# A Transport Based Clearing System for Dynamic Carpooling Business Services

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***Abstract*—The WiSafeCar (Wireless Traffic Safety Network Between Cars) project aims at creating a comprehensive wireless communication and service platform targeting vehicular networks, striving to reduce accidents and traffic congestion. Within the frame of this project, a dynamic carpooling transport system was designed, reacting in real time to events and user transport requests. In order to allow this system to integrate seamlessly with other transport modes, but also to encourage users to use carpooling, a clearing service has been implemented to solve the inherent compensation issues. Both the carpooling system and the underlying utility services have been prototyped, using the Netlogo simulator, to prove not only the efficiency of WiSafeCar at reducing the congestion in cities; but also to validate the business models to be implemented and more precisely the clearing algorithm.**

***VANET; clearing service; business model; dynamic carpooling***

## I. Introduction

WiSafeCar is a Eureka/Celtic founded European project that consists in researching and prototyping efficient car-to-car and car-to-infrastructure networking mechanisms in order to provide a support layer to a wide range of services to the users on the move, whether they are in their car or simply walking by. WiSafeCar uses state of the art car-to-car networking protocols – such as IEEE 802.11p and an efficient service oriented architecture. The services to be provided range from security related services such as geo-localized hazardous weather information to a dynamic urban transport solution reacting in real time to the status of the traffic and to disrupting events. An excerpt of the services to be provided is shown on Table I below. This paper will focus on the urban transport solution of the WiSafeCar project which consists in providing a dynamic carpooling service, as well as the peripheral services required to implement the associated business model.

While there are numerous attempts to provide a carpooling service, they did not meet the success hoped for, mainly due to the lack of flexibility and to the lack of incentives. Firstly, there is a lack of flexibility since drivers and passengers are required to register their travel preferences in advance, resulting in a mostly static routing problem as shown in [1,2,3,4,5]. Lots of effort was put in adding more dynamicity in the carpooling problem [6]. Efforts to properly model the underlying theoretical problem concluded that it was a subcase of the classical pick-up and delivery optimization problem [7,8], and as such NP-hard. A heuristic based solution to solve this problem was proposed in [9] and subsequently modified in [10].

The lack of incentive for the drivers, passengers and also the inexistence of reliable business models for the service providers is also a strong constraint on the deployment of a dynamic carpooling service and finding and validating viable business models as been one of the main focuses of every attempt at proposing a carpooling solution [11]. Moreover, the transportation and logistics market is growing very fast and the competition is hard and efficiency and time are key factors for the enterprises. Inter-modal freight tracking and fleet management is seen as the future of the transportation that promises a seamless inter-modal transportation system that is efficient, safe, flexible and environmentally sound; and meets the needs of the customers and the industry.

In order to deploying dynamic services, it is actually mandatory to solve new business issues. Basically, a customer may subscribe to a carpooling service or he might pay through the use of a credit card or even via his/her telephone bill. However, all of these payment concepts have drawbacks for the user: higher costs, difficulty of use, necessity to register before use, security issues, etc. They also create complex problems for the service provider as this requires handling a lot of contracts to be able to serve all possible mobile users.

TABLE I. WiSafeCar and Dynamic Carpooling Services Dependencies

| *Name* | *Overview* |
|---|---|
| Dynamic Carpooling | Provides real time planning for carpooler, with driver – passenger automated allocation and taking into account unforeseen events |
| Clearing | Provide compensation mechanisms to allow easy implementation |
| Location Tracing | Generate events when the user is not at the planned position |
| Route Planner | Planning route to expected destination, including stops to fetch carpoolers |
| Traffic Information | Traffic information provided by several third parties such as the road administration and other transport companies using a standard message format (Datex II) |
| Parking places | Real-time parking place availability info (Informational Service) |

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Our basic argument relies on the need for a clearing mechanism to harmonize the services offered by different carpooling providers. A carpooling provider might be a company (with employees), but it can also be an independent carpooling provider (with its members). A situation without clearing facilities is one where each party must make a prerequisite bilateral agreement with another party in order to do business with it. The benefit of such a clearing system is that it considerably simplifies the situation by introducing the role of a trusted party, who secures the interchange among parties without each of them having to set up prior bilateral agreements.

Thanks to the clearing mechanism, dynamic carpooling solutions can be easily deployed and adopted by the user because it solves the compensation issues between the drivers (offer) and the passengers (consumers).

In the context of dynamic carpooling, considering navigational services, we identified the role to be played by clearing activities at two distinct levels, namely financial clearing, and transport information and other clearing services.

Besides the basic payment and billing functionalities, it should be noted that some added value services can be offered by the clearing system such as archiving financial and transport transaction data, the aggregation of this data for deriving information, specific security services, etc. Information clearing corresponds with a clearing activity that is based on the matching of requests expressed by end-users for information with some specific location – and possibly time – data.

There are various scenarios associated with information clearing that may be considered in the context of a transportation system. On the one hand, it can offer information contents enriched with location (and possibly time). This enrichment is either 'static' (as in the case of a map where points of interest have a location) or 'dynamic' (as in the case where the location of a container is continuously updated). On the other hand, the end-user can query the information content by providing a location (and possibly time) such as in the case where they are looking for a carpooling service or for points of interest near their actual location.

We argue that such a clearing mechanism is a mandatory part of any on demand transport system involving several different service providers, but to perform properly, it requires gathering precise information on the trips and travellers, such as duration, actual distance travelled, identity of the drivers and passengers, etc. However to enable a proper implementation of the whole dynamic carpooling system, including demonstrating the effectiveness of this associated value chain, a realistic simulation tool should be implemented. To offer services providers a way to validate their business models before the actual deployment, this tool should be able both to take into account the behavior of the drivers and passengers to allow implementing several scenarios, but also to simulate the car-2-car and car-2-infrastructure communication allowing the transmission of the required information to the relevant services. This paper focuses on simulating a dedicated clearing mechanism that was implemented for the WiSafeCar dynamic carpooling transport service, in order to test and validate business models and associated transaction and clearing services, but also to demonstrate the efficiency of the dynamic carpooling solution on a realistic simulation.

To that extend, in this paper we discuss in more detail the design part of the system, the clearing service and the possible business models. We first present the dynamic carpooling transport mode and the related requirements and peripheral services in Section II, focusing on the clearing and compensation mechanism. Section III highlights the agent based simulator that will be used to perform simulations of the overall system. Before concluding, Section IV presents the results obtained in the context of several realistic use cases, showing the versatility of the simulator and the need and efficiency of the clearing service in the context of a dynamic carpooling transport mode.

## II. Dynamic Carpooling Transport Mode

Carpooling consists in sharing a personal vehicle with one or several passengers sharing part or an entire trip in common. While traditional carpooling requires a prior agreement among the persons that will share a ride, the dynamic carpooling transport mode aims at offering a planning solution able to react in real-time to any additional driver or passenger joining or living the "pool" of carpoolers. Dynamic carpooling will be able to generate on the fly – or within reasonable bounds – new planning and to provide them to the affected carpoolers. Also, any event that could have an impact on the planning should be taken into account, such as any significant traffic congestion, incident or road-works requiring either a re-routing or purely and simply a whole new planning computation. The dynamic carpooling will also be included in a step by step recommendation service, guiding each carpooler for the whole duration of their trip and providing up to date information concerning the shortest path to reach their destination. That is why the WiSafeCar communication and services platform is of utmost importance, since it maintains a seamless link between the mobile users and the service backend. The overall platform is described in [10].

### *A. Flexible, Real-Time Planning Solution for Carpooling*

Since there is no need for any in-advance planning, the dynamic carpooling transport solution relies on each user owning a mobile terminal such as a smart-phone running the ad-hoc carpooling client application, which in turns relies on the WiSafeCar communication and service platform to provide the actual planning and recommendation service. Each user enters on his mobile terminal his requirements, such as

Figure 1. WiSafeCar Services Platform

departure and arrival time and locations. This data alongside up to date information on traffic conditions for instance, is continuously processed using a flow algorithm. Any context change – traffic jam or accident – is immediately taken into account and a new planning is provided to the affected users directly on their terminal.

### *B. Data Collection and Position Tracing*

The WiSafeCar project is developed in Luxembourg, among other cities. There, the location tracing service collects positional data directly from the users using a multi-agent system (MAS), allowing a quick detection of any abnormal user position resulting in a new itinerary computation. This tracing service is tightly disconnected from the rest of the system and is subject to the user – through the application running on its mobile phone – voluntarily sending position updates when he detects an event possibly impacting his planning. This ensures that our application invades the little privacy as possible.

Moreover, third party transport provider services maintain up-to-date timetables and the road administration provides data concerning road-works, accidents, etc. mainly through standard web services connected to the main application platform as shown on Fig. 1.

### *C. Travel Transactions and Compensation*

For the purpose of modeling and clearly defining how the various actors participating in the dynamic carpooling service will interact with each other, we introduce two formalisms borrowed from the finance and business domain: transaction and clearing [12,13]. A *transaction* is the digital counterpart of the planned ride to be shared by a driver and a passenger, while *clearing* consists in compensating the changes in the actual trip, which may not be setup as planned; for instance as a result of intangibles events (traffic congestion, snow, etc.).

#### *1) Transaction Based System*

The value exchange procedures in WiSafeCar – for the transport scenario – rely on the existence of so called transactions, which are generated each time a driver and a passenger agree on traveling together during a carpooling trip. The content of one transaction depends on the business model but in general they contain the same type of data. For instance in the case of the dynamic carpooling transport mode, one transaction could contain information such as the amount of kilometers in one trip, the duration of the trip, a unique identifier for the driver and another one for the passenger.

The above parameters are gathered from all the participants to the transaction: drivers, passengers, etc. and there are dual transactions associated with each trip: one for the driver and one for the passenger. If the driver has to drive four passengers, there will be in turn eight transactions produced: two for each pair of driver / passenger.

#### *2) Clearing Service*

The clearing service plays three main roles in our application. The first one consists in allowing several actors to interact seamlessly within the dynamic carpooling transport mode: drivers, passengers, the carpooling service and the communication platform providers among others. The clearing house – who is hosting the clearing service – is also one of the considered actors. All the aforementioned actors exchange value when a carpooling trip is agreed upon or during the trip itself: the carpooling service provider gives an added value to both the drivers and the passengers through the real time planning service; the driver provide the passenger(s) with a transport; the communication platform provider allows relaying positional and traffic information as well as planning updates to and from the carpoolers. Theses exchanges are assessed thanks to the clearing service: it allows proper compensation for the service rendered by each actors according to the *business model* agreed upon.

Secondly, it assesses the validity of the transaction data. To that extend, it ensure that the dual transactions generated once a carpooling trip is agreed upon by all the parties are valid and homogeneous. It simply means that the transaction generated for the driver and its passenger counterpart should contain the same information. Any significant difference would mean a tentative of fraud or that some kind of data corruption did append during the processing of the transaction data.

The third role of the clearing service follow from one the main characteristics of the dynamic carpooling system that needs to react to unforeseen events in real time: any kind of event having an impact on the trip of one carpooler will also change the distance or time spent on a trip or both. The clearing service must take into account these changes since they have an impact on the value exchanged between the involved parties. An additional transaction, called "compensation transaction" is produced as a result of the unforeseen event. In specific cases, for instance when the new planning generated as a result of the event includes changing the organization of a car (a driver has to take or leave a passenger or a passenger has to change car), new transactions reflecting this new trips will be necessary.

Several implementation and in depth studies of service clearing on a more general basis are for instance available in [12] and [13].

#### *3) Transaction and Clearing Services Implementation*

The transaction and clearing services are implemented in a mostly distributed way as shown on figure 1. The high level services rely on an Enterprise Service Bus to communicate with each other using standard SOAP [14] based messages. In our implementation, the Mule ESB is used as well as the Saddle layer [15] for workflow designing. This approach allows the seamless integration of several third party developed services into our architecture and as such offers good opportunities for future evolutions.

The second half of the transaction service is distributed among the carpoolers terminal: each one runs a client application keeping track of several parameters such as the amount of kilometers spent with one driver, possible deviation from the initial planning, etc. These parameters are sent to the clearing system at the end of the trip by all the parties. Detailed implementation information for the whole platform is available in [10].

## III. Multi-Agent System Based Simulation

### A. *Urban Traffic Simulation in Netlogo*

The Dynamic Carpooling Simulator (see figure 2) within WiSafeCar was implemented, based in previous versions, in NetLogo (http://ccl.northwestern.edu/netlogo/), a multi-agent programming language and modeling environment for simulating natural and social phenomena.

Urban Traffic Simulation starts in Netlogo with the Gridlock model by [16]. Several enhancements have been done based on this initial model included in NetLogo distribution. In [17] we have an extended version of the Gridlock model that consists in an abstract traffic grid with intersections between cyclic single-lane arteries of two types: vertical or horizontal. Based on this enhanced version of the Gridlock model, the GTI group from the University of Vigo has carried out new extensions improving the MAS simulator in order to make it more realistic [18]. A new version of the simulator has been developed in collaboration between the GTI group from the University of Vigo and SSI of the CRP Henri Tudor in Luxembourg. The new version presented in this paper (see Fig. 2 on next page) we mainly add the dynamic carpooling functionality. But, we also enhance some of the previous functionalities of the multiagent system in order to get a more realistic scenario.

Since the Dynamic Carpooling System design had been previously carried out, the goal of the simulator was to evaluate how it works with different parameter settings and to gather information related to the trips in order to analyze current business models and/or to develop new ones. The Dynamic Carpooling Simulator includes a set of new features, which are described in detail in [19] that allow simulating: user creation, carpooling matching algorithm, high populated areas, accidents and also allow storing all the data related with the simulation.

### B. *Dynamic Carpooling Simulation*

In the context of the Dynamic Carpooling System described before, a partial prototype of the system [19] has been developed (see figure 2). The goal of the simulations done was to develop a quick prototype of the system to evaluate all the information related to the itineraries such as the distance covered, the time spent, the number of people who share the car during the different steps of the trip, etc.

At the end of each trip a new file, named with the user identifier, is created. We consider a trip as every route covered by one passenger since he gets into the car until he gets out. Therefore, the itinerary of one driver can contain several single trips. The mentioned file contains the information which is necessary to proceed with the corresponding compensation method. Users gather data at every step of the simulation by keeping count of the distance they have already covered. In the same way they count the time spent during their itineraries bearing in mind the passengers they are sharing with.

### C. *Transactions Generation in Netlogo*

Since we assumed that the first step in providing the carpooling service to a client is to ensure that he can afford the trip cost, we need to calculate the amount of credit the user must have in his account. With the aim of evaluating the clearing service, proposed for the Dynamic Carpooling System, in order to get a fair estimate of the cost of the trips, we have adapted the simulator to obtain data related to the ideal route a driver could cover in terms of traffic and accidents. Using these results we will be able to compare a normal trip, where traffic jams are common, with an ideal one by comparing the time spent during the route and the distance covered in both situations.

The simulation of the transaction starts when both a passenger and a driver arrange a trip. The simulator runs the

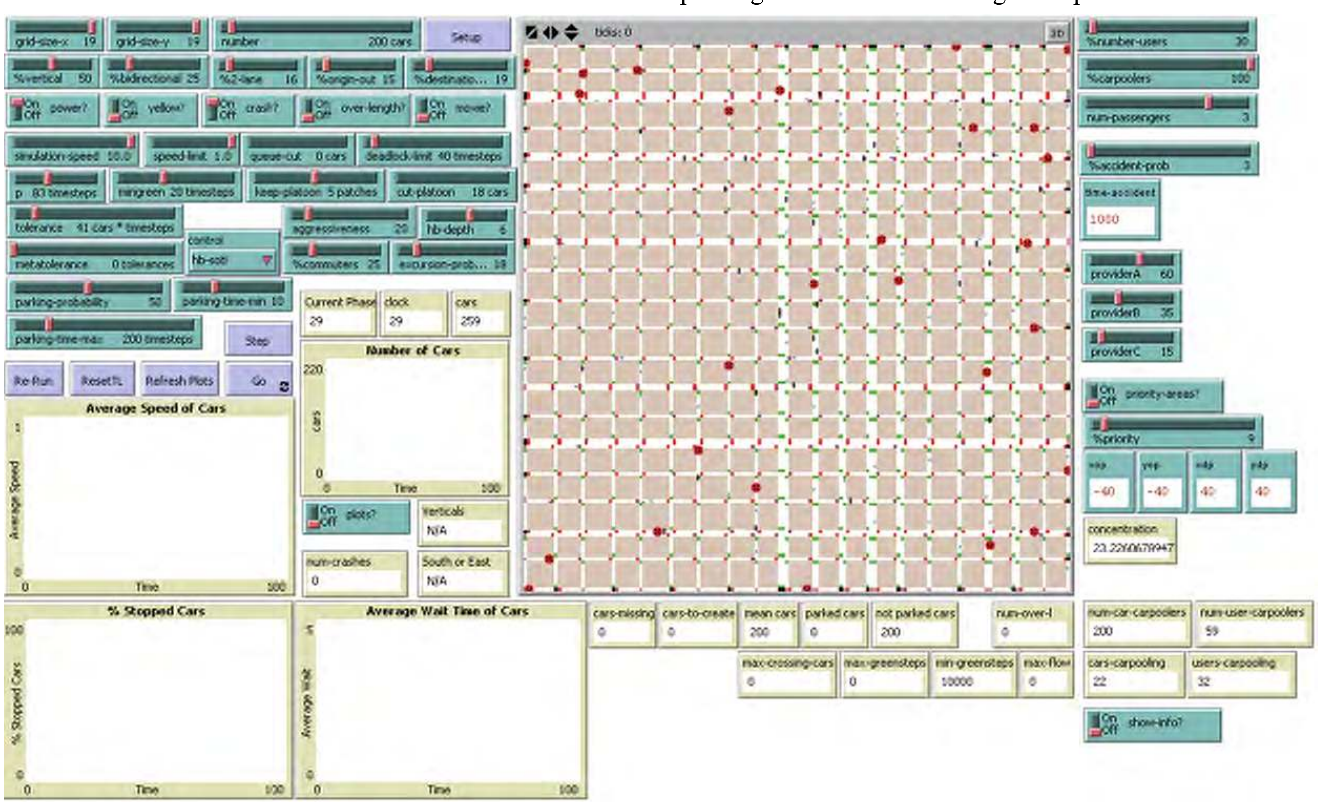


Figure 2. Snapshot of the Dynamic Carpooling Service Simulator

ideal situation in which the itinerary calculated by the route planner system is carried out without problems such as traffic jams, accidents or any inconvenient situation. In this simulation the data of the trip is gathered and the value of the route is calculated according to the business model. Then, once the system has checked the users are able to satisfy the agreement the transaction is generated.

The second step is to run a simulation with several random events that can cause alterations on the trip giving rise to variations on the value of the route calculated previously. In this case, when the trip is finished, a compensation transaction would be done in order to ensure a correct clearing between the two parties.

## IV. Experimental Results

The results presented in this section must be considered as initial case studies to clarify the design elements included in previous sections. Therefore, we do not provide here a deep technical description of the simulations, as a formal validation is in progress with a more realistic simulator.

### *A. Congestion Reduction*

Table II shows how the efficiency of the system increases with the increase of population and, of course, with the number of potential passengers and the percentage of drivers who belong to the system. The column %Traffic lists the percentages of traffic achieved with the carpooling service.

It is important to note that, in the conditions we have evaluated the system, even though the efficiency of the system is favored by the increase of the number of users, it is necessary to take into account the ratio of users served by the system. This maximum is reached when the number of drivers is five times greater than the number of users when the 50% of cars that belong to the system. We consider that this system could have a bigger impact on larger populations than on the smaller ones. We also consider that the persistence of a carpooling system is not possible without the integration of the public transports services, since many routes cannot be covered depending only on the drivers belonging to the system.

### *B. Clearing and Business Model*

#### *1) Clearing Scenario*

The considered clearing scenario relies on the following hypothesis and unfolding of events: Alice needs to go from Metz to Luxembourg Wednesday and she wants to arrive before 8am, Bob and Charlie want to go from Bettembourg to Arlon, Dave wants to go from Nancy to Brussels and must arrives before noon. A, B, C and D uses the WiSafeCar platform for the planning of their travels.

The recommendation system suggests the following planning: D takes B and C on his way to Brussels; D also takes A and makes a detour by Luxembourg for her. The system subsequently generates several transactions: from Alice's point of view, A was in D's car for 60kms. From Bob's point of view, B was in D's car for 40kms. From Charlie's point of view, C was in D's car for 40kms. Lastly from the driver's point of view, D drove A for 60kms, D drove B for 40kms and D drove C for 40kms.

The recommendation system computes the optimum itinerary for all participants and the number of spent in Dave's car. The overall cost of the trip is split in proportion of the number of kilometers done, the number of passengers in the car, each participant is informed of the planned cost and once everyone agrees the trip can start.

During the trip, if something occurs that has a significant impact on any parameter of the trip (traffic jam, roadwork…), the recommendation service computes a new planning to be submitted again to the carpooler and Compensation transactions are issued to reflect those changes. Once the trip is finished, the clearing service checks that the transactions obtained from all point of views are corroborating. Also the possible compensation transactions are subsequently applied. Finally, all participants are credited or debited according to their role in the trip.

#### *2) Business Models*

We are considering several transaction scenarios where four types of actors are involved: drivers, passengers, the clearing house and the carpooling operator. The purpose of these scenarios is twofold. Firstly they aim at demonstrating the good functioning of the system based on the previously mentioned actors while considering several value chain use cases. Secondly, there are used to prove that dynamic carpooling is a viable transport mode able to improve the quality of the road traffic in an urban context.

Depending on the business model and as an example, the carpooling operator could get either a fixed amount for each transaction successfully executed, a percentage of each transaction or both. Similarly, the clearing house operator could get a monthly fee, a percentage of each transaction processed or both. One of the main purposes of the improved NetLogo simulation tool is to allow testing some or all of the possible resulting business models by changing the parameters provided by each transaction, the threshold above which the compensation mechanism is triggered, etc. Thus, the simulation platform will have two different usages: one the one hand, it will help demonstrating the efficiency of the dynamic carpooling system and on the other hand, it will be a decision helping tool to facilitate negotiations between the actors involved in the resulting value chain.

#### *3) Simulation Results*

We tested different scenarios with several parameters and we simulated them in both normal and ideal ways. Regarding the ideal trip, we have assumed no traffic jams and the absence of accidents. The rest of the conditions remained the same as in the normal situation. In this context, we fixed the value of the amount of cars that belong to the system as the 50% of the total number of cars for each scenario. The number of passengers inside a car was 3 and the probability of accident established was 1%.

The size of the map and the distribution of the lanes was the same for all the simulations as well as the origin and destination of each car and passenger. For the traffic lights management we used the History-Based Self-Organizing method [18].

In order to obtain the efficiency of the transaction based business model, we have calculated the percentage of transactions which need to be compensated at the end the trip. Since the results of the ideal and normal trips are hardly ever exactly the same, we have assumed that a transaction need to be compensated provided that the real trip differs by more than one percent of the ideal one. With this in mind, we gather the results shown in Table II. The columns named %Time and %Distance contain the percentage of trips that satisfied the foreseen transaction in terms of time and distance respectively.

TABLE II. SIMULATION RESULTS FOR SEVERAL COMBINATIONS OF INPUT DATA

| *N* | *Number of Cars* | *Users* | *Users Served* | *%Time* | *%Distance* | *%Traffic* |
|---|---|---|---|---|---|---|
| *1* | 100 | 40 | 8 | 98,57 | 99,72 | 94,28 |
| *2* | 100 | 100 | 16 | 97,96 | 99,40 | 92 |
| *3* | 200 | 40 | 18 | 98,80 | 100 | 92,5 |
| *4* | 200 | 100 | 26 | 96,24 | 97,99 | 91,33 |
| *5* | 300 | 40 | 18 | 99,47 | 100 | 94,70 |
| *6* | 300 | 80 | 38 | 100 | 100 | 90 |
| *7* | 300 | 150 | 48 | 100 | 100 | 89,33 |
| *8* | 300 | 300 | 86 | 96,64 | 99,52 | 85,66 |
| *9* | 500 | 100 | 49 | 98,70 | 94,55 | 91,83 |
| *10* | 500 | 250 | 106 | 94,84 | 100 | 85,86 |
| *11* | 500 | 400 | 150 | 94,28 | 99,06 | 83,33 |
| *12* | 500 | 500 | 184 | 92,68 | 93,44 | 81,6 |
| *13* | 1000 | 200 | 110 | 67,54 | 95,24 | 90,83 |
| *14* | 1000 | 500 | 236 | 62,09 | 93,07 | 84,26 |
| *15* | 1000 | 1000 | 391 | 58,03 | 96,54 | 80,45 |

As we can see in Table II, for a low traffic level, the system proposed has a high performance causing that the compensation transaction, at the end of the route, in less than the 4% of the cases. These values start to differ when the number of cars is increased (see figures 3 and 4). When the level of cars is very high, there are significant variations in terms of time, and the percentage of compensation transactions reaches values close to 42%. If we think of a real situation, the same thing occurs if we compare the traffic during the rush hour and during the night. During the rush hour, the estimate of the right cost will be more difficult to calculate. Therefore, in order to estimate the suitable cost of the trips and to avoid many compensation transactions, we can take this information

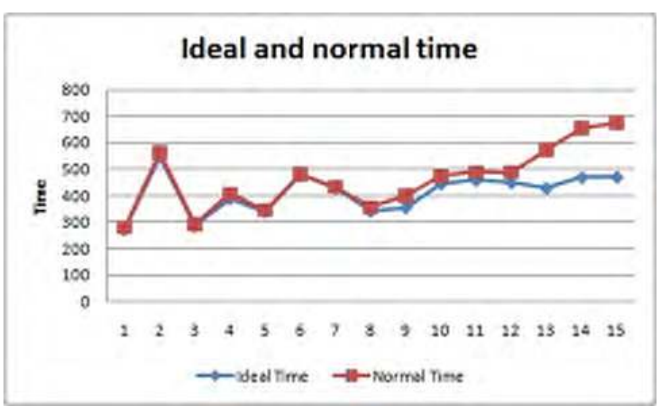


Figure 4. WiSafeCar Services Platform

into account when calculating the initial transaction.

The values shown in Table II show that the clearing service is of high importance in order to fairly compensate all the actors of the dynamic carpooling system. It is even useful in

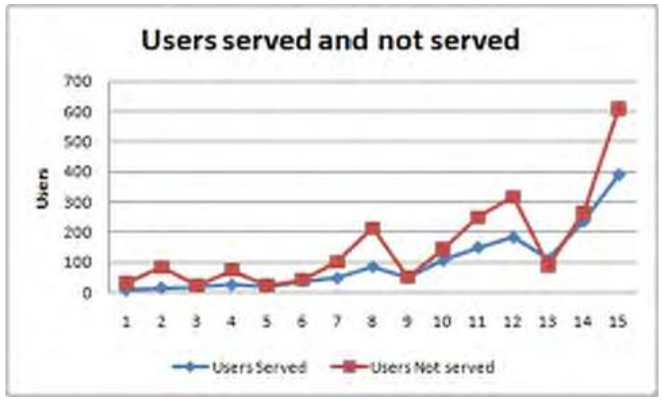


Figure 3. WiSafeCar Services Platform

"ideal" cases when the number and density of vehicles is limited, since the amount of correction performed is low but not negligible. When the density of cars reach higher values clearing service use becomes mandatory since grave disparities would exist otherwise. All in all, the Netlogo enabled simulator described in this document, even simple, is a valid tool to prove both the usefulness and efficiency of the clearing service and may be used as a test bed for services provider to evaluate define business models related to carpooling.

## V. CONCLUSIONS

This paper is focusing on the development of a transport based clearing system applied to the context of dynamic carpooling services. The main contributions presented in this paper related to the design and development of a clearing and compensation system applied to the carpooling transport services. The system has been validated in a case study using Netlogo simulator. We tested different scenarios with several parameters and we simulated them in both normal and ideal ways. The simulation results show that the system proposed for the estimate of the trip parameters has a high performance causing a compensation transaction at the end of the route in less than the 4% of the cases.

In case of a generalized use of this system the impact in sectors like economy and the environment would be enormous. The diminished traffic and, thus, the reduction of hours spent traveling, would affect hugely the quality of life of the citizens. Apart from all the benefits related to the traffic, the users have many economic advantages thanks to the sharing of costs which allows the individuals to retrench expenses. Dynamic carpooling will also generate revenue for all the intermediary actors and the tools described here will help finding the best business model that will leverage the revenue sharing depending on the considered context, such as the type and density of the regional area considered, the amount of traffic at peak hours, etc.

Future work will cover the security requirements associated to the clearing system, and we will consider more realistic simulations and scenarios.

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## REFERENCES

[1] Ferreira J.; Trigo P. and Filipe P., "Collaborative Car Pooling System". World Academy of Science, Engineering and Technology 54., 2009.

[2] Keenan, P. and Brodiey S. 2000. "A Prototype Web-based Carpooling System", Americas Conference on Information Systems, AMCIS 2000. Proceedings, 2000.

[3] Kelley, K.L., "Casual Carpooling—Enhanced". Journal of Public Transportation, Vol. 10, No. 4, 2007.

[4] Psannis, K.; Hadjinicolaou, M.; and Ishibashi Y., "Designing a Pervasive Architecture for Car Pooling Services". Advances in computer, information, and systems sciences, and engineering. 211-218, 2006.

[5] Yew, K.H.; Mustapha, E.E.; Do D.K. and Chen, Y.Y., "Pervasive Car Pooling System using Push Strategy", International Symposium on Information Technology, ITSim. Kuala Lumpur, 2008.

[6] Correia, G. and Viegas, J.M., "A conceptual model for carpooling systems simulation". Journal of Simulation 3, 61–68., 2009.

[7] G. Berbeglia, J.-F. Cordeau, I. Gribkovskaia and G. Laporte, "Static pickup and delivery problems: a classification scheme and survey", TOP 15, 2007.

[8] Parragh S.N., Doerner K, Hartl RF, "A survey on pickup and delivery models Part II", Technical Report, Univ. Vienna, 2007.

[9] C. Goessen, Z. Habbas, D. Khadraoui, "Heuristic for finding reliable and robust paths in dynamic networks", Information Processing Letters, 2010.

[10] Arnould G., Khadraoui D., Ayed H., Habbas Z., "Urban Transport Solution for The Wisafecar Communication And Services Platform", 26th ITS World Congress, Orlando, 2011.

[11] Massaro D. W. and al., "CarpoolNow: Just-In-Time Carpooling Without Elaborate Preplanning", WEBIST, Lisbon, 2009.

[12] Khadraoui D., "OpenSST - Basic clearing mechanism for online web applications", LinuxDays, Luxembourg, 2003.

[13] Feltus, C., Khadraoui, D., Pinto, F.C., "OpenSST based clearing mechanism for e-business", in Proc. International Conference on Information and Communication Technologies, 2004.

[14] "SOAP Version 1.2 Part 1: Messaging Framework (Second Edition)", http://www.w3.org/TR/soap12-part1/.

[15] "Saddle extension to the Mule Enterprise Service Bus", http://saddle-integration.org/.

[16] Wilensky, U. and Stroup, W. 1999. "NetLogo HubNet Gridlock model. Center for Connected Learning and Computer-Based Modeling". Northwestern University, Evanston, IL, 1999.

[17] Gershenson, C., "Self-organizing traffic lights", Complex Systems, Vol. 16 (1). 29-53, 2005.

[18] Burguillo, J.C.; Rodriguez, P.; Costa, E and Gil, F. "History-based Self-Organizing Traffic Lights", Computing and Informatics. Vol. 28, no. 2, 157-168., 2009.

[19] Armendáriz M., Burguillo J.C., Peleteiro A., Arnould G., Khadraoui D., "Carpooling: A Multi-Agent Simulation In Netlogo", in Proc. ECMS, 2010.