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IDENTIFICIRANJE RELEVANTNIH ČIMBENIKA PRIMJENE TEHNOLOGIJA ZA POTREBE DINAMIČKOG CARPOOLINGA

IDENTIFYING RELEVANT FACTORS OF APPLYING TECHNOLOGIES IN DYNAMIC CARPOOLING

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Izvorni znanstveni članak

Sažetak: *Razvoj i sveopća primjena brojnih suvremenih tehnologija (i usluga) znatno utječe na unaprjeđenje i dostupnost informacija u cilju povezivanja korisnika sustava zajedničkih vožnji osobnim vozilima (carpooling). Dinamički carpooling podržan informacijsko-komunikacijskim (ICTS) i lokacijsko-navigacijskim tehnologijama i uslugama (LNTS) predstavlja nadogradnju tradicionalnog i povremenog carpoolinga te suvremeni način povezivanja korisnika. U cilju kvalitetnijeg povezivanja korisnika u radu se analiziraju karakteristike ključnih programskih aplikacija koje mogu poboljšati funkcioniranje carpoolinga. Sustavnim pristupom (prema fazama istraživanja) omogućava se prepoznavanje relevantnih čimbenika primjene tehnologija za potrebe dinamičkog carpoolinga. Metodom anketiranja utvrđuju se potrebe korisnika carpoolinga unutar prometnog okruženja (prometne mreže). Cilj provedenog istraživanja je identificiranje relevantnih čimbenika primjene tehnologija za potrebe povezivanja korisnika carpoolinga i ukupnog razvoja dinamičkog carpoolinga. Doprinos članka ogleda se u utvrđivanju relevantnih čimbenika primjene tehnologija za potrebe razvoja carpoolinga kao alternativnog i održivog načina prijevoza.*

Ključne riječi: *čimbenici, dinamički carpooling / ridesharing, informacijsko-komunikacijske tehnologije i usluge (ICTS), lokacijsko-navigacijske tehnologije i usluge (LNTS), prometno okruženje*

Original scientific paper

Abstract: *Development and overall application of numerous advanced technologies (and services) affects significantly the improvement and availability of information with the aim of connecting the users of the carpooling system by passenger cars. Dynamic carpooling supported by Information-Communication (ICTS) and Location-Navigation Technologies and Services (LNTS) represents the upgrade of the traditional and casual carpooling and the modern method of connecting the users. In order to realize a better connection of users, the paper analyzes the characteristics of key software applications that can improve carpooling functioning. A systemic approach (according to research phases) allows identification of relevant factors of applying the technology for the needs of dynamic carpooling. The survey method was used to determine the needs of carpooling users within the traffic environment (traffic network). The aim of the carried out research is to identify the relevant factors of applying the technologies in order to connect the carpooling users and the total development of dynamic carpooling. The contribution of the paper is reflected in determining the relevant factors of applying the technologies for the needs of carpooling development as alternative and sustainable transportation mode.*

Key words: *factors, dynamic carpooling / ridesharing, Information-Communication Technologies and Services (ICTS), Location-Navigation Technologies and Services (LNTS), traffic environment*

1. INTRODUCTION

The dynamic or real-time carpooling / ridesharing (also known as instant ridesharing, dynamic ridesharing and ad-hoc 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. For carpooling to function well, commuters need to be able to connect with each other. 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 casual 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. Telecommunications is one of the keys to effective dynamic carpooling and can shape the way travel occurs. In general, the more reliable and more efficient the underlying communications technology is, the greater is the possibilities for achieving success with dynamic carpooling [1].

The world trends of implementing various models of shared rides by passenger cars (e.g. carpooling,

carsharing, ridesharing, etc.) are oriented to the need of using innovative systems and solutions from the domain of Intelligent Transportation Systems (ITS), Innovative Transport Systems (INTS), Information and Communication Technologies and Services (ICTS) and Location and Navigation Technologies and Services (LNTS) in order to increase the use of alternative and sustainable modes of travelling [2], [3].

The intensity of traffic system development in general, as well as the intensity of the development of shared ride models require increased application of information, communication and location-navigational technologies and services. In order to achieve efficiency in performing a shared ride by passenger cars the real-time transfer of relevant and necessary information is significant. In recent years there has been a substantial number of various types and categories of papers that analyse the application of information, communication, location and navigation technologies in the function of carpooling [4], [5]. 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 [6], [7], [8].

Until recently, carpooling systems had limited usage because of the lack of efficient data processing and information-communication support. However, recent development of information, communication and location-navigation services have contributed towards the upgrade and acceptance of the carsharing system. In the last 10 years a substantial number of various types and categories of papers have been analyzing the application of information and communication technologies in the function of carpooling. In previous studies [9] the analysis was made on the application of information and communication technologies in the function of carpooling.

The analysis of the current available studies has shown a lack of studies that identify and define the relevant factors of applying the technologies that affect the performance of joint rides by passenger cars – carpooling. Current solutions in the domain of joint rides by passenger cars are partial, non-standard, and non-regulated, and the terminology is non-uniform and / or unrecognized (carpooling ≠ carsharing). The implementation of the carpooling system, as well as other subsystems of urban public transport require satisfactory infrastructural capacities that certainly include the implementation of adequate information, communication, location and navigation support.

The aim of research is to identify the relevant factors of applying the technologies facilitating the connections of carpooling users and the overall development of dynamic carpooling.

The purpose of the performed research is to improve the connections of the users of joint rides by passenger cars by using the advanced technologies and services based on them (ICTS and LNTS). Section 2 describes the procedure, that is, the used research methodology.

2. RESEARCH METHODOLOGY

Systemic approach enables recognition of key factors of applying technologies for dynamic carpooling needs. The proposed research methodology, which consists of five main operation phases is presented in Figure 1. Systemic research of relevant factors is presented by a flowchart using UML (Unified Modeling Language) notation which shows all the activities of studying the relevant factors of applying the technologies for the needs of dynamic carpooling.

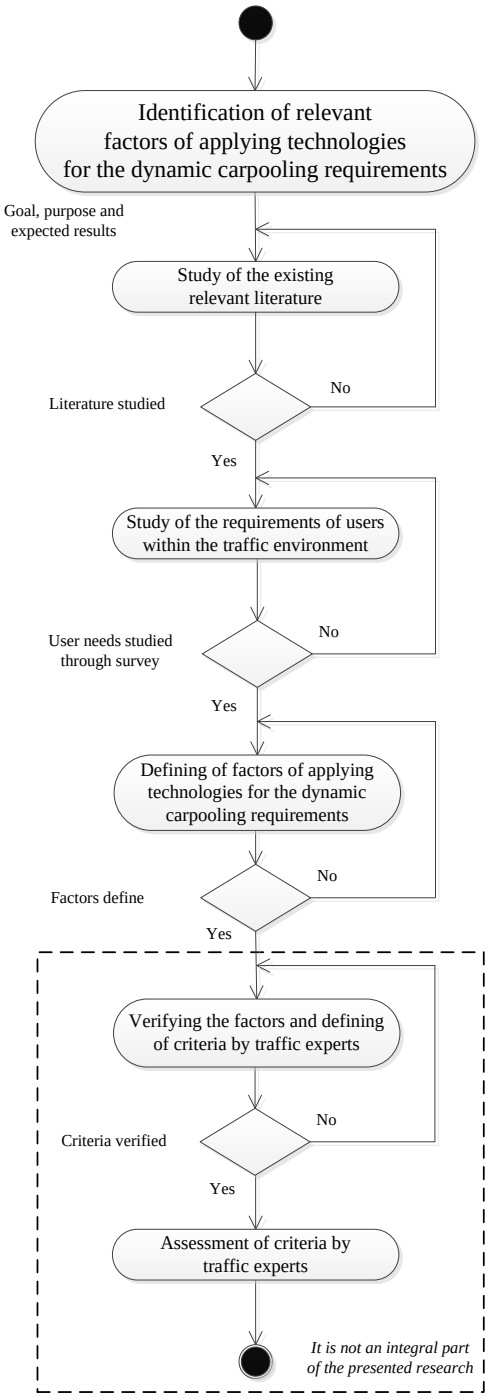

Figure 1. Research methodology of relevant factors of applying the technologies for dynamic carpooling requirements

This paper studies the first three phases (out of five). The initial activity while working on this problem included the study of the current relevant scientific literature that differs depending on the subject and objective of research, and includes the study of the characteristics of the system and the dynamic carpooling users (first phase). The study of the needs of the carpooling users within the traffic environment consists of quantitative research (second phase).

Quantitative research comprises the following knowledge obtained from the collected responses of targeted groups of users:

- Selection of relevant data from the survey;
- Segmentation of data and mapping of respondents according to the classification of workplaces, gender, age, passenger car ownership, parking, etc.;
- The weights of survey data and implementation of statistical tests; and
- Reports of quantitative results of research.

Subsection 4.2 shows the most important results of the survey of the users related to the implementation of the technology for the dynamic carpooling requirements.

The third phase of research comrises the defining of the factors of applying the technologies for the needs of realising the dynamic carpooling. Figure 1 shows the phases of systemic research of relevant factors of applyingthe technologies for the dynamic carpooling requirements.

The continuation of research (future plans) should encompass the definition of criteria for the selection of the technology for the needs of dynamic carpooling, checking of criteria based on qualitative research (traffic experts, fourth phase) and evaluation of criteria by traffic experts (fifth phase). For the evaluation of criteria the use of multi-criteria analysis is proposed. The properties of the multi-criteria analysis, such as: larger number of criteria, differences or conflicts among criteria, incomparable units of measuring criteria, selection of the best alternative (e.g. solutions, systems, implementation methods), or ranking the alternatives, can find adequate implementation in defining the factors of applying the technologies for the dynamic carpooling needs.

Further in the text the characteristics and requirements of dynamic carpooling are analyzed.

3. ANALYSIS OF THE CHARACTERISTICS AND REQUIREMENTS OF DYNAMIC CARPOOLING

In studying the carpooling system one can classify three types of problems or methods of sharing the vehicles and rides that depend on certain factors. The first suggested classification is into static (traditional carpooling as the first type of problem) and dynamic carpooling, and then the classification of the dynamic into casual (the second type of problem) and technology facilitated dynamic carpooling (the third type of problem). The core of static carpooling operation depends on interpersonal relationships and the agreement among family members, friends or employees (traditional carpooling). Casual carpooling depends on the starting location of the stop i.e. user location and at this level the relevant parameters in research [10] are identified, and the multi-criteria model is proposed in the selection of the locations in the urban environment.

The technology facilitated dynamic carpooling lies in the focus of this study. The static and dynamic classification of the carpooling system is presented in Figure 2.

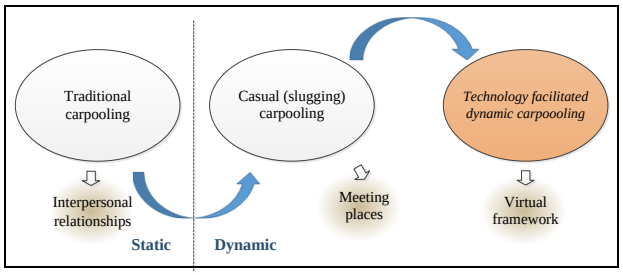

Figure 2. Static and dynamic classification of carpooling system

Dynamic carpooling facilitated by information and communication, and location and navigation technologies and services represents an upgrade of the traditional and casual carpooling and the advanced method of connecting the users.

Table 1. Characteristics of software applications in dynamic carpooling

Application	Technologies	Function / service
Web based client	Software module	Interface for controlling user accounts, editing, cancellation of trips and general communication among carpooling users.
Mobile terminal device client	Software module	Integration of wireless connection and GPS localisation. Plotting of GIS map of data of users and planned trips.
	Wireless connection	
	Localisation (GNSS, GPS / GLONASS, etc.)	
Trip matching module	Software module	Fast trip matching, filtering, scheduling and optimization of joint rides.
	Optimisation algorithms	
Database module	Database management system (DBMS)	Saving and loading data used for trip (rides) matching and user profile system.
	Database servers	
User communication module	Email servers	Communication among different carpooling users based on mobile telephony.
	Short Message Service (SMS) servers	
	Instant messengers / communication software	
API module of social network	Software web module	Connection to API (Application Programming Interface) of social network.
Payment	E-payment service provider	Transactions that refer to the realized rides, keeping the register on transport payments per user, transactions to bank accounts.
	Financial management	

Dynamic or real-time carpooling services have the tendency of relying on a similar set of technologies and share similar characteristics. The basic requirements of dynamic carpooling include the following elements of the value chain of information and communication technologies and services in the carpooling system, previously studied in [11]:

- user equipment (smartphones and other mobile terminal devices);
- applications (carpooling applications, GPS functionality);
- services (ride matching algorithms);
- network (constant network connectivity); and
- contents (traveller information, pre-trip information, data repository).

Table 1 shows the key software applications that can improve the carpooling operation. Software applications are described by applicable technologies and functions / services.

The technologies include Geographic Information System (GIS) or GLONASS (Russian: GLObal'naya NAvigatsionnaya Sputnikovaya Sistema), 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 the users and accessing a new segment of information. 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 [3]. For the needs of carpooling various multi-agent systems have been developed that are accessible by means of mobile terminal devices [12], [13].

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.

4. RESEARCH DESCRIPTION AND RESULTS

4.1. Survey description

With the aim of identifying the relevant factors of applying technologies for dynamic carpooling requirements, a survey has been performed among the target group of users of advanced technologies who are familiar with the issues of carpooling (the survey area is the City of Zagreb, Republic of Croatia). The survey was carried out in April and May 2015 in three different ways: by electronic mail (32 respondents, 7.459%), by web survey (382 respondents, 89.044%) and by interview (15 respondents, 3.497%). The surveyed group comprised respondents in the age between 18 and 65, and it covered the employed citizens and full-time students. These two groups of respondents represent the active population, considered to be commuting every day in the Zagreb transport network. In order to avoid, i.e. eliminate epistemological difficulties, the survey was applied on the sample of respondents that have almost equal level of education. Thus, every respondent's answer has the same value and equally forms the statistical mass. The survey encompassed a total of 429 respondents. The number of the surveyed employees in 2015 was 223 (51.981%), and of full-time students 206 (48.019%). Statistical error for 223 employees was E = 5.51% and for 206 full-time students it was E = 5.72%. From 223 surveyed employees there were 118 male respondents (in percentage 52.914%) and 105 female respondents (47.085%). From 206 surveyed full-time students there were 98 male respondents (in percentage 47.572%) and 108 female respondents (52.427%). The target group and the number of respondents represent a representative sample for research.

For defining of the representative sample it was necessary to determine the frequency of using carpooling (the carpooling system does not yet exist in the city of Zagreb) 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. The respondents who never use the carpooling option and the respondents who did not respond to the survey in full were eliminated from further analysis. Thus, the analysis takes into account the respondents: sometimes / monthly 3-4 days (19.438%), once a week (17.564%), 2-3 days a week (26.230%), and 4-5 days a week (22.482%). Therefore, the number of the respondents taken into account was 366. From 366 respondents, there were 191 employees with residence in the City of Zagreb (52.186%) and 175 full-time students studying in the City of Zagreb (47.814%) and who prevailingly use the carpooling services.

Further in the text the usage of information, communication, location and navigation technologies and services from the user's point of view in the function of carpooling has been analyzed.

4.2. Survey results

The survey provided the answers of the respondents about the application of certain information-communication services to the connection of the carpooling users. The application of information-communication services for the carpooling requirements is presented in Table 2. The data from Table 3 that refer to the years 2010 and 2012 are related to the carried out research [9], and the source and method of collecting data for 2015 is presented in subsection 4.1. In the mentioned survey question several answers could be given, i.e. three services mostly used by the carpooling users. The call services in order to connect the users are used by about eight out of ten respondents, seven respondents use electronic mail, and six out of ten respondents use SMS services. In 2015 the Social Networks / Media (Facebook, Twitter, My Space, LinkedIn etc.) and Instant messengers

/ communication software (WhatsApp, Viber, Skype, Line, etc.) are considered with special care as advanced methods of communication [14]. Social networks are represented by as much as 23%, i.e. Instant messengers / communication software with 17%. In the use of public Internet pages / portals, as well as carpooling applications of mobile terminal devices there was a noticeable trend of increase in the three observed years (2010, 2012 and 2015).

Table 2. Application of information and communication services in order to connect the carpooling users (a part of data dates from 2010 and 2012 [9])

Information and communication services	2010	2012	2015
Voice communication via mobile telephony	82%	87%	78%
E-mail	61%	63%	62%
SMS	74%	79%	49%
Social Networks/Media	n/a	n/a	23%
Instant messengers/communication software (WhatsApp, Viber, Skype, Line, etc.)	n/a	n/a	17%
Carpooling public websites	4%	7%	7%
Carpooling smartphone applications	1%	2%	3%
Carpooling operators (call centers)*	0%	0%	0%

** there are no carpooling operators in the city of Zagreb*

The biggest recorded fall happened in case of SMS messages (74% in 2010, 79% in 2012, and in 2015 only 49%). The reason is the development and widespread use of Instant messengers / communication software, which is realised due to its simplicity and numerous interactive possibilities (user grouping, etc.). The biggest development potential to connect the carpooling users belongs to the services based on Social Networks / Media and Instant messengers / communication software, because of numerous advantages such as simplicity and availability of usage by means of mobile terminal devices.

The significance of information and communication technologies and services in connecting carpooling users is shown in Table 3 for various research years (2010, 2012 [9] and 2015), and it is visible how vital that impact is on the future development of the carpooling model.

Table 3. Significance of ICTS in advancing connectivity of carpooling users (a part of data dates from 2010 and 2012 [9])

Significance of ICTS in advancing connectivity of carpooling users	2010	2012	2015
Of crucial importance	48.4%	50.19%	53.83%
Important and substantial contributions	42.66%	41.15%	39.62%
Contributions, but not significant	7.68%	7.64%	5.46%
Not important	1.26%	1.02%	1.09%
Total	100%	100%	100%

More than half of the respondents (197 – 53.83%) have chosen significance of ICTS as being of crucial importance (2015). More than one third of respondents (145 – 39.62%) have chosen significance of ICTS as important and substantial contribution, 20 respondents (5.46%) have chosen contributions, but not significantly, and only 4 respondents (1.09%) have chosen not important. Such results can be interpreted as the expected ones regarding the development of ICTS and its possibilities of implementation in the traffic environment.

4.3. Discussion

Applications for real-time booking of places in a passenger car have great potentials to enable the user who has the basic computer literacy to use this concept, thus reflecting the personal benefit of the user in visible savings while travelling by passenger car. The user-friendliness is insured by a simpler interface, and the applications are performed on mobile terminal devices that have access to the Internet. This type of carsharing is generally provided by the following infrastructure:

- GPS / GLONASS navigation instruments that determine the driving route and allow the accuracy of common rides;
- mobile terminal devices –smartphones in order to receive travel requests with expressed flexibility, and
- social networks that allow establishing of confidentiality and reliability between the driver and the passengers.

In order to realize a greater total number of users of joint rides by passenger cars, the application of technologies can be especially classified as shown in Table 4.

Table 4. Technological groups in the function of increasing the number of carpooling users

Technological group	Possibilities
Information and communication technologies	Mobile terminal devices (smartphones, tablets, etc.) carpooling applications
	Propagation of Internet services and potential of Future Internet (Internet carpooling portals)
	Ridematching Databases
	Social Network / Media and Social Networking Applications
Location and navigation technologies	Location Based Service (LBS)
	Availability of GNSS based location
	Hardware (RfID Cards, transmitters, receivers)

Today the innovativeness is reflected in combining the benefits of social networks to solve the carpooling issue, i.e. connection of the users and their personal safety. The lack of confidence and safety seems to be the main

problem for greater use of the system of joint rides by passenger cars, and the integrating social networks do have precisely the informing role about other users thus gaining confidence and reliability. One of the innovative characteristics of the system in the function of on-trip information is a mobile client. A mobile client consists of a software that is run on a mobile terminal device, and requires wireless Internet connection and built-in GPS / GLONASS support (containing GNSS receivers). The implementation of mobile applications allows the visibility of the contents and the ability of localizing the user, thus realizing the trip search and grouping of users (drivers and passengers). By adding such innovativeness it is possible to present a number of possibilities to overcome the current carpooling challenges.

5. IDENTIFICATION OF RELEVANT FACTORS

There are many factors that affect the system of joint rides by passenger cars, and that are closely related to attracting and accepting the users. The performed study, based on the presented research methodology in Section 2, has defined the factors that affect the usage of options of joint rides by passenger cars. Carpooling can be basically considered also by means of sociodemographic, traffic, spatial, time-related, psychological and technological factors that are presented in Figure 3.

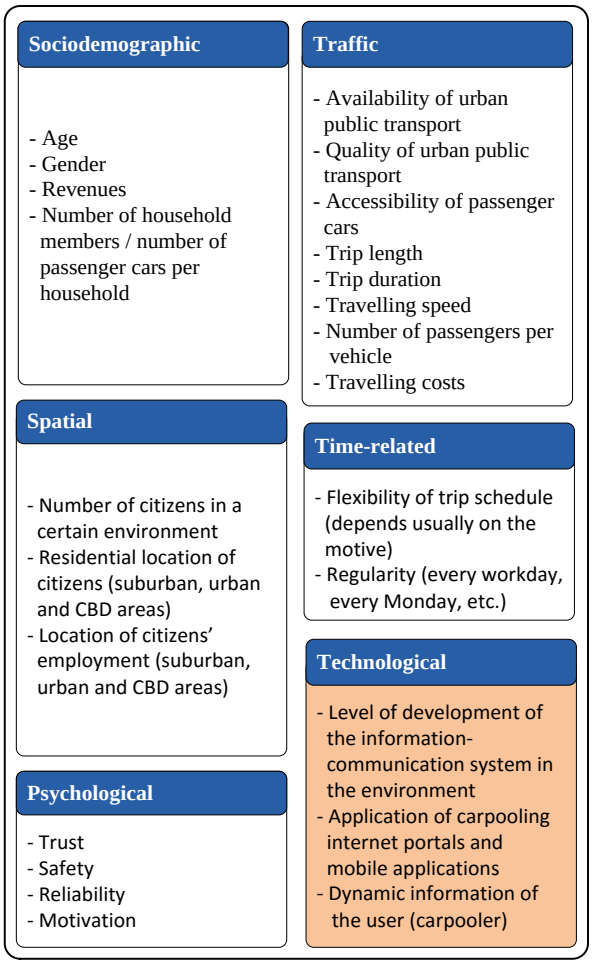

Figure 3 - Factors affecting the use of carpooling system

Studies [15], [16] confirm the mentioned factors; however, often there is an absence of psychological factors that have a significant impact on carpooling users. Psychological factors encompass the complexity of interactions among the individuals, and are characterized by psychological elements, such as confidence, safety, reliability and motivation of the user. Positive influence on the psychological factors can come from the application of various applications based on information and communication technologies (e.g. information exchange about the users via social networks, etc.).

Identified factors are interdependent and can be observed from various levels and approaches. Each of the factors consists of a number of elements and potential requirements related to the implementation of the technology in the function of dynamic carpooling. Figure 4 shows the interdependence of the recognized factors and the application of technologies.

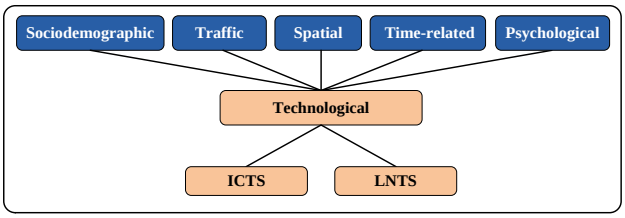

Figure 4. Interdependence of factors and technologies application

For instance, the interdependence is most simply presented through a sociodemographic element i.e. age of the user. The younger the carpooling user, the greater the benevolence of using the new and advanced technologies.

Out of identified factors that affect the performance of joint rides by passenger cars it is possible to define the selection criteria of the technology (ICTS and LNTS) for the dynamic carpooling requirements according to the target groups of users.

6. CONCLUSION

Joint ride by passenger cars (carpooling) parallel with the development of technologies (ICTS and LNTS) is becoming a more and more significant topic and subject of study on the transport demand management. Dynamic carpooling based on the strength of information, communication, location and navigation technologies and services has been a widely accepted concept to implement better transportation system.

With the aim of better connection of the users, the paper analyzes the characteristics of key software applications that can improve the carpooling operation. Based on the performed survey (in three phases) that included the analysis of the existing relevant literature and the users' needs for joint rides by passenger cars in the city of Zagreb, relevant factors of applying technologies for the dynamic carpooling requirements were recognized (sociodemographic, traffic, spatial, time-related, psychological and technological).

The survey provided answers of the respondents about the implementation of certain information and

communication services (voice communication via mobile telephony, e-mail, SMS, social networks / media etc.) and their significance was determined in case of connecting the carpooling users (in three observed years: 2010, 2012 and 2015). More than a half of the respondents (197 – 53.83%) chose the significance of ICTS as of crucial importance (2015). A potential limitation of research is the sample size. Further data should be collected in order to generalize results to a larger population.

The research results can be implemented in the procedure of introducing and operationalization of carpooling as partial measures of mobility management in the cities and in designing and production of various types of carpooling applications. The obtained research results also allow expansion of the possibilities of connecting the users of joint trips by applying the advanced information and communication technologies and the contemporary user terminal devices.

Future plans for the continuation of research include the defining of criteria (and sub-criteria) for the selection of technology for the dynamic carpooling requirements, verification of the criteria on the basis of qualitative research (traffic experts, proposed fourth research phase) and assessment of criteria by traffic experts (fifth phase). For the needs of criteria assessment, the use of multi-criteria analysis is expected.

7. ACKNOWLEDGEMENTS

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