Smart Space-based Ridesharing Service in e-Tourism Application for Karelia Region Accessibility
Ontology-based Approach and Implementation

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Abstract: The paper describes a ridesharing service proposed for improving tourism accessibility in Russian Karelia region. The ridesharing service has been developed using Smart-M3 information sharing platform as a smart space infrastructure, which increases the service scalability, stability and speed, as well as reduces the network load. The presented service is the first implementation of ridesharing concept based on the Smart-M3 platform. The paper describes technical studies carried out to develop the prototype of ridesharing service as well as empirical studies. An effective matching algorithm, which finds correspondences between driver paths and tourist start and end points, and two heuristics significantly reducing path matching time, have been presented. Besides, data analysis of online questionnaire developed to better cognize whether prospective customers will accept ridesharing services as an alternate mode of transportation is discussed.

1 INTRODUCTION

The unique cultural and historical heritage, abundant nature and landscape of the Russian Karelia region provide great opportunities for tourism development in the region. There are more than four thousand cultural, historic and nature objects, for instance eminent Kizhi ensemble, Vaalam Island and Monastery, Solovetsky Islands and Monastery. However, to facilitate the region tourism development appropriate infrastructure should be deployed. For instance, the lack of convenient public transportation affects the accessibility of attractive tourism destinations. Besides, the use of available transportation alternatives, for example taxi, results in considerable costs for tourist to reach the places of interest. Thus, to improve tourism object accessibility in the Karelia region a prototype of ridesharing service has been developed.

Ridesharing, also known as carpooling, lift-sharing or covoiturage, is a shared use of a car by the driver and one or more passengers, usually for commuting (Abrahamse and Keall, 2012). Ridesharing enables travellers to save travel costs and provides an alternative transportation way for tourists to reach desired destinations. Moreover, ridesharing is an eco-friendly and sustainable transportation technology (Cho et al., 2012) and therefore has been proposed, for instance, as a promising way to reduce carbon emissions.

Recently, there has been growing interest in the use of the web and computing methods in assisting with ridesharing (Kamar and Horvitz, 2009). There is a number of possibilities enabling search of fellow travellers: public forums and communities (like, *eRideShare* (eRideShare.com), *PickupPal* (PickupPal.com), *Zimride* (Zimride.com), *RideshareOnline* (RideshareOnline.com), *rideshare.511.org* (Rideshare. 511.org), *CarJungle* (CarJungle.ru), Podorozhniki (Prodorozhniki.com); private Web-services (e.g., *Zimride* service provides a private interface for universities and companies); and mobile applications (e.g., *PickupPal*, *Avego* (Avego.com).

However, most of mentioned services provide platforms for finding fellow travelers offline, rather than real time mobile services for generate rideshare plans. In everyday life people often make spontaneous decisions and are keener to pursue own schedules. Thus, the service should enable dynamic formation of carpools depending on current situation and people preferences. In this paper, dynamic ridesharing service implementation for mobile devices is described.

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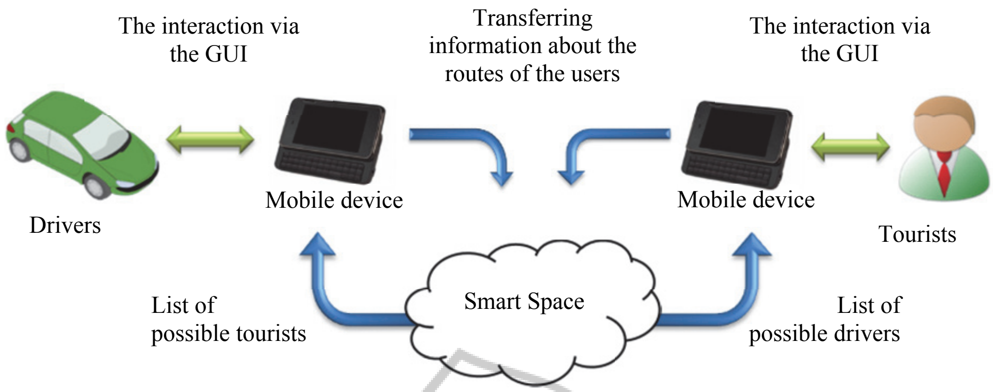


Figure 1: System working scenario.

Majority of existing ridesharing services for mobile devices, for instance PickupPal.com, Avego.com uses the client-server architecture what affects service scalability. Hence, to increase the service scalability, stability and speed, as well as to reduce network load, the prototype of the ridesharing service has been developed using the decentralized smart space infrastructure. Use of open sourced Smart-M3 information sharing platform (Honkola et al., 2010) makes it possible to significantly simplify further development of the system, include new information sources and services, and makes the system highly scalable. Presented service is the first implementation of ridesharing concept based on the Smart-M3 platform.

The aim of this paper is to describe technical studies carried out to develop the prototype of ridesharing service as well as empirical studies what forms encouraging ground for further service development.

The system working scenario can be found in Section 2. Section 3 introduces the logistic service ontology used to enable interoperability between different devices in the smart space. An effective matching algorithm, which finds correspondences between driver paths and tourist start and end points, and two heuristics significantly reducing path matching time, have been presented in Section 4. There are technical studies, focusing on the development of ridesharing support systems with travel route matching techniques (Jin and Hu, 2012); (Cho et al., 2012). The main difference of the proposed approach is that there are two heuristics developed, which significantly reduce matching time. In addition, a data analysis of online questionnaire developed to better cognize whether prospective customers will accept ridesharing services as an alternate mode of transportation, is provided in Section 5. Main results are summarized in Conclusion.

2 RIDESHARING SERVICE SCENARIO

Common service working scenario is shown in Figure 1. A tourist fills information about his/her schedule, preferences (Figure 2, a), most frequent routes, additional constraints, for example, max. delay, max. detour, social interests, etc. (Figure 2, b) using ridesharing service mobile application. Then, internal processing and depersonalization of provided information is implemented and it is transferred into the smart space.

After, using the algorithm for finding matching driver and passenger paths, the groups of fellow travelers are formed. Finally, within short period of time information about possible fellow travelers, their profiles, meeting points, meeting time, full recommendations about the route are provided to the tourist (Figure 3, a-d).

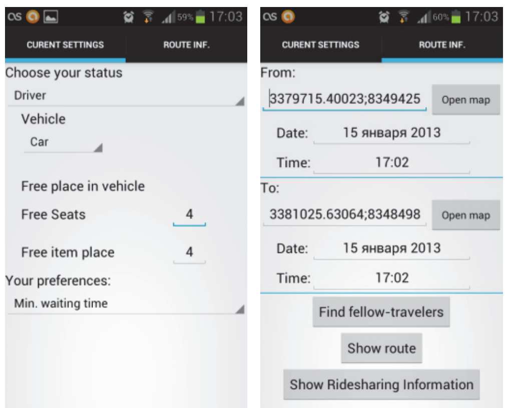
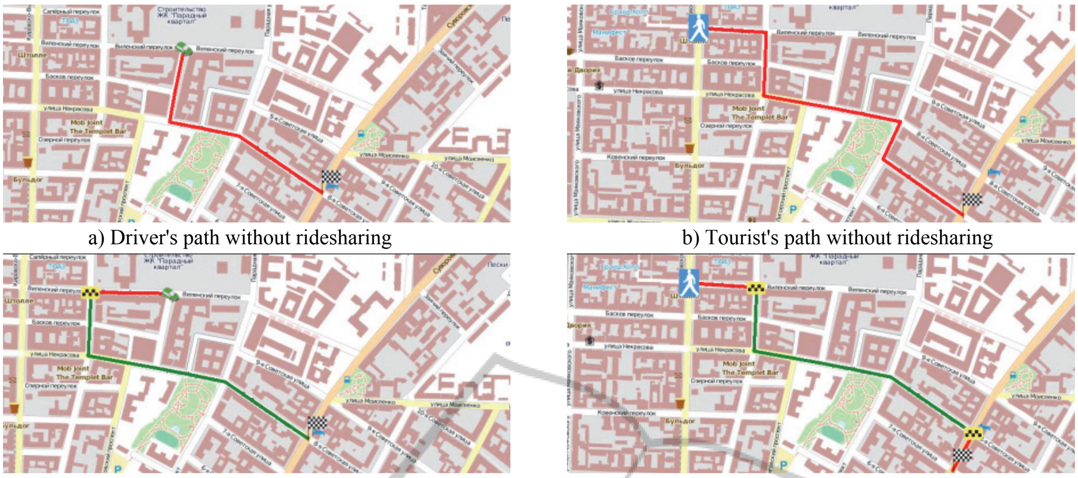


Figure 2: User's routes and preferences definition.



a) Driver's path without ridesharing
b) Tourist's path without ridesharing
c) Driver's path with ridesharing
d) Tourist's path with ridesharing

Figure 3: Found routes.

Figure 4 presents an example of preliminarily museum attending plan using ridesharing service.

Let´s assume that a tourist is going to Petrozavodsk and he/she would like to attend National Museum, Industry Museum, Local History Museum, Polar Odysseus Museum, and Geological Museum. Figure 4 presents the preliminary attending plan for a tourist. The tourist needs to specify in ridesharing service next place, which he/she would like to attend and the service automatically finds drivers, which will pick-up a tourist and drive him/her to the place near the specified museum.

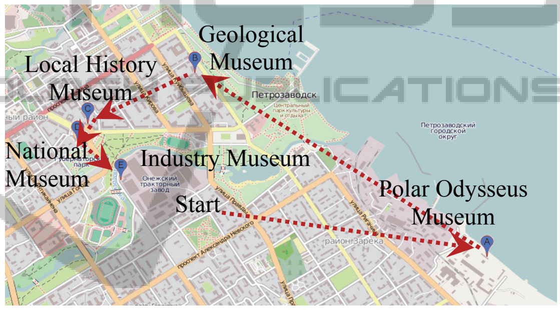


Figure 4: An example of museum attending plan in the capital city (Petrozavodsk) of the Republic of Karelia.

3 Smart-M3 PLATFORM

The open source Smart-M3 platform (Smart-M3 at Sourceforge) has been used for the pilot implementation of the presented ridesharing service. Usage of this platform makes it possible to significantly simplify further development of the system, include new information sources and services (Figure 5), and makes the system highly scalable. The key idea of this platform is that the formed smart space is device, domain, and vendor independent. Smart-M3 assumes that devices and software entities can publish their embedded information for other devices and software entities through simple, shared information brokers. Information exchange in the smart space is implemented via HTTP using Uniform Resource Identifier (URI) (Berners-Lee et al., 2005). Semantic Web technologies have been applied for decentralization purposes. In particular, ontologies are used to provide for semantic interoperability.

4 THE LOGISTIC SERVICE ONTOLOGY

The logistic service ontology describes the domain area of ridesharing at the macro level (Figure 6).

The macro level ontology is based on integration of parts of the mobile devices' ontologies. The logistics service ontology consists of three main parts: "actors", "vehicles", and "paths".

The "actors" are: "drivers" and "passengers". All of them are associated with class "vehicles" and have "paths". For example, "driver" has his/her own car and several points defining his/her home, work and other locations. "Passenger" may prefer some vehicle type and has points of home, work, and other locations.

The classes "driver" and "passenger" are subclasses of the class "actor" and inherits all its properties with two own properties. The class "passenger" is a subclass of the class "actor" and

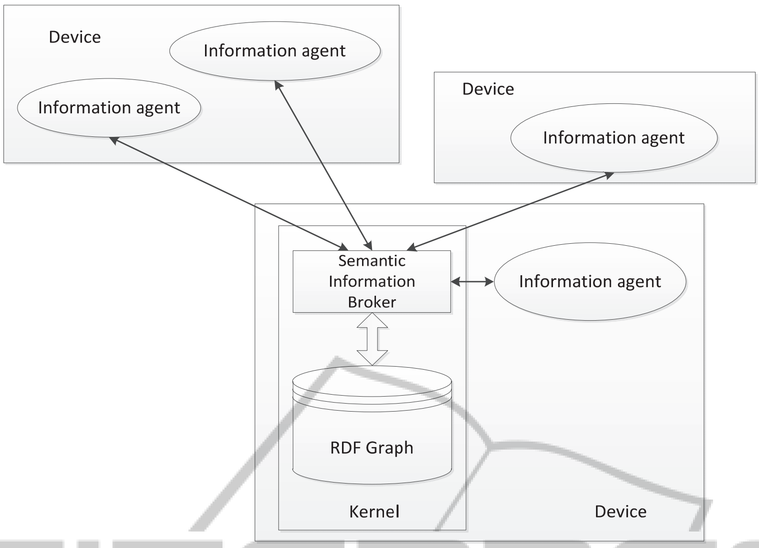


Figure 5: Smart-M3 platform.

inherits all its properties with own property "detour" the same as in the class "driver".

For the path definition, the set of points is used. This set is an ordered list of key points obtained as result of the shortest path searching algorithm (e.g., Dijkstra or A*).

More details about the logistics service ontology can be found in (Smirnov et al., 2010).

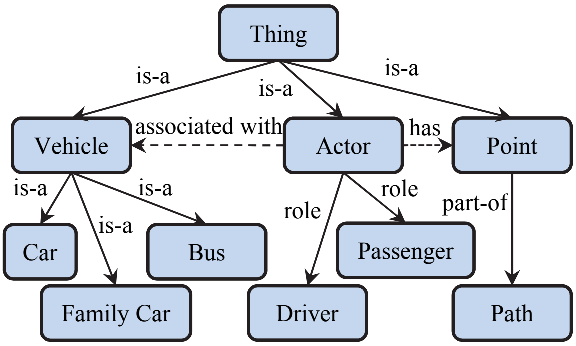


Figure 6: Logistics service ontology on the macro level.

5 ALGORITHM FOR MATCHING DRIVER AND PASSENGER PATHS

The problem of finding a matching path between the driver and the passenger in the ridesharing service can be formulated as follows: it is needed to determine the possibility of ridesharing between users, based on the information about their routes and restrictions set by users' services. The following algorithm describes the procedure of finding a matching path acceptable for the driver and the passenger in the presented ridesharing service.

Let A be the start point and B be the end point of the pedestrian's path. C is the start point and D is the end point of the driver's path. The shortest driver's path, is indicated by the solid line in Figure 7 (in generally, CD is not a straight line; it depends on the map of the region). The driver and pedestrian move almost in the same direction and in some parts of the routes the driver can give the pedestrian a ride. This situation is indicated in the figure by the dotted line (the CABD path) and it is the simplest situation, because the meeting points match with the start and end points of the pedestrian's path. A more difficult situation is searching for a meeting point when it belongs neither to the driver's shortest path nor to the pedestrian's one, but satisfies both the driver and the passenger. One of the possible situations is indicated in the figure by the dash-dot line with the meeting points E and F (the CEFD path).

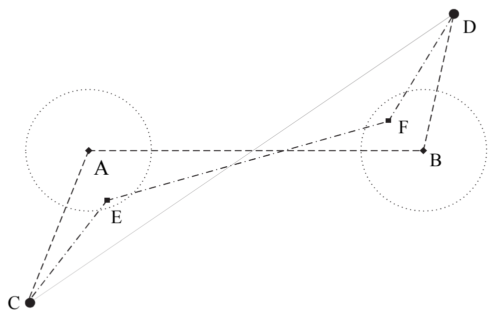


Figure 7: Matching driver and passenger paths.

The general scheme of the matching route searching algorithm will be follows:

```
FOR EACH driver DO
  FOR EACH passenger Do
    Find_mathing_path(driver.path,passenger.path); // according to the above
scheme
    constraint_checking();
    IF ALL constraints IS performed THEN
      set_passenger_for_driver();
  ENDFOR;
ENDFOR;
```

These points have to meet the following restrictions:

1. The distance between the start point of the passenger and his/her meeting point should be less than the maximum allowed detour of the passenger (dotted circle around point A).
2. The distance between the end point of the passenger and his/her drop-off point should be less than the maximum allowed detour of the passenger (dotted circle around point B).
3. The driver's detour should be less than the maximum allowed detour.

The goal functions for finding the meeting points are:

- Shortest total path (interesting for the driver);
- Minimal waiting time (interesting for the driver and passenger);
- Shortest distance between the passenger's start and end points and meeting points (interesting for the passenger).

As a result, the general task of matching paths has the exponential complexity; therefore, it is necessary to apply heuristics to reduce the task dimension. There are two heuristics proposed to reduce the algorithm complexity. The first one allows roughly reduce search space in short time and after that the second heuristic allows to reduce search space even more. However, computation complexity of a second heuristic is higher than first; therefore, it has to be used after the first heuristic.

5.1 Heuristics 1

Assumption: There is no need to calculate matching paths for all pairs of drivers and passengers. It is enough to build a set of candidate passengers for every driver.

$$(pp_1^x - dp_i^x)^2 + (pp_1^y - dp_i^y)^2 \leq (PDetour + DDetour)^2, \quad (1)$$

$$(pp_2^x - dp_i^x)^2 + (pp_2^y - dp_i^y)^2 \leq (PDetour + DDetour)^2, \quad (2)$$

where pp_1, pp_2 — the start and the end points of the passenger's path, dp_i — driver's path point i, *PDetour*, *DDetour* — detours of the driver and the passenger.

5.2 Heuristics 2

Assumption: There is no need to search through all possible combinations of meeting points. The following alternative sub-heuristics help to reduce the number of the possible combinations.

The first sub-heuristics selects points of the sector from which the driver starts. Figure 8 shows the situation when there is only one point ("C" point) meeting constraints (1) and (2). To determine the potential meeting points it is needed to calculate the angle (3) and select points in the area: $\left[\theta - \frac{\pi}{4}, \theta + \frac{\pi}{4}\right]$ (points L and M in Figure 8).

$$\theta = \text{arctg}\left(\frac{C^y - A^y}{C^x - A^x}\right) \quad (3)$$

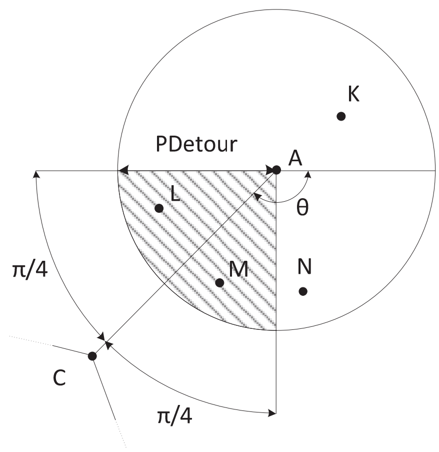


Figure 8: The first sub-heuristics.

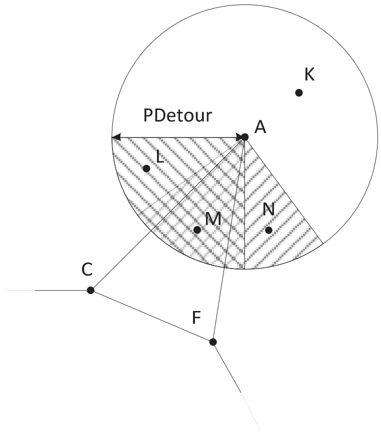


Figure 9: The first sub-heuristics with two driver's points.

Point A will always be within the list of the possible points as the passenger's start or end point. If there are more than one point meeting constraints (1) and (2), then the search area expands. This situation is shown in Figure 9 with two points C and F meeting the constraints (1) and (2), and point N is also included in the expanded area.

The negative sides of this sub-heuristics are:

- selected points can be further than the driver's maximal detour;
- some of potential meeting points can be lost if an incorrect angle is chosen.

The second sub-heuristics (Figure 10) selects meeting points in the intersections of the circles of radius PDetour around the passenger's start and end points with the circles of radius DDetour around the points of the driver's path.

In this case, all of the selected points are potentially reachable for both the driver and the passenger, with no need to determine the angle that restricts the selection area. The selection area can be expanded via increasing the number of the driver's path points meeting constraints (1) and (2).

Both sub-heuristics require the following constraints to work effectively:

- A large amount of drivers. Heuristics have strong limitations and filter out a lot of points. If there are no enough drivers, then the use of the heuristics will rarely produce positive result.
- A small value of DDetour. Heuristics will not be helpful with a large value of DDetour.
- Uniform distribution of roads on the map. The uneven distribution of roads (rivers, lakes, etc) leads to a lack of roads in some sectors, which could lead to the loss of possible meeting points due to the need to detour around the obstacles and to pick up the pedestrian on the other side.
- Both heuristics 1 and heuristics 2 are used in the logistics service prototype. Without using the heuristics, the system finds from 10 to 12 meeting points for each pair of driver and passenger and it needs to check all of 100–144 combinations to find the best one. With using the heuristics, the number of points is reduced to 8-9 points with 64–81 combinations for each pair of driver and passenger.

6 EVALUATION

The algorithm for matching driver and passenger paths has been tested using the following computer: Intel Pentium 4, 1.6 GHz, RAM: DDR1 512 Мб. For the experiments, the algorithm with proposed heuristics has been run on random datasets as input parameters for the predefined drivers and passengers (see, Table 1). Each dataset includes coordinates of start and end points of a fellow traveler. Experiments show that heuristics help to reduce the time of search in more than 1.5 times.

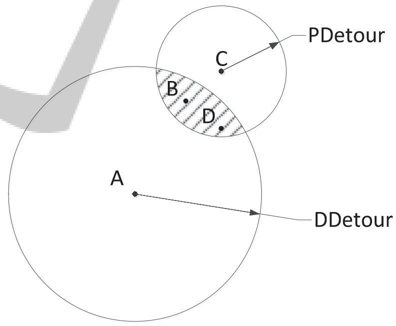


Figure 10: The second sub-heuristics.

Table 1: Results of the experiments.

Drivers	Passengers	Matching time, sec
1	1	0,0135
5	5	0,0316
10	10	0,0641
20	20	0,2248
40	40	1,5462
60	60	2,2416
80	80	3,4725

Figure 11 presents relationship between matching time and number of drivers and passengers in the service.

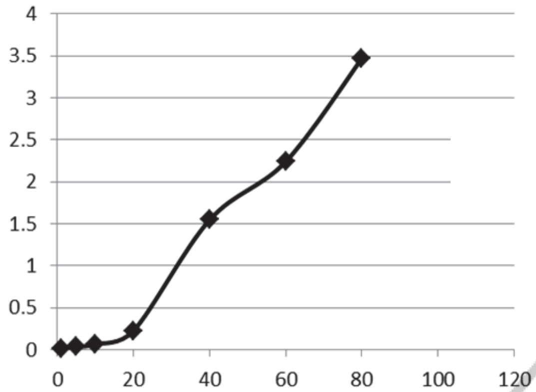


Figure 11: Relationship between matching time and number of drivers and passengers in the service.

7 QUESTIONNAIRE-BASED ANALISIS

To better cognize, whether our prospective customers will accept ridesharing services as an alternate mode of transportation, an online questionnaire has been developed.

7.1 Questionnaire Design and Respondent Selection

The questionnaire was constructed using Likert Scale statements and open-ended questions. The statements in Likert Scale were structured in a way that there were five choices i.e. (Strongly disagree; Disagree; Not Sure; Agree; Strongly Agree). We opted for Likert Scale when designing the questionnaire as it gives participants an opportunity to specify their responses on different levels. In response, the participants expressed their opinions pertaining to costs associated with travelling, security concerns (for instance, travelling with strangers), and issues relating to travel schedules/routes etc. Open-ended questions were poised to gain richer insight into peoples' attitudes towards ridesharing. For example, to establish main reasons why people use the service or why they make specific choices while using ridesharing service abroad.

Ridesharing service has been proposed as an assuring approach to improve tourism in Russian Karelia accessibility for local tourists and those who travel across the border. The study took place during November and December 2012 and responses were gathered both from Russian and Finnish population. In all, forty eight (N=48) responses were collected. However, forty six (N=46) were used to perform the analysis because two responses were incomplete. Out of the 46 respondents, there were 33 males (71.7%) and 13 females (28.3%) with an average age of 32 years (ranging from 20 to 68 years). From Finland (primarily Oulu region), 26 responses were received and 26 participants completed the questionnaire from Russia (St. Petersburg and Petrozavodsk).

7.2 Analysis of Questionnaire Results

More than half of the participants (56.5%) reported that they had never used ridesharing in their respective countries. Interestingly, a bigger number of participants (76.1%) stated that they did not use ridesharing abroad. A significant number of participants (32.6%) stated that they rarely used ridesharing and the remaining (10.8%) informed that they either used it on monthly, weekly or daily basis.

More than half of the respondents (54.3%) confirmed that they would prefer to use the mobile-based ridesharing application. The responses suggest that people have an inclination to use the service for reasons such as reduced travel costs (80.7%) and saving time (69.5%). These findings were confirmed by the responses to open-ended questions where majority of the respondents stated that they preferred ridesharing to save travel costs and time. Yet, a number of participants (39.1%) stated that they would use ridesharing only when it is time efficient when compared with public transport, or, when their destination is not accessible via public transport (36.9%). Besides, there is a similar amount of respondents who stated that they will use ridesharing even though a destination would be accessible by public transportation (45,6%) and also when by public transportation it would be faster (32,6%). Therefore, we can cautiously propose that ridesharing is a promising solution to improve tourism object accessibility.

Although the data analysis indicates positive attitudes towards the acceptance and potential usage of ridesharing, the service will need to be incorporated with features that will enhance security. Security aspects were stated as main reasons why people would not use ridesharing. For instance, the majority of the respondents (65.2%) will use ridesharing only together with people who is suggested by personally known person. Therefore developing ridesharing further is a prerequisite through social networks, facilitation of comments and feedback and an option to share individual experiences.

8 CONCLUSIONS

The paper proposes the smart space-based ridesharing service to improve tourism in Russian Karelia accessibility. The paper describes the service architecture, main algorithms, used heuristics (which help to reduce the time of search in more than 1.5 times), implementation, and the questionnaire developed to cognize whether prospective tourists will accept ridesharing services as an alternate mode of transportation. Developed questionnaire analysis shows applicability of this type of transportation in Karelia region (respondents would like to use the ridesharing service for reduced travel costs (80.7%) and saving time (69.5%)). Smart-M3 information platform is used as a smart space infrastructure for the presented approach. Use of this platform makes it possible to significantly increase the scalability and extensibility of the prototype system. The algorithm for finding appropriate fellow travelers for drivers as well as definition of acceptable pick-up and drop-off points for them is presented in the paper. This algorithm can effectively find appropriate fellow travelers for drivers. Importance of driver path and passenger start and end points matching has been confirmed by analysis of questionnaire results. For instance, majority of the respondents would rideshare if there is no need to change their travel routes (50%) and when it fits well with their schedules (73.9%).

Although there are positive attitudes towards the acceptance and potential usage of ridesharing, the service will need to be incorporated with features that will enhance security. Besides, integration of social networks, facilitation of comments and feedback and an option to share individual experiences are planned in the future work.

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