51], Sibiu and Timișoara in *TRANSPower—Supervised Implementation of Sustainable Urban Transport Concepts* [52], Suceava, in *MIDAS—Measures to Influence transport Demand to Achieve Sustainability* [53], Brăila in *PILOT—Planning Integrated Local Transport* [54]) and organisations (such as *The Romanian Public Transport Association* in *LINK—The European forum on intermodal passenger travel* [55]) started to implement several forms of ICT-based intelligent mobility solutions.

There is a ride sharing community and several initiatives that Romania joined, such as [56, 57]. EkoRoad [58] and 4 in masina [59] are two Romania-based car-sharing/carpooling services available on mobile devices. The former has expanded its area at European level [60].

In Romania, the market share of electric and hybrid vehicles is now less than 0.01 % [61]. A single public charging point is available in Bucharest (however, it is estimated [62] that in 2020, the market share will reach over 5 %). Fuel prices have increased in recent years and their evolution is now uncertain. As the development of infrastructure is not expected soon, the city of Bacău could significantly benefit from the implementation of several “soft” measures for improving its transportation capacity, efficiency and comfort (see [63] for a review on Clean Transport Systems and related issues). Bike-sharing (which will be implemented in the future) and car-sharing/carpooling are such measures which may have a high benefit-cost ratio.

Our future work will focus on developing a carpooling application for mobile devices. The already implemented features (such as routes definition, or operation on maps) will be preserved and some more will be added, such as finding the nearest vehicle available on the way, therefore approaching a dynamical perspective designed to fit the users’ needs and to optimise the efficiency of the shared system. Another research direction that we will investigate refers to the use of ACO metaheuristic [64, 65] for solving the *Daily Car-Pooling Problem* and to the assessment of this metaheuristic performance when compared to the results in [66].

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## References

1. Coates, A.: Guide to victory. *Popular Gov.* **9**(1–4), (1943). <https://archive.org/details/populargovernmen914inst>. Accessed Nov 2014
2. Transportation and Parking, West Virginia University. <http://transportation.wvu.edu/prt>. Accessed Nov 2014
3. DART’s RideShare program site. <http://www.ridedart.com/services/rideshare>. Accessed Nov 2014
4. San Francisco Bay 511 program site. <http://www.511.org>. Accessed Nov 2014
5. Covouiturage Ecolutis site. <http://www.ecolutis.com>. Accessed Nov 2014
6. Villefluide project site. <http://www.villefluide.fr>. Accessed Nov 2014
7. Carpooling and Ridesharing across Europe site. <http://www.ridefinder.eu>. Accessed Nov 2014
8. NuRide project site. <http://www.nuride.com>. Accessed Nov 2014
9. Knapen, L., Yasar, A., Cho, S., Keren, D., Dbai, A.A., Bellmans, T., Janssens, D., Wets, G., Shuster, A., Sharfman, I., Bhaduri, K.: Exploiting graph-theoretic tools for matching in carpooling applications. *J. Ambient Intell. Humaniz. Comput.* **5**(3), 393–407 (2014)
10. Ferrari, E., Manzini, R., Pareschi, A., Persona, A., Regattieri, A.: The car pooling problem: Heuristic algorithms based on saving functions. *J. Adv. Trans.* **37**, 243–272 (2003)
11. Nagare, D.B., Moore, K.L., Tanwar, N.S., Kulkarni, S.S., Gunda, K.C.: Dynamic carpooling application development on Android platform. *Int. J. Innov. Technol. Explor. Eng.* **2**(3), 136–139 (2013)
12. Graziotin, D.: An analysis of issues against the adoption of dynamic carpooling. <http://arxiv.org/abs/1306.0361> (2010)
13. Chan, N.D., Shaheen, S.A.: Ridesharing in North America: past, present and future. *Transp. Rev.* **32**(1), 93–112 (2012)
14. Austin car2go site. <https://www.car2go.com>. Accessed Nov 2014
15. U-T San Diego News site. <http://www.utsandiego.com>. Accessed Nov 2014
16. Zipcar car sharing project site. <http://www.zipcar.com>. Accessed Nov 2014
17. City Hire Club site. <http://www.citycarclub.co.uk/>. Accessed Nov 2014
18. DeBruin, L.A.: Energy and feasibility analysis of gasoline engine start/stop technology. Undergraduate Honors Thesis, Ohio State University (2013). [https://kb.osu.edu/dspace/bitstream/handle/1811/54555/Start-Stop\\_Thesis.pdf](https://kb.osu.edu/dspace/bitstream/handle/1811/54555/Start-Stop_Thesis.pdf). Accessed Nov 2014
19. Suggested Upper Merged Ontology site. <http://www.adampease.org/OP/>
20. Open Cyc Platform site. <http://www.cyc.com/platform>
21. ISO 14825:2011 site. [http://www.iso.org/iso/iso\\_catalogue/catalogue\\_tc/catalogue\\_detail.htm?csnumber=54610](http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=54610)
22. SWEET Overview site. <http://sweet.jpl.nasa.gov/>
23. Open Geospatial Consortium site. <http://www.opengeospatial.org/>
24. Becker, M., Smith, S.: An ontology for multi-modal transportation planning and scheduling. Tech. report CMU-RI-TR-98-15, Robotics Institute, Carnegie Mellon University (1997)
25. Houda, M., Khemaja, M., Oliveria, K., Abed, M.: A public transportation ontology to support user travel planning. In: Loucopoulos P., Cavavero J.L. (eds.) *Proceedings of the International Conference on Research Challenges in Information Science, RCIS’2010 19-21, Nice, France* (2010)

26. Cho, S., Kang, J.I., Yasar, A.U.H., Knapen, L., Bellemans, T., Janssens, D., Wets, G., Hwang, C.S.: An activity-based carpooling microsimulation using ontology. *procedia computer science*. In: The 4th International Conference on Ambient Systems, Networks and Technologies (ANT 2013), The 3rd International Conference on Sustainable Energy Information Technology (SEIT-2013), vol. 19, pp. 48–55 (2013)
27. Dimitrakopoulos, G., Bravos, G., Nikolaidou, M., Anagnostopoulos, D.: Proactive, knowledge-based intelligent transportation system based on vehicular sensor networks. *Intell. Trans. Syst.* **7**(4), 454–463 (2013)
28. Correia, G., Viegas, J.M.: A conceptual model for carpooling systems simulation. *J. Simul.* **3**, 61–68 (2009)
29. Wilkowska, W., Farrokhkhiavi, R., Zieffle, M., Vallée, D.: Mobility requirements for the use of carpooling among different user groups. In: Ahram, T., Karwowski, W., Marek, T. (eds.) *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics (AHFE 2014)* (2014)
30. Ciari, F.: Why do people carpool? Results from a Swiss survey. *Swiss Transport Research* (2012). <http://www.strc.ch/conferences/2012/Ciari.pdf>
31. Watts, R., Belz, N., Fraker, J., Gandrud, L., Kenyon, J., Meece, M.: Increasing carpooling in Vermont: opportunities and obstacles. University of Vermont Transportation Research Center (2010). [http://www.uvm.edu/~transctr/trc\\_reports/UVM-TRC-10-010.pdf](http://www.uvm.edu/~transctr/trc_reports/UVM-TRC-10-010.pdf)
32. Correia, G., Viegas, J.M.: Carpooling and carpool clubs: clarifying concepts and assessing value enhancement possibilities through a stated preference web survey in Lisbon, Portugal. *Trans. Res. Part A* **45**, 81–90 (2011)
33. Zhou, G., Huang, K., Mao, L.: Design of commute carpooling based on fixed time and routes. *Int. J. Veh. Technol.* (2014). <http://www.hindawi.com/journals/ijvt/2014/634926/>
34. Liu, N., Feng, Y., Wang, F., Liu, B., Tang, J.: Mobility crowdsourcing: toward zero-effort carpooling on individual smartphone. *Int. J. Distrib. Sens. Netw.* (2013). <http://www.hindawi.com/journals/ijdsn/2013/615282/>
35. Zhang, D., He, T., Liu, Y., Stankovic, J.A.: CallCab: a unified recommendation system for carpooling and regular taxicab services. In: *Proceedings of the 2013 IEEE International Conference on Big Data*, pp. 439–447 (2013)
36. Zhang, D., Li, Y., Zhang, F., Lu, M., Liu, Y., He, T.: coRide: carpool service with a win-win fare model for large-scale taxicab networks (2013). <http://www-users.cs.umn.edu/~tianhe/Papers/coRide.pdf>
37. Asakaite, I., Celik, B.: Mapping of logistics infrastructure of central and Eastern Europe for automotive Industry. Master Thesis, Göteborg University (2006). [https://gupea.ub.gu.se/bitstream/2077/9603/1/2006\\_72.pdf](https://gupea.ub.gu.se/bitstream/2077/9603/1/2006_72.pdf)
38. Government of Romania. Ministry of transport (2007) Sectorial operational programme transport 2007–2013. [http://www.fonduri-ue.ro/res/filepicker\\_users/cd25a597fd-62/Doc\\_prog/prog\\_op/5\\_POST/2\\_POST\\_Eng.pdf](http://www.fonduri-ue.ro/res/filepicker_users/cd25a597fd-62/Doc_prog/prog_op/5_POST/2_POST_Eng.pdf). Accessed Nov 2014
39. Romania—Open datasets site. <http://date.gov.ro/>. Accessed Nov 2014
40. European Environment Agency (2014) monitoring CO<sub>2</sub> emissions from passenger cars and vans in 2013. EEA Technical report 19/2014. <http://www.eea.europa.eu/publications/monitoring-co2-emissions-from-passenger>. Accessed Nov 2014
41. Inforegio EU Regional Policy site. [http://ec.europa.eu/regional\\_policy/index\\_ro.cfm](http://ec.europa.eu/regional_policy/index_ro.cfm). Accessed Nov 2014
42. National Institute of Statistics (2014). <http://www.insse.ro>. Accessed Oct 2014
43. European Statistics site. <http://ec.europa.eu/eurostat>. Accessed Oct 2014
44. Kaparias, I., Bell, M.G.H.: Key performance indicators for traffic management and intelligent transport systems. 7th framework programme, contract no. 218636 (2011). <http://www.polisnetwork.eu/publicdocuments/download/516/document/d-3-5—key-performance-indicators-for-traffic-management-and-its-final.pdf>. Accessed Nov 2014
45. Bacău County Council (2014) strategy for sustainable development of Bacău county for the period 2010–2030. <http://www.bids-see.ro/>. Accessed Nov 2014

46. European Commission, DG Enterprise & Industry (2009) The potential of intelligent transport systems for reducing road transport related greenhouse gas emissions. A Sectorial e-Business watch study by SE Consult, Final Report. [http://ec.europa.eu/enterprise/archives/e-business-watch/studies/special\\_topics/2009/documents/SR02-2009\\_ITS.pdf](http://ec.europa.eu/enterprise/archives/e-business-watch/studies/special_topics/2009/documents/SR02-2009_ITS.pdf). Accessed Nov 2014
47. Bacău County Council site. <http://www.csjbacau.ro>. Accessed Nov 2014
48. Millard-Ball, A., Murray, G., Schure, J., Fox, C., Burkhardt, J.: TCRP Report 108: Car-sharing: Where and How it Succeeds. Transportation Research Board of the National Academies, Washington DC (2005)
49. Shaheen, S.A., Wright, J., Sperling, D.: California's zero-emission vehicle mandate: linking clean-fuel cars, car sharing, and station car strategies. *Trans. Res. Rec.* **1791**, 113–120 (2001). TRB Paper 02-3587, Institute of Transportation Studies, UC Davis
50. BLISS project site. <http://www.bliss.ub.ro>. Accessed Nov 2014
51. Transport and Environment Alliance for Urban Sustainability (CIVITAS TELLUS project). <http://www.civitas.eu/content/tellus>. Accessed Nov 2014
52. Transport Research and Innovation portal. [http://www.transport-research.info/web/projects/project\\_details.cfm?id=11355](http://www.transport-research.info/web/projects/project_details.cfm?id=11355). Accessed Nov 2014
53. Midas Europe project site. <http://www.midas-europe.com>. Accessed Nov 2014
54. PILOT—Planning Integrated Local Transport. <http://www.pilot-transport.org>. Accessed Nov 2014
55. TRANSPOWER—Supervised Implementation of Sustainable Urban Transport Concepts. [http://www.transport-research.info/web/projects/project\\_details.cfm?id=35675](http://www.transport-research.info/web/projects/project_details.cfm?id=35675). Accessed Nov 2014
56. Roadsharing services project site. <http://www.roadsharing.com>. Accessed Nov 2014
57. Carpool Rideshare project site. <http://www.carpoolworld.com>. Accessed Nov 2014
58. Ekoroad travel project for Romania site. <http://www.ecodrum.ro>. Accessed Nov 2014
59. 4 in masina project site. <http://4inmasina.ro>. Accessed Nov 2014
60. Ekoroad travel project site. <http://www.ekoroad.com>. Accessed Nov 2014
61. Varga, B.O.: Electric vehicles, primary energy sources and CO<sub>2</sub> emissions: Romanian case study. *Energy* **49**, 61–70 (2013)
62. APIA (2014) Romanian association of the vehicle producers and importers. <http://apia.ro>. Accessed Nov 2014
63. European Commission, Directorate-General for Mobility and Transport (2011). Study on clean transport systems. Project 2010 final report. <http://ec.europa.eu/transport/themes/urban/studies/doc/2011-11-clean-transport-systems.pdf>. Accessed Nov 2014
64. Crişan, G.C., Nechita, E.: Solving TSP with Ant algorithms. *J. Comput. Commun. Control* **3**, 228–231 (2008)
65. Pintea, C.M., Crişan, G.C., Chira, C.: Hybrid Ant models with a transition policy for solving a complex problem. *Log. J. IGPL* **20**(3), 560–569 (2012)
66. Swan, J., Drake, J., Özcan, E., Goulding, J., Woodward, J.: A comparison of acceptance criteria for the daily car-pooling problem. *Comput. Inf. Sci.* **III**, 477–483 (2013)

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