The application of the latest territorial components for sustainable mobility in district cities

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Abstract. The paper is focused on the application of new approaches of designs in district cities like Klatovy. The main part is description of the latest approaches and urban territorial solution. The emphasis is put on the traffic in city centers, latest trends in parking, implementation of toll or support of all the means of transport to ensure sustainable mobility including technical trends in traffic. The intention is mainly focused on the implementation of C-ITS, public transport preferences or the introduction of new concepts such as Mobility Hub, which can ensure economic returns on investment and especially sustainable mobility in historic parts of smaller and medium-sized cities.

Keywords: mobility, parking, traffic control, smart city, transport master plan

1. Introduction
The city of Klatovy is located in Plzeň region, 40 km southward from Plzeň. Klatovy are district city and the district is the biggest in the Czech Republic. The population of the city is 22 257 inhabitants (2020). The altitude of the city is 405 meters above the sea level. The city is the second largest of Plzeň region. From the transportation point of view is the city formed by the through roads of I. class, which are going from north to south and they are connected from the west. The II. class roads are connected from the east. The data for the traffic intensity and the vehicle composition of traffic flow are proportional to the size of the city. For the intersections in the center of the city – Domažlická and Plzeňská the intensity of the vehicles is about 19 thousand vehicles per day (see fig. 1). The directional survey of the whole city was conducted, and it serves as a groundwork for the generel. The suvey showed that the highest intensities are made by intercity relations, which means from the one part of the city to another. Thus, surprisingly not the transit transport, as it would be expected for the city like Klatovy. One of the objectives of the suggested adjustments is change of transport behaviour and create conditions (public transport, cycling transport, pedestrians) in order to allow the citizens to use other means of transport. [1]
From the transportation point of view is the city perceived as the city of short distances. It is possible for the travels through the city (if the walking distance is good) use other means of transport than cars such as bicycle, train, or bus. The example of accessibility of the public transport in the city is in the fig. 2. Public transport accessibility isochrone in Klatovy and accessibility of walking relations. Based on these types of analytical background it is possible to design particular measures and recommendations for the city of Klatovy regarding the development of transport network and transport itself and its connection to the surroundings.

**Figure 1.** Intersection Plzeňská – Domažlická and traffic intensity diagram [1].

**Figure 2.** Public transport accessibility isochrone in Klatovy and accessibility of walking relations [1].

The level of the service is possible to determine by individual colour, which is obvious from the fig. 2.

| Colour | Description                                      |
|--------|--------------------------------------------------|
| Green  | Public transport accessibility isochrone 5 min (300 m) |
| **Low level of service** | (0-49 lines in both directions in 24 hours) |
| Orange | Public transport accessibility isochrone 5 min (300 m) |
| **Medium level of service** | (50-99 lines in both directions in 24 hours) |
| Red    | Public transport accessibility isochrone 5 min (300 m) |
| **High level of service** | (100 and more lines in both directions in 24 hours) |
The general is looking into the individual means of transport and its mutual interaction and it is made for three time periods. In the general are distinguished short-term solutions (prospectively year 2025), medium-term solutions (prospectively year 2035) and long-term solutions (prospectively year 2045). The main problem is individual car transport and its spatial structure – too wide roads with many lanes, intersections controlled by traffic lights with fixed signal plan. Another issue is the cheap long-term parking in the center of the city – which allows long-term parking of the vehicle and blocking the possibility of turning parking of the vehicles (multiple shot-term parking). Therefore, the solutions of these problems are connected with the new approaches of intelligent parking, which could be used also for toll systems and navigation including the sustainable mobility in the center of the city. These new approaches are described in this article including the introduction of the new ITS (Intelligent Transport Systems) systems and Smart City.

2. Application of the new systems and approaches in parking

The parking is very present problem for almost every larger city. Most of the cities suffers from insufficient number of parking spots in the street network. Designing of the new parking sites is very complicated and economically demanding, therefore the cities are trying to use existing parking sites as effectively as possible. [2] Many studies are providing the solution for the problem with parking in the streets regarding the aspects of the new approaches like reservation, sharing services or even autonomous vehicles (shuttle). The genetic algorithm was used, based on the SUMO, AIMSUN simulation for the optimization of the carpool lane according to the requirements of the traffic flow and parking principles. The scenarios with maximum flow were tested and various rates for the parking services. The results show the compromise between traffic demand and network capacity because the extent of the parking services may vary. [2-5]

The example of the parking system is Amsterdam, one of the greenest cities in Europe. The parking there is very expensive with the goal to reduce number of the vehicles in the city. Wireless sensors provides data about parking in the real time in available places. These informations are accessible for the users on the dashboards of their vehicles. The city is investing to the underground parking lots excessively and they support drivers to use P+R outside of the city center and then travel to the center by public transport. [6] The up-to-date parking system is in San Francisco. The price is based on the demand; thus, it is dependant on the number of free spaces. The parking system introduces blend of the time prices and technology, which uses deeply covered sensors in the pavement for the monitoring of the availability of free parking spots. [7]. All the mentioned systems have a common denominator and that is the technical and technological background of the city. The city must gradually design and implement new systems to enable the integration of all services, and the acquisition and transmission of information and data. Parking is a very effective way to start the new approaches of Smartcity and ITS, as it allows a simple economic model of return on investment in the city.

Drivers and road users, who wants to find free parking spot in the city or in locality may book the parking spot by mobile application or simply by entering the final destination in navigation in vehicle. The requirement is sent to the Mobility Hub, which has all the information about parking lots in the city and other selected information about the locality. This system can also be used for the toll system. Information about vehicle position and motion in the traffic network is possible to obtain by cooperative system - V2X (vehicle-to-everything) communication, which informs about local adjustments, free parking spots around, number of vehicles and other important information or information about driving the vehicle. The drives have online knowledge about the state of the traffic obtained from the center of traffic control for the road V2X, as well as the information about the potential free parking spot using the Mobility Hub by LTE (Long Term Evolution) and 5G in the future. [2]

C-ITS (Cooperative Intelligent Transport Systems) systems are based on the V2X communication, i.e. between vehicle and infrastructure or between vehicles. Within this communication bidirectional exchange of data take place and the specific technology DSRC (Dedicated Short-Range Communications) which is working on 5.9 GHz frequency is used. This frequency zone is reserved for safety applications in traffic worldwide. Within this communication the IEEE 802.11p standard is used, which was evolved into the ITS-G5 standard in Europe. Apart from ITS-5G, the public telecommunication network of mobile operators is used for the data transfer in C-ITS. Systems, which
use ITS-G5 and GSM (Global System for Mobile Communications). [2] The mobile network is used for the communication in vehicles, like Wi-Fi and Bluetooth. The function needs an application or defined API (Application Programming Interface), where it is possible to use DATEXII format for the data transfer on the level of Mobility Hub and traffic control center with subsequent transfer to web application of the mobile phone with map foundation and display with necessary data. The usual IT approaches are used for the data transfers, including collecting data, identification of data, automatic verification of data, encoding data, interpretation of data. Mobility Hub can have cloud solution, which is suitable for administration and redistribution of huge amount of data – big data. The basic approach to the virtual parking is in the next picture (fig. 3). [2]

Figure 3. Principle of virtual parking with data from Mobility Hub (ED – external data, TCC – traffic control center, VMS+TS – variable message signs + traffic sign, AV – autonomous vehicle, BS battery storage, RSU – road site unit, CCTV – closed circuit TV, MA [2].

3. Organization of the transport in the city center and introduction of the new technologies

The center of the Klatovy is defined by the streets Plzeňská, Podbranská, Komenského, Jiráskova a Dobrovského. The organization of the traffic in the center of Klatovy do not consider change of the system of one-way streets. In the prospective year 2025 is the center of the city designed as Zone 30, which is often combined with the priority to the right and mitigating measures. This zone would contribute to safer traffic in the center and it would also lead to the elimination of superiority of automotive transport. In the prospective year 2035 there is plan for introduction of a fee for the travels through the city. In case the driver would only drive through the city and the journey would not have the source or final destination in the square, then the transit will be charged. The scheme of traffic service of the city in the 2025 is in fig. 4.
3.1. Optimization of the supply routes for heavy transport

The next topic, which is necessary to cover is the determination and optimalization of the supply routes for individual businesses. At least 35 businesses was found from the available information and findings from field research, which needs to be supplied by heavy transport. The most convenient routes are designed for serving the supply needs. On all these roads there should be allowed of vehicles above 12 t. In 2025-2035 period all the transit transport should be banned, and the entry should be allowed only to supply transport. All the other transit transport would be lead through ring roads. It is suggested that the existing II. class roads which creates north-western ring road should be transfer to the I. class road number 22 in 2025-2035 period. The optimalization of the supply routes for heavy transport can take place even before mentioned time period and before the suggested transfer to the road of the first class.

Figure 4. Scheme of the categorization of the roads in Klatovy (year 2025) [1].
3.2. Plans for managing traffic in the city

Up-to-date method for controlling the traffic with the traffic lights are as adaptable as possible for the current situation in the intersection and its surroundings. These are especially dynamic systems, which work with detectors and strategic decision-making algorithm. For ensure the adaptive behaviour of the whole line of intersections with traffic lights or whole defined area, it is necessary to secure mutual communication between the intersections and priority decision-making about the traffic control, public transport preference, cyclist preference and pedestrian connections. That is why the most recent systems are based on hierarchical structure of individual components and every intersection with traffic lights is design by the newest knowledge for the dynamic control with the full ability to react to the events in the nearest surroundings, including accidents, emergencies etc. and at the same time to enable the coordinated control in line for the most significant roads including adaptive coordinated control of whole areas with traffic lights. For securing these new functions it is necessary to prepare given specification of systems for the own monitoring, complete diagnostic for remote control and adjustment of the attributes of own control processes with prioritization. For the design, it is necessary to respect all the requirements for construction works (shortening of the pedestrian crossings, narrowing of the traffic lanes etc.), also to add the new detectors for V2X communication to the intersection for the introduction of the C-ITS, which are used for public transport preference. Addition of the camera system with information panels for notification and navigation of the vehicles to the free parking spots or the information about the traffic with the connection to the National transport information center.

The suitable solution for controlling the traffic in the city is the use of technology or more likely combination of technologies, which would increase the passability of city network, if possible with the lowest ecological load, and at the same time as fastest within continuity and safety in road transport. In the future, Klatovy will need the implementation of telematic systems. For that would be convenient the central headquarters, where all the systems direct. The city would have general knowledge about the traffic situation, awareness of the drivers, parking capacities or another information, which would simplify life of citizens of the city or its visitors.

3.3. Regulation of traffic in the city center

In these times the drivers are not very motivated to travel to the city center other way than by car. The prices for the parking in náměstí Míru are very low – first 30 minutes for 10 Kč (0,4 €) and in part of the square even for 1 Kč (0,04 €) (!) and every following hour for 20 Kč (0,8 €). For the city center these
are extremely low prices for the parking. For the motivation of the drivers to leave the car outside of the city center would be better to increase the prices for the parking in the square. But this measure alone would not be enough and it is necessary to provide parking sites which would be close to the square and where the prices for the parking would be favourable. It is also possible to build a parking lot with higher capacity (or to use existing one), which would be in larger distance from the city center, but there would be secured attractive lines of public transport. In Klatovy there was defined 8 areas marked from A to H. It is expected that the biggest deficits in parking spaces would be in housing estate – see in the fig. 6.

Figure 6. Parking in Klatovy – marked areas for planing the technological designs [1].

Nowadays it is possible to choose from the wide range of companies, which are concerned with supplying and operating of parking machines. Parking machines help to monitor the occupancy of the parking spots, entrance to the individual city zones and it is easy to secure this system for a huge area. The main advantage of parking machines is, that most of the types is autonomous and it is possible to handle it remotely.

3.4. Technical solution of parking for securing the entrance to certain part of city

Another possibility for the supervision of the entrance to locality are hydraulic entrance posts, which are embed to the pavement. This solution is an alternative for surface parking with parking gate. The diameter of the post is around 100 mm and it is covered by anticorrosive coat. The posts are equipped
with automatic drive, which is possible to unblock manually. The slide in/out takes from 4 to 10 seconds. The example of hydraulic posts is in the fig. 7.

Figure 7. Example of hydraulic entrance post and their application (source: https://www.ynt.cz/, https://www.hormann.cz/).

The application of post is suitable especially for elimination of vehicles from rest zones, where it is necessary to limit the movement of the vehicles, but not persons. Nowadays it is often used solution in many cities because the movable post is not disturbing in historical parts of the cities and it do not ruin the architectonic character of the city. This technology is usually use as standard element of mitigation of the traffic in larger agglomerations i.e. Olomouc, Praha etc. The posts are not very much convenient if the turn-over of the vehicles is fast. For the design and installation of the parking system it is necessary to make a project and documentation to choose the contractor and supplier of the whole system. With respect to the arrangement of the historical center of Klatovy it suggests itself to use progressive technologies for the monitoring of the entrance by camera system. With the use of time stamp and addition of variable traffic signs it is possible to control the transit and parking of the vehicles in selected area or even investigate some city toll system. This toll system needs to be prepared legislative as it is in larger cities. The location of cameras would be similar to the position of gates or posts. It is even possible to use combination of gate or post system and cameras for licence plate recognition. The advantage of the system is its placement always in the entrance and exit of certain area, with the possibility to attachment to facade of the house or street lightning and monitoring of the licence plates of the cars. It is also feasible to collect the fines afterwards if the restraint is broken. The system allows to recognize different vehicles, clarify the view and the monitoring is not disturbed by buses or integrated rescue system. The example of additional camera to gate system or the position of the cameras for licence plate detection and other parameters is in the fig. 8.

Figure 8. Example of recognition of the licence plate by camera system (https://www.google.com).

To secure smooth passability of the area, the information about no entry or another information about state of the traffic or final destination is possible to solve by defined measures combined with variable traffic signs with LED technology, which could, based on the actual traffic situation, close or restrict the entrance to selected part of the city. In defined places there can be the information about parking. To
secure the navigation to parking spot the variable parking signs are used, which navigate to the free parking capacities, chosen areas etc. The navigation system is implemented by variable parking signs, which can show the direction to the parking lot and the number of currently free spots, alternatively the information free/occupied. The information about he occupancy of the parking lot are obtained from the detection layer in specific area, which is integrated to superstructure system.

Many technologies are used for parking, which can detect the location or space directly and then guide you to an available parking space. For in-pavement detection, parking magnetometric in-pavement detectors are used, which can use not only space occupancy detection but also detection of the passage of a number of vehicles. Parking detectors often communicate using Sigfox or LoRa technology on an open 686 MHz frequency. Parking detectors are particularly suitable for use in reserved parking spaces, but the applicability is of course wider and some detectors cannot even be recognised as having been installed. Parking detectors are often in the form of concrete paving stones and, when viewed superficially, blend in with other paving stones or may be covered with paving stones of a type matching the paving stones, so that they are virtually indistinguishable from the surrounding paving stones to the naked eye.

3.5. Passenger check-in and vehicle tracking

The current state of the art directly requires that modern check-in channels are available to passengers. It is therefore not only possible to rely on the situation where check-in is carried out at the check-in facility on the bus exclusively by the driver, but modern channels must also be offered. More check-in options increase passenger comfort (the passenger chooses the ideal solution for him or herself) and can also reduce the time spent at stops (no need to handle cash), which will result in an increase in travel speed and thus the attractiveness of the public transport service.

The current technical possibilities also offer real-time monitoring of the position of the vehicles, thanks to which it is possible to guarantee interchanges even in the event of delays (dispatching control). Last but not least, it is advisable to make data on the current location of vehicles available to passengers (via connection search engines, on an online map, in specialised mobile applications, etc.).

The goal of the city of Klatovy is to offer passengers modern forms of check-in. From a technical point of view, this can be achieved in basically two ways - by developing our own solution or by using already existing platforms (e.g. by developing functionalities in the Public transport - PT system on the Klatovy public transport), which will lead to the creation of a mobile application or a separate suitable card, with the progressive option being to use a regular payment card.

Standard bank payment cards can be used as carriers for subscription coupons or can be used to pay individual fares directly in the car. They are therefore a direct alternative to a transport card. At present, individual fare payments by bank card are already possible in the PT; the project of a bank card as a carrier for subscription coupons is foreseen in the future.

Tracking the position of vehicles by central dispatching is a very useful functionality in case of influencing the journey and continuity of connections if there are deviations from the timetable. This makes it possible to benefit from the advantages of transfer systems (clearer line network) and eliminates the risk of missing connecting services. If the dispatching centre is also connected to the information centre, it can provide passengers with up-to-date information on traffic incidents.

Vehicle monitoring can be solved by establishing its own Klatovy dispatching centre or by connecting the Klatovy public transport to the central regional dispatching centre of PT, which is usually in operation 12 to 16 hours a day. On-board computers used in regional transport communicate with the PT dispatching centre, which coordinates public transport in the entire PT territorial district. The on-board computers installed in the Klatovy public transport vehicles are identical to those used throughout the PT system, which potentially results in a simple implementation of functionalities for connection to the PT central dispatching system. All of this leads to the provision of public transport preference through a proactive approach of using C-ITS.

4. Final recommendations for the implementation of new technological approaches

When designing transport, Smart City and telematics systems for smaller cities, including some specific technological approaches, it is advisable to draw on strategic material - a transport master plan that
presents possible potential transport solutions based on a comprehensive analysis, data collection and addressing the full range of issues presented in the text. But it is also needs focus on technological site of telematics systems and need to follow facility management of underground parts of it, in the current modern way. The entire supplied telematics system or Smartcity solution does not only concern the equipment itself, but the entire infrastructure that needs to be monitored and ensured adequate maintenance, facility management, including sophisticated maintenance planning of technical and technological systems, including progressive methods of predictive maintenance. [8, 9]

A clear innovative trend is the deployment of the Urban Mobility Hub, which can use new approaches for data collection, control functions, stumbling upon existing solutions, but also innovative approaches such as V2X solutions, which are a clear future trend, but not all vehicles are equipped with on-board units yet and the infrastructure is not equipped either. Therefore, implementation in the long term is dependent on other factors. On the other hand, IoT (Internet of Things) sensors are already viable and cheap solutions on the market that can be implemented relatively quickly, and drivers are familiar with or even use IoT technology elsewhere. The virtual space for charging reservations has similar problems to V2X, but also the deployment of toll systems where it is possible to combine a virtual parking system with license plate recognition, etc.

However, the older generation in particular may be sceptical about these systems, although some applications are already available on the market. External data and information are available and can be used. On the other hand, it is often inaccurate and very expensive to maintain available and good quality data to obtain valid transport information. Data is important for traffic modelling and predictive approaches in traffic management, parking, truck detection, supply, etc. It is also important to mention the financial perspective on these new systems and applications. An essential part is the solution of the economic side and the return on installed systems. The lowest price is often considered, although the subsequent return on investment may be significantly longer. Lower reliability or longevity for cheaper solutions often leads to higher maintenance costs, so it is recommended to take other parameters into account when choosing systems than just the price. [10]

This paper could be summarized as follows: for the implementation of new approaches and technologies it is advisable to commission research, prepare a strategy paper, discuss it and set out the steps for the implementation of new approaches and technologies.

**Conclusion**

The paper is processed as a practical example of the creation of a concrete proposal for a project of the transport master plan and transport concept of an important settlement in the Czech Republic in the city of Klatovy. Proposals for solutions are both for immediate application and for long-term view and implementation. Approaches to avoid transit through the city and the city centre using telematics systems and furthermore parking systems and possible parking detection in the centre can be recommended as suitable measures to maintain mobility. This should be done in such a way that excessive traffic - i.e. just passing through, or long-term parking in the case of stationary traffic - is disturbed in the first place.

The conceptual design of the introduction of new solutions and the implementation of new systems leads to fundamental benefits for the city. The introduction of the Mobility Hub concept as one of the approaches of the system solution for parking can lead to further expansion of the systems and provision of data and information to citizens. Connection to the central control system of data from light-controlled intersections, PT preferences, C-ITS use will also enable smoother implementation of future systems such as tolls in the city center, etc. The new trends are part of future approaches for city size such as Klatovy, but also other cities to ensure sustainable mobility in the historic or central part of the city.

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