Solving last mile problem as a personal service for citizens

Miroslav Svítek
Faculty of Transportation Sciences (FD)
Czech Technical University in Prague
Prague, Czech Republic
svitek@lss.fd.cvut.cz

Patrik Horažďovský
Faculty of Transportation Sciences (FD)
Czech Technical University in Prague
Prague, Czech Republic
horazpat@fd.cvut.cz

Sergey Kozhevnikov
Czech Institute of Informatics, Robotics and Cybernetics
Czech Technical University in Prague
Prague, Czech Republic
Sergei.Kozhevnikov@cvut.cz

Xenia Pogorelskih
Department of analytics and development
SEC «Smart Solutions»
Samara, Russia
pogorelskih@smartsolutions-123.ru

***Abstract*— The last mile problem is crucially important for big cities because we need to find the ideal balance between different criteria: the mobility of people, comfort and unique characteristics of every person, profit of transport system and other criteria in more complex models.**

To solve this problem for dynamic not fixed routes part, we offer to use ontological description of citizens and transport system for matching and multi agent technologies to plan different types of transport. To prove the idea a prototype of intelligent multiagent transport system matcher was created. Based on a simple model with basic Person, Transport and Infrastructure description we proved the feasibility of the approach.

As the next step is to add more concepts and parameters to the model, because the designed architecture shows full openness scalability and to prove the concept on a test data from the city of Prague and the city of Samara.

As a result, in this paper for the first time we want to present the whole Smart Transport System as a personal service provided for citizens. The main idea of the work to make a step for changing the current paradigm where people adjust their plans for transport schedules. The new paradigm will show how the smart transport can provide personal service to every citizen according to their needs.

Keywords*— *smart city, smart services, ontology, multi-agent technology.

I. Introduction. Problem statement.

In general, the transport is very complex problem in Smart City approach. Transport influences lives of all persons and also influences thinking of people. Thinking about transport can change whole cities and whole areas and regions. First thing, the first question, when people want to find a new place for living is how much it cost and hand in hand how they can reach their destinations - school, work and another similar activity in town. Because of that reason villages around large cities have multiplied the number of their permanent residents over the past few years. This effect is perfectly visible at the villages near railway lines and another main transport routes.

This first phenomenon (money and possible transport) caused in few last years that habitants changed their habits and they are willing to travel longer distance to work. Another effect of this thinking is that villages, which are not in sufficient distance from main transport routes have completely different problem. Residents are leaving these villages. This population movement strongly affects transport needs for new populated areas. The quality of infrastructure and public transport connection to the main destination influence area development.

Current state of public transport system is generally based on the fixed routes without any possible changes. Every transport connection has special time in timetable when it can be in service. This approach is very clear and passengers can be sure that they will be transported in the planed time. This approach is very good at the main lines of public transport in the city center. If the passenger wants to travel by public transport to town periphery or to the new integrated village, it is possible that the main line is not going there and the passenger have to change a line. Because of the fixed routes and times, it is possible that the following connection doesn't exist or it is gone. Passenger have to wait or to find another possibility to transport, like a taxi. Another possibility is, that the main line going to the passenger destination but only with the few connections. Passenger has to find in timetable, which specific connection is suitable for him. Because of many possibilities of the main line, the timetable can be hardly readable. The comfort of public transport is reduced and passengers change type of transport, especially individual vehicle transport. This situation is caused by last mile problem – final part of the road, when passengers have to change lines to reach their final destination. This paper is focused especially to this last mile problem.

This last mile problem is influenced by many parameters and approaches, for example the solution can be a combination of fixed and dynamic lines of public transport, especially created for the last mile. Definition of the dynamic lines is simple, the sequence of stops changes dynamically depending on the specific demand for transport by passengers or current state of transport in region. The same conditions are set to the time schedule of every single connection. Solving this task, we also need to take into consideration the parameters of the request from people. We need to take into account citizens' characteristics, constraints, abilities and preferences. In result, if there are not a demand, the final last mile dynamic connection is not in operation.

The question is, how and what kind of transport can be the last mile dynamic public transport? This question supports the complexity of this Smart City solution. The idea is to create dynamic part of transport where every means of transport (public, shared cars, rented scooters, bicycles and others) can be used in time of need, depending on passenger.

In this paper we try to state two different problems. The first problems statement is how to solve the last mile problem taking into consideration the various parameters of people and transport infrastructure. From mathematical point of view, we are solving the Assignment problem.

In more broad way the model can be complex when we add more criteria, because we need to find the ideal balance between different criteria: the mobility of people (they need to get home from the public transport stop), comfort (we need to take into account unique characteristics of every person and his abilities), profit (the empty bus cannot transport only one person) and other criteria's.

As a result, in this paper we try to state the second more complex problem described by a model with various numbers of concepts, attributes and satisfaction functions. The model described for the first time present the Smart Transport System of the City as a personal service provided for citizens. This model can change the paradigm where people adjust their plans for transport schedules and show how the smart transport can provide personal service to every citizen according to their needs.

II. State of the Art. How the modern transport systems work

Linda Steg [1] investigated the possibility of abandoning the personal car in the direction of public transport. She conducted a computer survey of people in search of patterns. As a result, it turned out that many people are not ready to give up a personal car due to the fact that it is not status and does not give freedom of movement. However, many people were concerned about global problems, such as ecology, and were willing to switch to public transport for a higher purpose. Thus, increasing people's awareness of the problems created by personal transport, as well as improving the comfort and accessibility of public transport can force people to abandon the personal car. This work was published in 2003. What has been done since then?

Armando Cartenì and Ilaria Henke [2] investigated the impact of the quality of transport stops on people's satisfaction with the trip. The result of the study was the fact that the convenience of the stopping point plays an important role only for short trips. In the case of a long trip the quality of the trip comes to the fore.

Enda Murphy and Joe Usher [3] analyze the Irish experience of introducing Bicycle exchange in the city. They note that the main users of the system are relatively young men with incomes above average. It is necessary to work to attract women to use bicycles, as well as to make the system more accessible to different levels of income. They also note the positive effect on the health of citizens. The most interesting result of the study is the conclusion that bicycles are extremely popular as a tool with which you can move between different public transport stops. Based on this, it can be assumed that with the expansion of the network of Cycling points, the system will become popular among citizens to solve the problem of the last mile.

A. How the last mile problem is solved

Leonidas Anthopoulos [4] compares 10 Smart cities by level of development. It marks the development of smart mobility in the city of Tampere through car parking space removal and local bus transportation. His attention was also paid to the transport systems of Seoul and Melbourne. Let us consider them in more detail.

Topis (Transport Operation & Information Service) manages real-time public transport in Seoul. The system collects and processes information on urban traffic and uses it to effectively manage bus intervals, reduce congestion and take timely action in the event of an accident. The main objective of the system is to attract more citizens to the use of public transport. As a result, the system has achieved its goal, people's satisfaction with the transport system has increased and the use of public transport has increased.

Also in Seoul there is a system of night buses "Owl Bus" based on Big Data technologies. Buses run from midnight to 05:00 am. Routes are optimized so that you do not have to wait long for a transplant if necessary. The system attracts more and more users, allowing them to lead a night life without using taxi services.

The network of bus routes SmartBus operates in the city of Melbourne. The network features are:

- relatively frequent use of buses,
- real-time display of transport information at bus stops,
- priority for buses at some traffic lights,
- dedicated bus lanes,
- buses and stops equipped for the elderly, disabled and blind.

For 5 years, the system has managed to increase coverage by 15-60% on various bus routes, which is undoubtedly a good indicator [4].

Shen Yu and others [5] offer car sharing to solve the last mile problem. They built an agent-based simulation model to assess the performance of an integrated passenger-car-public transport interaction service. Studies have shown that such a system reduces the average number of vehicles on the roads during peak hours, that car sharing is more profitable than using buses with low demand, and that such a model is likely to be financially viable.

Aditi Moorthy and others [6] are exploring the possibility of using a taxi on the last leg of the way to solve the last mile. As a result of the analysis, they conclude that the use of a combination of public transport and taxi on the last mile is 37% cheaper than using a personal car all the way. However, in some cases, the high waiting time for public transport and the high cost of a taxi do not allow to apply such a scheme.

Miles Tight and others [7] offer a radical vision of the last mile solution: an almost complete rejection of cars. Only the elderly, the disabled and people in professions requiring speed have the right to use cars. All other people have to get on foot or by bike to a public transport stop and then use it. Children should study exclusively in schools around the house and reach them on foot or by Bicycle. In their opinion, such a system will completely change the appearance of the city and solve many problems.

Chan and Susan Shaheen, Nelson [8] noted the positive aspects of sharing a variety of vehicles: car, bike, scooter. Public transport is limited by routes and schedules and sometimes has to travel extra distances to use it. Sharing also allows you to move flexibly, efficiently and environmentally friendly.

Arthur Scheltes and others [9] are considering the possibility of using unmanned taxis at the last mile stage. They built an agent-based simulation model to analyze this possibility. The result showed that such a system is able to compete only with the option of walking. However, the increase in the permitted speed of vehicles, the movement of empty vehicles and pre-booking can slightly improve the situation.

Enda Murphy and Joe Usher [3] note that rental bicycles are a popular means of moving between stops where you need to make a change. But for the last mile, they are not actually used, because there are no rental points near the house.

Miles Tight and others [7] suggest attaching all children to schools at the place of residence. However, in the case of New Zealand, this is likely to lead to an inadequate rise in the price of real estate near good schools and stratification of society.

B. Solutions how to make Transport System personal oriented

Elise Grison and others [10] studied the impact of context and user profiles on route selection. The results showed that the choice of route depends on the user profile. Some citizens seek to make their trip as efficient as possible, to achieve maximum speed at minimum cost. Others are very concerned about getting pleasure from the trip: the comfort of the vehicle and the opportunity to travel part of the way with a friend. Elise Grison and others point out the need to add features to route planners that take into account the user's context to personalize the application: the purpose of travel, emotional state, the need for comfort. In addition, it is certainly necessary to take into account the entire profile of the user, his personal characteristics.

Dávid Földes Affiliation and Csaba Csiszár [11] affiliation is considering the issue of personalizing the mobility of citizens. They analyzed the existing planners and came to the conclusion that they do not take into account the personal preferences of people. They proposed their own algorithm, which in planning pays special attention to the walking part of the walk, as an important connecting part of the path. The algorithm takes into account the physical condition of the tracks and tries to maximize the pleasure of walking. As a result, the algorithm offered more real and comfortable routes than other planners.

To meet these challenges, the entire public transport system needs to be completely overhauled. In the work of Saraju P. Mohanty and others [12] the concept of a Smart city is given. The ideal concept of a smart transport system includes the following characteristics:

- Flexibility implies the combined use of different types of transport.
- Efficiency is to optimize the trip to meet all the requirements of the passenger.
- Integration requires planning a complete door-to-door route.
- Clean Technology means that the route must be built with the requirements of the environment in mind.
- Safety involves improving the safety of travel for all categories of passengers.

The transport system to be developed must meet these criteria.

As we can see the transport system moves towards personal oriented approach and better flexibility in routes and means of transport.

III. Model 1- Smart transport system

In our model we try to describe Smart transport system as a complex service part of the Smart City solution. In our work we propose to make a step toward intelligent transport system, that plan the transport according to personal needs and characteristics of every citizen's request.

In our first iteration Model 1 (basic model) we propose to use ontology description of the transport infrastructure as well as detailed description of transport system users. We put in the model different types of transport (car sharing, segway, bicycle, scooters, bus). Different types of users (need to take into account: age, disabilities, preferences) and Infrastructure parameters. Different external factors for making decision (weather, price, availability) are not included. This will help to make the matching between transport as resource and request for transportation as a demand.

A. Parameters of the model

We model the dynamic part and define input parameters, which influence all whole transport system. For this reason, it is defined 3 areas of interest.

- Passenger (person)
- Transport
- Infrastructure

1) Passenger

- Where is the starting and final stop/destination? (Basic parameter of the passenger route)
- Special demanded conditions (low floor vehicle, children, handicap).
- Price (price of the transport connection)
- Comfort
- Age
- License

2) Transport

- Vehicle type – mean of transport which means of transport is possible to offer to the passenger (bus, car, bike, scooter, segway, by foot)
- Capacity of vehicle (what capacity can be offered to dynamic connection)

Identify applicable funding agency here. If none, delete this text box.

- Vehicle actual position (GPS position)

3) Infrastructure

- Available start and stops locations (location where passengers can start or end travel for special types of vehicles)
- Charging stations (for specific means of transport)
- Roads (for different means of transport)

In basic model we do not take into account the time characteristic.

B. Method

From the mathematical point of view in our first model we are solving assignment problem (Passenger – Vehicle) - a fundamental combinatorial optimization problem. Because of non-equality between resource and demand we can say it is nonlinear and then the linear assignment problem. Every person in this approach can be considered as a complex demand with different parameters. Every mean of transport can be considered as complex resource with different parameters. So in first iteration the problem can be simplified to the resource demand model that can be solved by multi-agent (MA) approach.

In the multi-agent approach, the solution of any complex problem of allocation, planning and optimization of resources is built by successive approximations, from the roughest, simple quick solution to more complex and better solutions, i.e., the convergence of the solution is controlled. For this purpose, a collection of basic typical software agents is created, which try to achieve the set targets (ideal values of indicators), and having received the maximum possible in the current situation, do not leave attempts to improve them. This approach can be used for planning on many criteria, including price, comfort, speed, etc.

The implementation of the multi-agent approach in the development of intelligent dynamic planning systems is based on the concept of networks of needs and opportunities (PV-networks) and the method of conjugate interactions for the management of resources of enterprises in real time in the virtual market [Skobelev].

For the mathematical formulation of the problem of resource allocation in planning, it is assumed that each of the resources can have its own criteria. Formally, the task can be formulated through the satisfaction of order agents and resources.

The proposed satisfaction function covers for example limited resource availability based on priority, economic convenience and environmental and social sustainability. In the future in our model we can manage different criteria. And change the weight of every. In the basic model we consider all the criteria equal with even weights. The overall satisfaction of every agent will be the sum.

Thus, the formalization of the multi-criteria task of planning orders and resources in the resource demand network is proposed. The target functions of network agents are introduced in the form of scalar convolution of satisfaction functions, showing the deviation of the current indicators of the criteria from the preferred ones. Satisfaction of the whole system (and, accordingly, the specified value indicators) increases during the operation of the system.

In the proposed paradigm, the solution of any complex problem of management and construction of an acceptable quasi-optimal plan (schedule) for the use of resources is proposed to be considered as a process of self-organization of a community of competing and cooperating software agents representing the interests of the needs and capabilities of all participants in decision-making processes.

C. Results of modeling

To prove the feasibility of the proposed approach the Smart transport prototype was created based on the ontology problem domain descriptor and MAT engine. We put the data of the first model, describe basic characteristics of citizens, transport and environment.

The prototype consists of a basic ontological description of classes and relationships of all concepts of the world, the event generator, the world of agents (system engine), the basic classes of agents, visual components and tracking messages about changes in the degree of satisfaction of agents, as well as some auxiliary components.

The prototype can be modified for a new subject area and can be easily expanded with new classes and relationships.

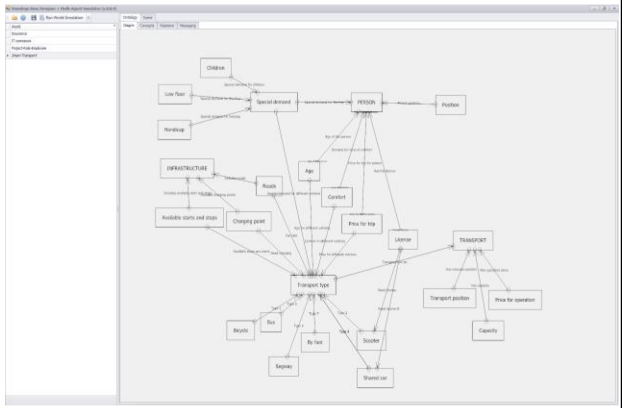


Fig. 4. Basic model classes description

The model does not take into account several criteria as

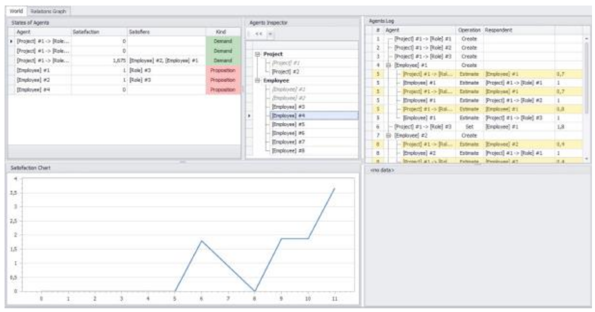


Fig. 3. Results of interactions and satisfaction function

plan of transport. The time is not considered at all. But the results of modeling are showing feasibility of the approach.

At the same time, the model shows that not all users can be satisfied by all criteria, but taking into account the critical ones (a person cannot drive a car without a license), the model shows the number of vehicles and the degree of satisfaction.

IV. Model 2 Smart Transport System as personal service in Smart city solution

As a next impact we want to state the second more complicated Model 2, that is not developed but can represent the real existing transport system, or even take into account more complex cases. In this model we can collect in real time all the orders with different parameters and plan them for different resources.

We can describe the model with already mentioned 3 classes (passengers, transport, infrastructure) but add one more – environment. All of the agents will have wide variety of criteria.

A. *Passenger agent*

If the passenger wants to use dynamic transport, for him it is necessary to define several parameters:

- Where is the starting and final stop/destination?
  - Basic parameter of the passenger route
- Final destination arrival time
  - To creation a dynamic part of transport
- Time of departure
  - This parameter is tentative; departure time can be changed depending on another parameters
- Travel time
  - How much time the passenger is willing to spend in public transport
- Time of delay
  - How much “delay” time is tolerated if someone make a new demand when the dynamic connection is already created
- Vehicle type
  - Which means of transport is acceptable to the passenger (Bus, car, bike, scooter, Segway,…)
- Special demanded conditions
  - Low floor vehicle, bike transport, handicap, etc. requirements
- Waiting time
  - How much time the passenger is willing to wait for dynamic transport
- Transfer time
  - How much time is required before following connection arrive?
- Price
  - Price of the transport connection

B. *Vehicle agent*

This type of parameters is focused to operator of public transport or to the carrier.

- Vehicle type – mean of transport
  - Which means of transport is possible to offer to the passenger (Bus, car, bike, scooter, Segway,…)
- Capacity of vehicle
  - What capacity can be offered to dynamic connection
- Vehicle actual position
  - Knowledge where vehicles are located in current time – which vehicle can be used for the transport
  - GPS position
- Vehicle actual position – following connection
  - Knowledge where vehicles of following connection are located in current time
  - Delay elimination
- Vehicle occupancy
  - Is it possible to offer concrete vehicle to the dynamic connection?
  - Online automatic passenger counting in vehicle
- Technical parameters of the vehicle
  - Size, width, height, weight

C. *Infrastructure agent*

- Bus stops locations
  - Location of places, where passengers can start or end travel
- Transfer point
  - Location of places, where passengers can change to the following connections, main lines
- Important locations, transfer point
  - Definition of location that is preferred to use
  - Charging stations
- Type of road
  - Parameter of all roads in region – Max width, height, weight of vehicles
  - Danger places
- Actual infrastructure data
  - Closed roads in current region
  - Traffic accident
  - Traffic jams
  - Dispatching restriction

D. *Environment demand*

- Weather
  - Weather conditions can significantly transform offered dynamic connection
- Pollution
  - Quantity of CO_2 or another emission can be a significant parameter for dynamic route creating
- Environment type – relief
  - territory type affects the use of means of transport

E. Additional model characteristics

Making a step toward ideal transport system of the future we need to take into account more cases that we should consider. Among them:

- The system should give recommendations on the start time of the route for reasons of traffic jams, the schedule of shops, the ability to share a trip with friends or avoid a meeting.

- Criteria for every trip can differ, because of the user. Before each trip, a person must pass a short survey on the current mood and desires. Problem of variative solutions based on people's ontology.

- The transport system must interact with the route planner of each person. Each route planner needs to interact with a personal avatar who knows the shopping list, favorite magazine where you can go after work, friends that want to share marsh route, a list of scheduled non-urgent cases in which you can stop along the way.

- This means we need personal scheduler for planning and request for the time slots and synchronized p2p planners.

- It is necessary to increase the number of rental points. To have as much as the garbage containers in each yard. And to be able to pre-book a Bicycle/scooter/rollers, etc.

- From technical point of view the system should poses the ability to manage two planning strategies, JIT and ASAP.

- The system should motivate office workers to move more and specifically offer ways that involve walking or Cycling as an alternative to the most effective route.

- The system should run a lot of different-sized unmanned electric buses that pick up people near their starting points of the route.

- For all these areas it is necessary to work with actual data. The system cannot be dynamic without actual data, because the system don´t know requirements to transport. These areas intersect and interact with each other.

In the transport system of the future from our perspective the persona will just point "I want to go from A to B. I need different variant for money and comfort suits for me". And the system, will offer him different variants. In future transport system even public transport schedule will be formed based on real time demands from people. And solving the global transport task will be combination of resources and demands.

V. EXAMPLE FROM PRACTICE

For demonstration of the new dynamic approach the area near Prague was chosen. This area include the town Mníšek pod Brdy and small villages Kytín, Chozavá and Nová Ves. Public transport is characteristic by two main lines in this region. One of them is the train line and the second one is the bus line (317). These lines are the most important connection from this area to Mníšek pod Brdy and Prague. Another lines are only the folloving connections to the main lines. In the next figure 3 there is a scheme of public transport with new proposals for cycling.

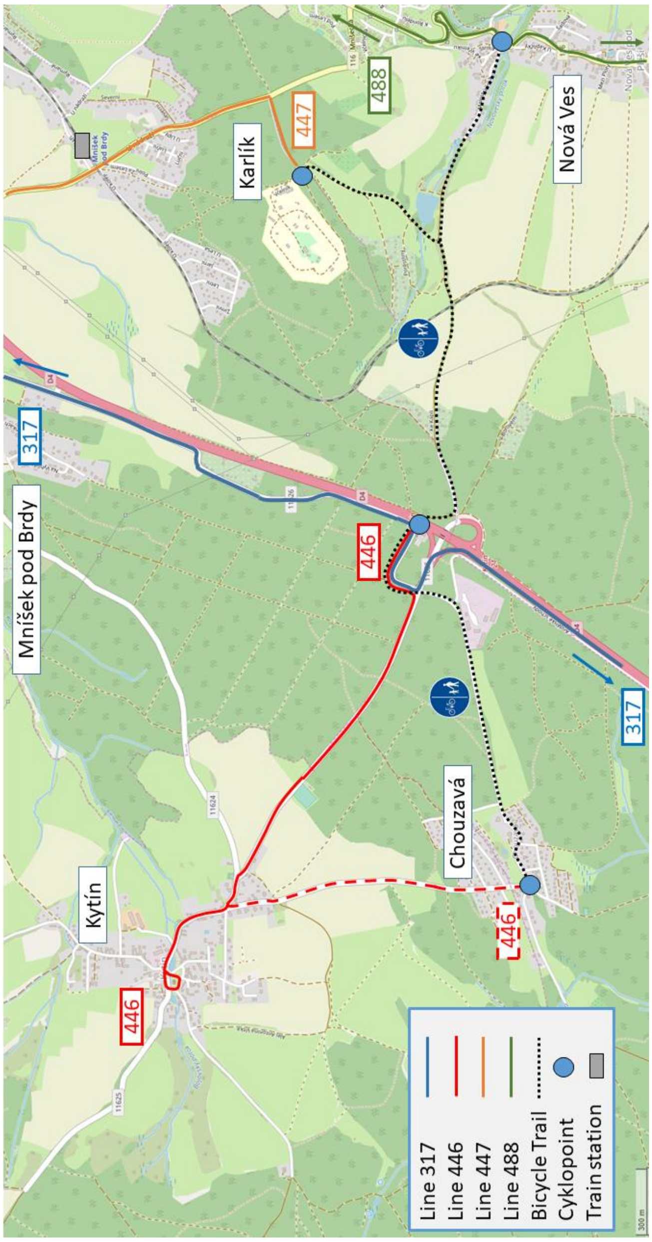
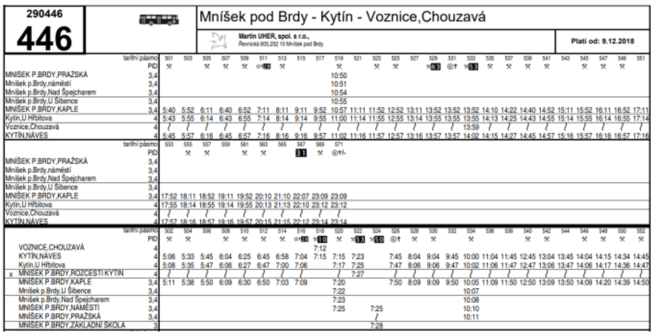


Fig. 3 - Test area for dynamic public transport

For the last mile problem there are several connection otions.

In current situation passengers have to change a line if they want to go to village Kytín at transfer point. This transfer point is in the forest and the line 446 is waiting to 317, so the line 446 is typical following line. The problem is if the passenger want to go to Chouzavá. There is only one connection for a day by 446 line to Chouzavá. (Fig. 4)



290446

446

Mníšek pod Brdy - Kytín - Voznice,Chouzavá

Martin UHER, spol. s r.o.,
Řevnická 605,252 10 Mníšek pod Brdy

Platí od: 9.12.2018

tarifní pásmo		501	503	505	507	509	511	513	515	517	519	521	523	525	527	529	531	533	535	537	539	541	543	545	547	549	551
PID		⚒		⚒	⚒	⚒	⑥†28	⚒			⚒		⚒	⚒		⚒63	⑥†	⚒53	⚒	⚒	⚒	⚒		⚒	⚒	⚒	
MNÍŠEK P.BRDY,PRAŽSKÁ	3,4										10:50																
Mníšek p.Brdy,náměstí	3,4										10:51																
Mníšek p.Brdy,Nad Špejcharem	3,4										10:54																
Mníšek p.Brdy,U Šibence	3,4										10:55																
MNÍŠEK P.BRDY,KAPLE	3,4	5:40	5:52	6:11	6:40	6:52	7:11	8:11	9:11	9:52	10:57	11:11	11:52	12:52	13:11	13:52	13:52	13:52	14:10	14:22	14:40	14:52	15:11	15:52	16:11	16:52	17:11
Kytín,U Hřbitova	4	5:43	5:55	6:14	6:43	6:55	7:14	8:14	9:14	9:55	11:00	11:14	11:55	12:55	13:14	13:55	13:55	13:55	14:13	14:25	14:43	14:55	15:14	15:55	16:14	16:55	17:14
Voznice,Chouzavá	4	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	|	13:59	|	|	|	|	|	|	|	|	|
KYTÍN,NÁVES	4	5:45	5:57	6:16	6:45	6:57	7:16	8:16	9:16	9:57	11:02	11:16	11:57	12:57	13:16	13:57	13:57	14:02	14:15	14:27	14:45	14:57	15:16	15:57	16:16	16:57	17:16

tarifní pásmo		553	555	557	559	561	563	565	567	569	571
PID			⚒	⚒		⚒	⚒		31	⚒	⑥†♿
MNÍŠEK P.BRDY,PRAŽSKÁ	3,4										
Mníšek p.Brdy,náměstí	3,4										
Mníšek p.Brdy,Nad Špejcharem	3,4										
Mníšek p.Brdy,U Šibence	3,4										
MNÍŠEK P.BRDY,KAPLE	3,4	17:52	18:11	18:52	19:11	19:52	20:10	21:10	22:07	23:09	23:09
Kytín,U Hřbitova	4	17:55	18:14	18:55	19:14	19:55	20:13	21:13	22:10	23:12	23:12
Voznice,Chouzavá	4	|	|	|	|	|	|	|	|	|	|
KYTÍN,NÁVES	4	17:57	18:16	18:57	19:16	19:57	20:15	21:15	22:12	23:14	23:14

tarifní pásmo		502	504	506	508	510	512	514	516	518	520	522	524	526	528	530	532	534	536	538	540	542	544	546	548	550	552
PID		⚒	⚒		⚒	⚒	⚒	⚒	⑥†28	⚒10	⚒	⚒53	⚒50	⑥†	⚒	⚒		⚒			⚒	⚒		⚒	⚒	⚒	⚒
VOZNICE,CHOUZAVÁ	4									7:12																	
KYTÍN,NÁVES	4	5:06	5:33	5:45	6:04	6:25	6:45	6:58	7:04	7:15	7:15	7:23		7:45	8:04	9:04	9:45	10:00	11:04	11:45	12:45	13:04	13:45	14:04	14:15	14:34	14:45
Kytín,U Hřbitova	4	5:08	5:35	5:47	6:06	6:27	6:47	7:00	7:06		7:17	7:25		7:47	8:06	9:06	9:47	10:02	11:06	11:47	12:47	13:06	13:47	14:06	14:17	14:36	14:47
x MNÍŠEK P.BRDY,ROZCESTÍ KYTÍN	4	|	|	|	|	|	|	|	|		|	7:27		|	|	|	|	|	|	|	|	|	|	|	|	|	|
MNÍŠEK P.BRDY,KAPLE	3,4	5:11	5:38	5:50	6:09	6:30	6:50	7:03	7:09		7:20			7:50	8:09	9:09	9:50	10:05	11:09	11:50	12:50	13:09	13:50	14:09	14:20	14:39	14:50
Mníšek p.Brdy,U Šibence	3,4										7:22							10:07									
Mníšek p.Brdy,Nad Špejcharem	3,4										7:23							10:08									
MNÍŠEK P.BRDY,NÁMĚSTÍ	3,4										7:25		7:25					10:10									
MNÍŠEK P.BRDY,PRAŽSKÁ	3,4												|					10:11									
MNÍŠEK P.BRDY,ZÁKLADNÍ ŠKOLA	3												7:28														

Fig. 4 – Timetable 446 bus line

For this reason, there is the new possibility, to use bikesharing and choose shorter way using bicycle trail. Another possibility is to make the line 446 dynamic and to crate new connection (extension) to Chouzavá. This possibilities are chosen by passenger, environment or another type of input parameters.

Similar problem occurs when passengers want to travel to the small village of Karlík from Mníšek pod Brdy. Normally passenger must take a line 447, but there is a similar problem like 446 – there is only few connections per day. New possibility is to take a line 317 and at Cyklopoint take a bike. Another possibility is to take a line 488 and at a small village Nová Ves change to the bike. Line 447 can be also dynamic, so if there is a high demand for transport to Karlik, the new connection of 447 is created.

Optimal result can be combination of this solutions – passenger can use train to Mníšek pod Brdy (frequent traffic jams on the highway) – line 447 is dynamically created in the section Train station MpB – Karlík or Nová Ves and then passengers can use bikes to Chouzavá or Kytín.

One of this solutions is offerd to passenger. Optimal decision is chosen by algorithm based on mentioned parametres.

VI. CONCLUSION

In this paper for the first time we want to present the Smart Transport System of the City as a personal service provided for citizens. The main idea of the work is to change the paradigm where people adjust their plans for transport schedules and show how the smart transport can provide personal service to every citizen according to their needs.

ACKNOWLEDGMENT *(Heading 5)*

This work was supported by Student grant competition of Czech technical university in Prague SGS19/080/OHK2/1T/16

REFERENCES

[1] L. Steg, “Can public transport compete with the private car?” IATSS Research, vol. 27, 2003, pp. 27-35.

[2] A. Carteni, and I. Henke, “Public Transport Quality and Travel Experience: The Italian Case Study,” European Scientific Journal, 2017.

[3] E. Murphy, and J. Usher, “The Role of Bicycle-sharing in the City: Analysis of the Irish Experience,” International Journal of Sustainable Transportation, vol. 9, pp. 116-125, Jul 2014.

[4] L. Anthopoulos, “Smart utopia VS smart reality: Learning by experience from 10 smart city cases,” Cities, in Press.

[5] Shen, H. Zhang, and J. Zhao, "Embedding autonomous vehicle sharing in public transit system: An example of last-mile problem," Tech. Rep., 2017.

[6] A. Moorthy, R. De Kleine, G. Keoleian, J. Good, and G. Lewis, “Shared Autonomous Vehicles as a Sustainable Solution to the Last Mile Problem: A Case Study of Ann Arbor-Detroit Area,” SAE Int. J. Passeng. Cars – Electron. Electr. Syst, vol. 10, 2017.

[7] MR Tight, F Rajé, and PM Timms, “Car-free urban areas – a radical solution to the last mile problem or a step too far?” Built Environment, vol. 42, pp. 603-616, December 2016.

[8] S. Shaheen, and N. Chan, “Mobility and the Sharing Economy: Potential to Facilitate the First- and Last-Mile Public Transit Connections,” Built Environment, vol. 42, pp. 573-588, December 2016.

[9] A. Scheltes, and G. Correia, “Exploring the use of automated vehicles as last mile connection of train trips through an agent-based simulation model: An application to Delft, Netherlands,” International Journal of Transportation Science and Technology, vol. 6, 2017, pp. 28-41.

[10] E. Grison, V. Gyselinck, and JM Burkhardt, “Exploring factors related to users’ experience of public transport route choice: influence of context and users profiles,” Cognition, Technology & Work, vol. 18, November 2015.

[11] D. Földes, and C. Csiszar, “Route Plan Evaluation Method for Personalized Passenger Information Service,” Transport, vol. 30, pp. 273-285, October 2015.

[12] S. P. Mohanty, U. Choppali and E. Kougianos, “Everything you wanted to know about smart cities: The Internet of things is the backbone,” IEEE Consumer Electronics Magazine, vol. 5, no. 3, pp. 60-70, July 2016.