Application of Information and Communication Technologies and Services in Carpooling Systems

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Abstract - **Carpooling as a strategy of transport demand management represents sustainable and alternative transport mode and a measure for achieving savings in several different segments (economic, ecological, spatial, transport, etc.) and stakeholders (for individuals, companies, cities, and others). Environmentally sustainable transport represents designing of the future transport infrastructure capacities in order to create minimal negative impact on the environment. One of the basic principles and measures for realization of sustainable transport are: meeting the transport demand by means of changes in the models of use and mobility of surface transport, as well as models of production and consumption, and more effective usage of passenger cars and infrastructure along with expansion of application of new information and communication technologies and services. This paper analyzes the application of information and communication technologies and services for the purpose of developing the carpooling system. Using a survey method the current situation, trends and the possibilities of applying information and communication technologies and services have been defined in case of the users of carpooling option in the city of Zagreb.**

Keywords - carpooling system, dynamic carpooling/ridesharing, information and communication technologies, information and communication services

I. INTRODUCTION

As one of the mobility management strategies carpooling has experienced in recent years its revitalization stimulated by the need for sustainable transport modes in the cities. For the inclusion of a larger number of users, mainly daily commuters, there is need to ensure the accessibility to all the elements that are part of the car- and ride-sharing. The dynamic or real-time carpooling/ridesharing is a service which enables connecting and scheduling of passengers in the function of shared rides in a very short period of time using advanced technologies. Traditionally, carpooling arrangements between two or several unrelated individuals to travel to work or study were relatively inflexible. Dynamic carpooling allows additional flexibility of shared rides allowing the drivers and passengers to agree on occasional shared rides in advance or within a shorter period of time, and it is based on the application and integration of various technologies. The basic characteristics of dynamic user connection are simplicity, flexibility and practicality. The purported benefits from increased carpooling are substantial. Successful carpooling could, from a societal perspective, reduce fuel consumption and emissions, reduce congestion during peak travel periods, reduce parking costs for travelers and employers, provide a reliable alternate mode for travelers, and promote greater equity in transportation by ensuring that mobility is maintained for lower-income travelers. For commuters, major rideshare benefits include travel time savings, cost savings (namely fuel and parking) and increased mode choices [1].

Today carpooling makes from 8 to 11% of share in the trip modal split of the cities in the USA and Canada. According to [2], in 2011 in North America there were 638 different carpooling services. On the basis of the comprehensive authors' study and research in July 2014 it was determined that there were more than 1,500 of carpooling services in the world. This number includes online (services based on the internet) and offline carpooling services and programs (projects).

The implementation and the possibility of the technical and technological solutions using information and communication technologies and services in connecting the users of carpooling by passenger cars (dynamic/real-time carpooling) are analyzed. Major enhancements are realized by the integration of the basic functionalities of the mobile terminals and navigation devices using the Internet contents (carpooling websites) and by the implementation of various applications for the requirements of connecting the users. In this paper a survey method is used in order to determine the current state and the possibilities of application of information and communication technologies and services for the purpose of developing carpooling systems.

II. APPLICATION OF TECHNOLOGY IN THE FUNCTION OF CARPOOLING SYSTEMS

In recent years there has been a substantial number of various types and categories of papers that analyse the application of information, communication and location navigation technologies in the function of carpooling. For carpooling to function adequately, the passengers should have the possibility of accessing timely information about the vehicles and rides, realizing communication and interconnections. The application of the information and communication technologies affects especially positively the connecting of the users in order to realize joint mobility.

One part of the papers analyses the application of location and navigation systems for the needs of connecting the users of the system of shared rides by passenger cars [3], [4], and others deal with the application of wireless technologies and the usage of mobile terminal devices and the development and application of web-services as user support [1], [4], [5], [6].

Location-Based Services (LBS) by means of mobile telecommunication infrastructure deliver to the carpooling system users relevant information depending on the current location of the users of shared rides and thus provide Value-Added Services (VAS). LBS services are linked to applications that integrate the geographical location with other information. An important fact in introducing LBS services lies in the characteristics of mobile terminal devices whose hardware and software features can satisfy a certain level of the quality of using LBS services. Apart from hardware and software features, the supported information and communication technologies are of the same significance. With rapid development and widespread information and communication technologies integrated into mobile terminal devices, determining the position on the move has become everyday practice.

The technologies include Geographic Information System (GIS), Global Navigation Satellite System (GNSS), Radio Frequency Identification (RfID) and various other technologies to determine the location with more or less precision, coverage, and higher or lower costs of installation and maintenance. An increasing role in using and studying carpooling belongs to GNSS systems that together with GIS information technologies and Augmented Reality (AR) enable locating of the users and accessing a new segment of information [7]. Determining the location of carpooling users can be realized also by applying other technologies, such as locating by means of base stations (GSM, UMTS, LTE) and WLAN. Apart from obtaining precise information on the location of the carpooling users in space, the RfID technology is introduced also to solve the drawbacks in sharing the transport costs among the carpooling users [8]. For the needs of carpooling various multi-agent systems have been developed that are accessible by means of mobile terminal devices [9], [10].

The preparation for carpooling can encompass different methods of connections, including: public websites (that act as points at which transport supply and demand meet), closed websites (e.g. for employees, students and other groups), carpooling smartphone applications, manned carpooling agencies and/or usage of automated ride matching software) and pick-up points for carpooling purposes.

Carpooling public websites can be of closed and open type. The open carpooling websites are, namely, available to all internet users thus referring to a greater number of potential users. The closed-type websites are different; they serve only the defined groups of users, such as e.g. employees of certain companies to agree on the term of departure from work and arrival to work. Since late 1990s numerous carpooling projects have proposed the usage of internet websites and application of mobile communication systems to establish connections among users, and since 2004 also networking of the users via social networks.

The application of internet carpooling website encompasses a series of new strategies for the creation of the critical mass of users, such as: partnerships at the level of the city, region or big companies, plans of financial incentives for the users, networking via social networks and real-time carpooling services with the use of automated ride-matching programs [11].

With the development of new generations of information and communication networks the users require services that are personalized, adapted to the current context, intelligent, mobile and always accessible. Connecting of new concepts is infrastructurally based on the existing internet network and 3rd/4th Generation (3G/4G) and supported by Artificial Intelligence (AI) mechanisms which allow automation of the process and their personalization and high level of competitiveness (parallel performance). One of the advanced integrative approaches from the information and communication domain is the application of the Cloud Computing (CC) concept which provides flexibility regarding location of accessing computer resources [11], [12]. The basic requirements of dynamic carpooling include these elements: smartphones, constant network connectivity, GPS functionality, ride-matching algorithms and data repository.

Dynamic carpooling supported by information and communication technologies and services represents upgrade of the traditional and occasional carpooling as well as modern way of connecting users. Dynamic or real-time carpooling services have tendency of relying on the similar assembly of technologies which share similar characteristics. Figure 1 shows the connection among the information systems in the function of carpooling.

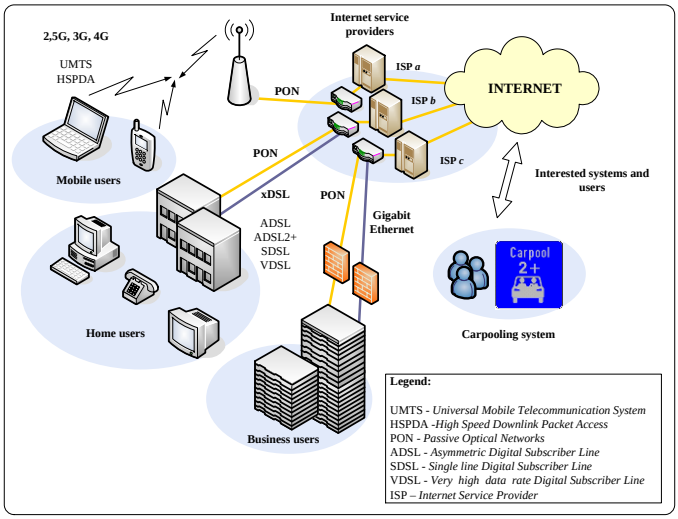

Figure 1. Connection of information systems in the function of carpooling [4]

Dynamic carpooling uses development of mobile telephony and enables its users to organize joint drives in short periods of time from virtually any place in the world which is covered by mobile network.

III. SURVEY DESCRIPTION

In order to explore the trends and capabilities of applying the information and communication technologies and services with the aim of greater use of carpooling services in the city of Zagreb, a study was conducted in the form of a survey among the citizens of Zagreb. The survey was carried out in two terms

(April 2010 and April 2012) in three different ways: by electronic mail, by web survey (link: http://www.fpz.unizg.hr/autozasve) and by interview. The data were collected from two target groups of users: employed citizens and full-time students from the city of Zagreb, and the included age group of the respondents ranged from 18 to 65 years of age. These groups represent the active population, and are considered to commute every day along the transport network of the city of Zagreb. The survey sample comprised the employed persons that have their residence outside the narrow city center of Zagreb, and their working place is in the city center - Central Business District (CBD) with minimal distance from the place of residence to the place of work being five kilometers. The method of collecting data is shown in Table I. To avoid, i.e. eliminate epistemological difficulties, the survey was applied to the sample of respondents who have on the average the same degree of education. That way all the answers have the same value and each answer equally forms the statistical mass. The survey encompassed in total 1,408 respondents in 2010, and 1,430 respondents in 2012. The largest number of data was collected by using a web survey and it amounts to 66.136% (2010) and 78.392% (2012).

TABLE I. METHOD OF COLLECTING DATA FOR THE NEED OF RESEARCH

Method of collecting data	***Number of respondents***	***Percentage of respondents (%)***	***Number of respondents***	***Percentage of respondents (%)***
	2010		***2012***	
e-mail	401	29.016	288	20.139
web surveys	944	66.136	1121	78.392
interview	63	4.848	21	1.469
total	1,408	100	1,430	100

The number of the surveyed employees in 2010 was 659, and of full-time students 749. In 2012 there were 677 surveyed employees, and 753 full-time students. The number of the respondents according to the target groups is shown in Figure 2.

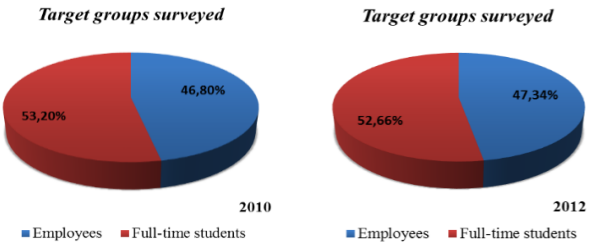

Figure 2. Number of respondents according to target groups

Statistical error for 659 employees in 2010 was E = 3.81, and in 2012 for 749 employees it was E = 3.56. Statistical error for 655 full-time students in 2010 was E = 3.76, and in 2012 for 753 full-time students it was E = 3.55. The target group and the number of respondents represent a representative sample for research. Table II. shows the number of respondents (n) according to the groups, percentage of respondents (in %), level of reliability (c), share of answers (r) , total quantity of target population (N) and statistical error (E).

From 659 surveyed employees in 2010 there were 345 male respondents (in percentage 52.352%), and in 2012 there were 361 male respondents (in percentage 53.323%). There were 314 female respondents in 2010 (47.648%), and 316 in the year 2012 (46.677%). There were 749 surveyed full-time students. From these in 2010 there were 319 male respondents (in percentage 42.59%), and in 2012 there were 314 male respondents (in percentage 41.7%). There were 430 female respondents in 2010 (57.41%), and 439 in the year 2012 (58.3%).

TABLE II. TARGET GROUP AND NUMBER OF RESPONDENTS

Target group of respondents	***Employees***	***Full-time students***	***Employees***	***Full-time students***
	2010		***2012***	
Number of respondents n	659	749	677	753
Percentage of respondents (in %)	46.804	53.196	47.343	52.657
Level of reliability c	95%	95%	95%	95%
Share of answers r	50%	50%	50%	50%
Total size of population N	408,864	64,397	397,365	64,695
Statistical error E (%)	3.81	3.56	3.76	3.55

For defining of the representative sample it was necessary to determine the frequency of using carpooling by passenger cars, and the frequency was classified according to the period of usage (never, sometimes, once a week, 2-3 days a week and 4-5 days a week). The option “sometimes”, when it comes to the frequency of usage means monthly usage of carpooling 3-4 times a week. Frequency of carpooling in 2010 and 2012 is shown in Table III.

TABLE III. FREQUENCY OF USING CARPOOLING

Ord. No.	***Frequency of using carpooling***	***Frequency***	***Percentage (%)***	***Employees***	***Full-time students***
		2010		***2012***	
A1	never	367	26.289	341	24.099
A2	sometimes (monthly 3-4 days a week)	389	27.865	315	22.261
A3	once a week	254	18.195	269	19.011
A4	2-3 days a week	181	12.966	203	14.346
A5	4-5 days a week	205	14.685	287	20.283
	Total	1396	100	1415	100
A6	did not respond to the survey in full	12	0.00852	15	0.0105
	Total	1,408	-	1,430	-

When it comes to the mode of using passenger cars and according to the data from 2010 there were 42.954% of persons that were usually acting as drivers. This number decreased to 39.199% in 2012. The number of passengers increased from 52.284% in 2010 to 55.4% in 2012 (Table IV.). The respondents that never use the carpooling option (A1) and the respondents who did not respond to the survey in full (A6) were eliminated from further analysis. Thus the analysis takes into account the respondents who are numbered as A2, A3, A4 and A5 shown in Table IV. Therefore, the number of the respondents taken into account was 1,029 for 2010 and 1,074 for 2012. From 1,029 respondents in 2010, there were 474 employees with residence in the City of Zagreb (46.064%) and 555 full-time students studying in the City of Zagreb (53.936 %) and who prevailingly use the carpooling services. From 1,074 respondents in 2012, there were 497 employees with residence in the City of Zagreb (46.276%) and 577 full-time students who study in the City of Zagreb (53.724%) and use carpooling services.

TABLE IV. CHARACTERISTIC OF PERSONS USING CARPOOLING

Characteristic of persons using carpooling	*Frequency*	*Percentage (%)*	*Frequency*	*Percentage (%)*
	2010		*2012*	
I usually drive	442	42.954	421	39.199
I am usually a passenger	538	52.284	595	55.4
Both (sometimes I am driver and passenger)	49	4.762	58	5.4
Considered respondents	1,029	100	1,074	100

Respondents were asked in the survey about the place of residence and they could choose among the options: urban, suburban and rural. In the urban area there were 74.64% of respondents, in suburban 20.02% and in rural area 5.34% (2010). In 2012 in the urban area there were 78.12% of respondents, in suburban area 17.32% and in rural are there were 4.56% of respondents.

When it comes to the driving license (B category) there was no substantial difference between the two observed groups of users (employees and full-time students) in the years 2010 and 2012.

In 2010 from 474 employees, 423 respondents owned a driving license, whereas 51 respondents did not have a driving license. In percentages 89.241% of surveyed employees owned a driving license and 10.759% of respondents did not have a driving license. In 2012 from 497 employees, 449 respondents owned a driving license, and 48 respondents did not. In percentages, 90.342% of surveyed employees had a driving license, and 9.458% of respondents did not. In the observed student population for the year 2010, there were 478 respondents with a driving license (86.126%), and 77 did not have a driving license (13.874%) In the observed student population for the year 2012 from 577 students, 498 respondents had a driving license (86.308%), and 79 did not have a driving license (13.692%). The provided data show very small deviations in the two observed years (2010 and 2012).

One of the most important questions in the survey was the ownership and the possibility of using a passenger car. It was found that 328 of surveyed employees own a passenger car (69.198% in 2010) and 365 surveyed employees owned a passenger car (73.441% in 2012). The data show smaller increase in the ownership of passenger cars, but this does not represent a substantial deviation in the analysis of carpooling users. The possibility of using a passenger car as a driver is especially expressed in the student population. That is because students mostly use vehicles that belong to their family members. In the student group there were 107 respondents (19.279% - 2010) who owned a passenger car or had the possibility of using a passenger car. In 2012 that number slightly increased to 121 respondents (20.971%).

For a more efficient application of carpooling it is necessary to obtain relevant information about the carpooling users. This information should be available on the visible service plan (e.g. via Internet portal or mobile applications). Published information about the users are mostly inconclusive because the users are not satisfied with public announcement of their data (their profile and daily trips). Further in the text the usage of information and communication technologies and services from user's point of view in the function of carpooling has been analyzed.

IV. SURVEY RESULTS

Information and communication technologies as significant driving force and integrator of carpooling users represents a special segment and the subject of analysis. The analysis of the survey results takes into account the knowledge of work and usage of computers, usage of mobile terminal devices, use of public internet portals/websites for connecting drivers and passengers, use of applications for mobile terminal devices for carpooling using passenger cars, etc.

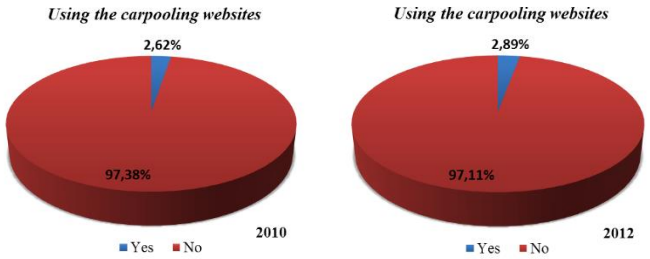

Figure 3. Share of users according to the use of internet portals/websites for connecting the drivers and passengers

Out of 1,029 respondents, 43 respondents (4.18% - 2010) said that they did not usea computer, and two years later out of 1,074 respondents, 31 respondents (2.89%) did not use a computer. All respondents who did not use a computer came from the employees group. Mostly all of the respondents used mobile terminal devices. Out of 1,020 (99.13% - 2010) and only 9 (0.87%) respondents did not use mobile terminal devices. Two years later, out of 1,066 respondents (99.26%) used mobile terminal devices, and only 8 (0.74%) respondents did not use mobile terminal devices.

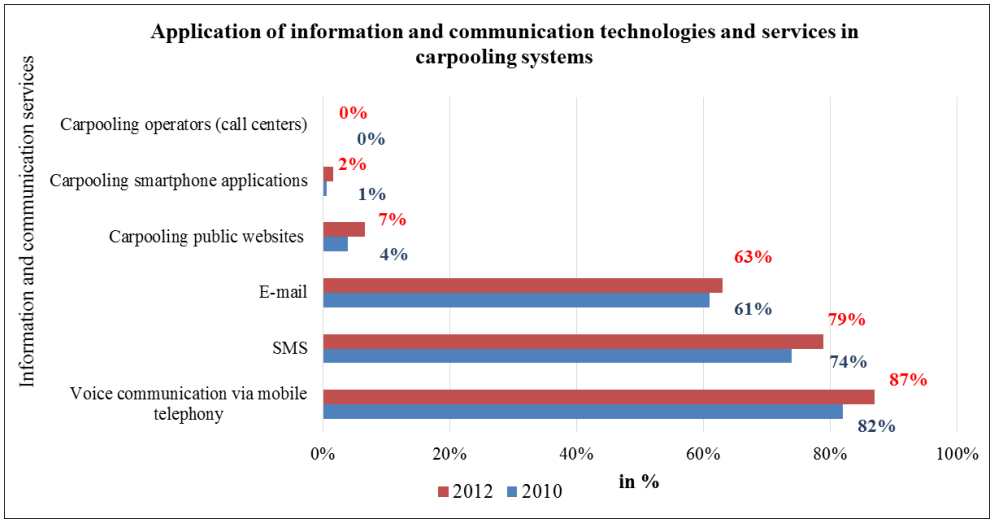

Figure 4. Application of information and communication services in order to connect the carpooling users

The development of carpooling option and increased number of carpooling users considerably depends on the use of the specialized internet portals and web pages for connecting drivers and passengers. Only few respondents (27 or 2.62% in 2010 and 31 or 2.89% in 2012) used specialized internet portals and web pages for connecting the drivers and passengers. The majority of respondents (1,002 or 98.38% in 2010 and 1,043 or 98.11% in 2012) did not use specialized internet portals and web pages for connecting the drivers and passengers. Both groups of respondents are shown in Figure 3.

The use of applications for mobile terminal devices for carpooling purposes are a very important parameter in developing the carpooling system in the world.

For the moment, only few users use mobile applications for carpooling (according to research: 6 in 2010, and 18 in 2012), and these offer great possibilities regarding flexibility in connecting drivers and passengers (Figure 4). Despite the small number of users, there is still a significant increasing trend in using mobile applications for carpooling. This increase refers only to the users belonging to the student group.

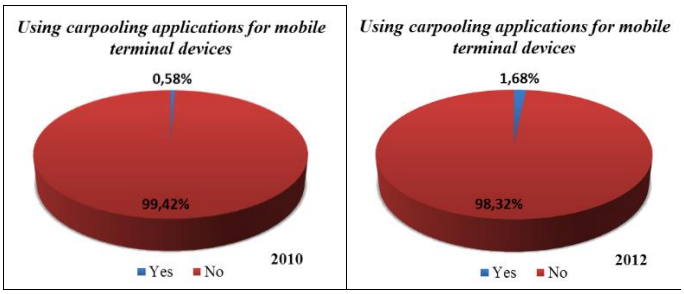

Figure 5. Share of users who use carpooling applications of mobile terminal devices

The survey gives answers of the respondents about the use and significance of information and communication services in connecting carpooling users. The application of various information and communication services for the purpose of carpooling is shown in Figure 5. In the specified question it was possible to choose several answers, i.e. at most three services that the user uses the most. Eight out of ten users use calling services for connection with carpooling users, whereas seven users use SMS services and six users use e-mail. There is slight increase in the use of public carpooling web pages and portals and mobile applications for carpooling on mobile terminal devices for the two observed years (2010 and 2012).

The significance of information and communication technologies and services in connecting carpooling users is shown in Figure 6 for various research years (2010 and 2012), and it is visible how vital that impact is on the future development of the carpooling model.

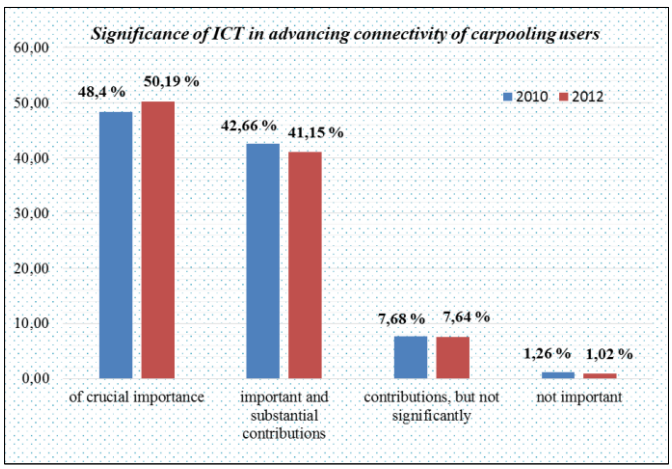

Figure 6. Significance of ICT in advancing connectivity of carpooling users

Almost half of the respondents, i.e. 498 of them (48.40% - 2010) assessed that information and communication technologies and services have vital impact on carpooling, about forty percent of respondents (439 – 42.66%) think that

information and communication technologies and services have important impact on carpooling (in the sense of essential contribution). Only a small number of respondents (79 – 7.68% and 13 – 1.26%) think that information and communication technologies and services have a small and insignificant impact on carpooling. In 2012 half of the respondents, 539 of them (50.19%) evaluated that information and communication technologies and services have vital impact on carpooling, about forty percent of respondents (442 – 41.15%) think that information and communication technologies and services have important impact on carpooling. Only a small number of respondents (82 – 7.64% and 11 – 1.02%) said that information and communication technologies and services have small and insignificant impact on carpooling.

It is important to observe the development of carpooling system as one more possibility of transport in the cities and it is important to plan accordingly the common platforms (together with other public transportation modes) based on information and communication technologies.

V. CONCLUSION

Carpooling development will depend on the future evolution of information and communication technologies, and three segments are especially important: interoperability and integration of the databases; development of advanced systems for connection of users, and openness of users towards carpooling mobile applications. Tendency of carpooling development has been focused on the research of advanced carpooling approaches which focus on determination of the starting locations or the users meeting places. For future research detailed analysis of available carpooling websites and mobile applications in the function of carpooling. That kind of analysis would include a set of parameters combined with the following services: publishing ads for drives, connecting users, grouping users (companies, small firms, faculties), operation system (for mobile applications), real-time ridesharing services, location-based services (LBS), commercial acess for companies, possibillity of SMS integration, social networks for connections, possibility of automatic creation for connections, type of maps, creating driving routes, organizing of sharing and payment services, calculation of ecological prevention, etc.

Increase in the number of carpooling option users is possible with the implementation and integration of technological, organizational and intra-organizational system properties. The results of the conducted research can be used in the process of introducing and operationalization of a dynamic carpooling/ridesharing system. Expanding the possibilities of connecting carpooling users lies in the use of new information and communication technologies and advanced user terminal devices.

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