Smart Transport and Mobility Strategy and Action Plan for Chisinau City

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The goal of the **Chisinau Smart Transport and Mobility Strategy** and Action Plan is to help develop a desirable intelligent transport system for Chisinau city that is practical and cost-effective for an efficient and effective transport management system (using Intelligent Transport Systems) in Chisinau city.

Through the technical assistance and expert support for the **Chisinau Smart Transport and Mobility Strategy** and Action Plan, the Chisinau authorities will be able to learn from the Czech and EU experience and approaches in modern practices of mobility planning and traffic management, which will ultimately secure equitable access of all social groups to urban infrastructure and will increase the quality of life in Chisinau.

In a medium- and a long-term timeframe **Chisinau Smart Transport and Mobility** Action Plan, should change the life in the city as its scope is to:

- Ensure all citizens are offered transport options that enable access to key destinations and services;
- Improve road safety;
- Reduce air and noise pollution, greenhouse gas emissions and energy consumption;
- Improve the efficiency and cost-effectiveness of the city mobility and public transport;
- Contribute to enhancing the attractiveness and quality of the urban environment and urban design for the benefits of citizens, the economy and society as a whole.

Content

4 DESIGN PART

4.1 Visions

Basic Vision:

"Chisinau - a Safe and Accessible City with Quality Public Transport" (the City of Chisinau is the Green City of the Future)

Definition of vision:

Transport has always been, is and will be one of the most fundamental factors influencing the development of society and cities. If the city of Chisinau is to be competitive and attractive to current and potential residents, and if it is to be the first choice within Moldova, defined areas of interest in transport must be given maximum support.

The analytical part and visions clearly revealed 4 basic pillars that the city must unconditionally address. They are:

- „Traffic in Motion“ Pillar (e.g. Light coordination functions and preconditions for establishing coordination, description of dynamic management of traffic lights, ITS, assumptions of parking space occupancy detection),
- „Parking“ Pillar (e.g. Parking space occupancy management, introduction of paid parking zones),
- „Public Transport“ Pillar (e.g. Methods of payment for public transport, optimization of line management, involvement of rail transport),
- „Active Mobility" Pillar (e.g. Cycling as part of the transport system and active mobility - general principles for designing networks of cycling routes in Chisinau, Bike sharing),
- Road Safety (e.g. Recommendation of framework measures to reduce accidents - the topic permeates all 4 basic pillars of transport).

4.2 Traffic in Motion Pillar

Based on the previous report and current data we would like to propose following technologies to improve traffic control system in the city of Chisinau. The most important part of intelligent traffic system is collected precise data and make based on this information the right decisions in the system.

After the pilot project which consist of replacing 2 intersections and installing detections system for the traffic regulation. After the proof of concept will be done, the next replacing of controllers and connection to the central system will be following. The replacing strategy should be split into areas and after one area is fully replaced continue with the next one. Areas should be selected based on the coordinated route and traffic relations in the network (fig. 4.2.1).

Figure 4.2.1: Location of traffic light controllers

To improve the whole system, it is not just about replacing the controllers and create advanced traffic engineering solutions like coordination and public transport preference. It must be also connected with traffic counters and strategic detectors. When all these parts will be connected into traffic control systems with the right configuration of strategies, then the traffic regulation will be effective and improve the traffic situation in the whole system.

Important part of traffic solution is also parking management. The city should be equipped with new technologies consisting from on street and off-street parking solutions. Proposed solution is described in the chapter 4.2.2. After off-street parking implementation it would be suitable to connect these systems with public transport ticketing in the system Pak and Ride. The modern cities are not just for cars but the main strategy goal is also reduction of individual transport in the urban area. To create Park and Ride facilities and connect the parking tariffs with the tickets for public transport is the important step how to individual transport in the urban areas.

4.2.1 Traffic Light Control System

The fact is that common level of intersection saturation at real implementation is 80-90%. Considering this fact, intelligent traffic solution can improve traffic comfort through the intelligent traffic control: traffic light controllers, maintenance and programming software and full control over urban traffic management centre.

Real time traffic actuated control can increase the capacity of intersections and the traffic network and comes from traffic engineering design reflecting local conditions of intersection, group of intersections or whole traffic network considering traffic elements affecting traffic such as public transport vehicles and their preference, emergency vehicle routes and cars and their real-time behaviour together with traffic peaks and traffic volume scenarios defined by the traffic engineer directly to the traffic controller. Traffic engineering design for each intersection should be designed by experienced traffic engineer with the help of traffic engineering SW. This system communicates via OCIT 2.0* protocol (and others) and allows monitoring, creating of scenarios, statistical evaluation, data collection and interaction with urban ITS elements. Modern traffic controllers use an IP communication. This will provide the best possible response and immediate interaction.

On field infrastructure with distributed intelligence it should be by itself able to manage all common traffic situations including many extraordinary traffic variations coming from traffic accidents or limited road closings.

To achieve integrated and intelligent traffic system is necessary to have the right infrastructure, devices and supporting system. One of the key element necessary for integrated traffic system is traffic controller which has to be able to collect information from the detectors and on board units of the vehicles and set up the traffic plan base of the actual traffic situation and which is able to be connected together and to the urban traffic management centre.

Therefore, within the first steps of process of creating modern and effective traffic infrastructure is necessary to install the traffic controllers into the intersections which are on the main routes and are the most overloading and congested by traffic. In the intersection should be installed modern detection systems which can get the accurate and real time information about the current traffic situation and send them to the controller. In the intersections should be also installed traffic plans and scenarios created by traffic engineer in modern programs, which are able to extend, add or finish the green time of signal groups on the base of information from the detectors.

Within the next step the intersections should be connected into coordination and create the green wave which will improve the fluency of traffic flow and increase the capacity of route. The intersections should be also connected to the central traffic management system which can control and coordinate traffic from the highest level.

The new technology based on controllers, detection system and connection to UTC (Urban traffic control) software can offer also monitoring of all devices, traffic analysis (with using of the traffic counters) and area management.

The flagship project is recommended to be implement on the less exposed route. From all the information mentioned above, the key elements of the modern and effective traffic systems are:

- Modern traffic light controllers and detection systems
- Public transport preference / emergency vehicle preference
- Coordination of intersections (green wave)
- Central control system

Based on the detection system can be created automatic scenarios for specific situation in the traffic network. This functionality makes the system more flexible and reactive for specific situations which can occur in the network.

4.2.1.1 Functionalities of traffic light controller and detection systems

Traffic light controller is an essential component of the up-to-date traffic control system in urban areas according to the latest performance and safety standards.

Key features of the modern traffic controllers are:

- Local control with the traffic design logic without connection to UTC
- Time synchronisation and coordination of other traffic controllers
- Easy configuration of traffic logic with predefined logical functionalities
- Easy remote access with possibility of traffic logic upload
- Touch screen with service functions, signal plan visualisation and hand control
- Central control – possibility to cooperate with UTC and other controllers
- Public transport preference (active, passive, preconditioned, absolute)
- Integrated emergency system (IES) preference
- Special logic programming possibility via user defined code (user defined special functions)
- Multi-system programming - Switch point basis - Parametrical definition - Stage transition definition system - OML support
- Standards EN 50556, EN 50293, EN 12675, EN 61508-1, 2, 3, 6, EN 61010-1, SIL 3.

Enlarge description of controller functionalities:

- Real-time visualization latency. The latency since a command is sent into the controller until the return values are received must be less then 2s. This includes the information of the bar diagram representing the states of all connected and monitored signal groups. This value is valid for local maintenance tools as well as for the UTC connection.

- Green state extension step visualization. The visualization of a running signal plan in the form of a bar diagram must provide information about the detector data-based extension steps (and their numbers) by a different indication of the signal group state during the green state extension period. The visualization must also provide information about the elements facilitating the extension (other signal groups, detectors, logical conditions, etc.).

- Complete remote maintenance of the traffic controller. It shall be possible to remotely upload – traffic logic and algorithms, traffic logic parameters, HW parameters and sensitivity of the loop detectors. The signal plans and schedule changes shall be applicable without the need to restart the traffic controller.

- Direct public transport and emergency vehicle priority telegram receiving. The telegrams cannot be reduced to a form of one-bit (detector relay contacts) information. The communication between the controller and the vehicle must be uninterrupted regardless of the underlying protocol. The telegrams shall be received directly by the traffic controller without a need to pass through a central system. Central system can receive the data as well but only for information purposes.

Traffic controllers should be able to perform traffic control in fixed time regime and traffic actuated (dynamic) regime.

Fixed time traffic control is traffic control base of fixed traffic plan created by traffic engineer and upload to the controller. This control has exactly the lengths of the individual signals and cycles and cannot be changed without changing the control logic of the controller. It is only used in the case of simple junctions or when the intersection does not allow for any reason the installation of traffic detectors.

Dynamic traffic control dependent on traffic demand at the junction. Demand is realized by detecting a vehicle / cyclist / pedestrian on the basis of detection points (detectors). These detectors send information to the controller and affect the intersection behaviour in each subsequent cycle. As required at the time of the intersection, the traffic light controller is able to change the green lengths for a particular signal group, activate the respective signal group in a non-collision direction according to the current requirement, or to include / remove the complete phase. As a result, the signalling plan changes from cycle to cycle, and its length or composition always depends on the demand / intensity at the specific intersection. Thanks to real data from the detectors, the junction is continuously regulated in step 1s and reacts immediately to the actual intensity of the vehicles at a given time. Detection is able to work with parameters such as vehicle intensity, delay length, column length, based on which it is possible to set the logic composition of the signal plan with maximum utilization of the intersection capacity and handle as many vehicles as possible in the shortest possible time.

Detectors are necessary components of dynamic traffic control, because they collect and send to the controller information about actual traffic situation on the intersection. They can be divided by detection methods to:

- Inductive loops
    - The FEIG detectors are used
- Video detection
    - Traficam (FLIR) – these cameras are connected to the controller via relay contacts using the supplied 4TI interface
    - Thermicam (Flir)
    - CitiLog (XCam) – cameras are integrated into the controller via an Ethernet interface
- IR detection
- Radar detection
    - Icoms – connection via relay contacts
    - Smartmicro – integration via Ethernet or RS485 interface
- Magnetic detecors
    - Sensys – connection via Ethernet interface

In case that detector is in error mode for any reason, the junction switches to fixed control only for the lane where the detector is defective. In the remaining lanes and directions, the signal groups are recalculated continuously based on the intensity of the vehicles for best handling. Thanks to real data from the detectors, the junction is continuously regulated in step 1s and reacts immediately to the actual intensity of the vehicles at a given time. Cycle length can be changed cycle by cycle.

Communication must be ensured for data transmission between the controllers, or between the controller and the central unit. This communication can be done using:

- Ethernet connection (cabel, optics, WiFi)

- Log connection RS232/485
- Radio communication

Communication protocols are used to transmit data. The data structure is given by the protocol manufacturer / operator and determines the way the data is processed and the range of information that is transmitted between the controllers, the controller and the programming / service tool, or the controller and the traffic control centre. These protocols may be open for public use, or the controller manufacturer may have an internal protocol that is closed to other competitors. Communication protocols can be divided into:

- Traffic data transfer logs and settings with the programming tool for the controller (control logics recording and servicing of the controller)
- Protocols for communication between the controllers or the traffic control center

Several types of communication protocols are defined for the **Car2X** communication system (fig. 4.2.2); some communication services such as GPRS or UMTS can be used for some types of services. For services that are marked as critical for traffic safety, new access network techniques and information transfer are defined. Three basic areas of operation can be seen in the illustration. The ad-hoc domain represents the communication between vehicles (Car2Car) and between the vehicle and the RSU (Road Side Unit), the gateway to the backbone network (the domain of the infrastructure). It ensures data transfer between vehicles and server (servers) collecting traffic information. The physical layer for data transmission indicated by blue arrows will be implemented using the IEEE 802.11p standard. [1] In-vehicle domain communication is used to connect individual vehicle systems to the Car2Car communication system (AU - Application Unit and OBU - On Board Unit).

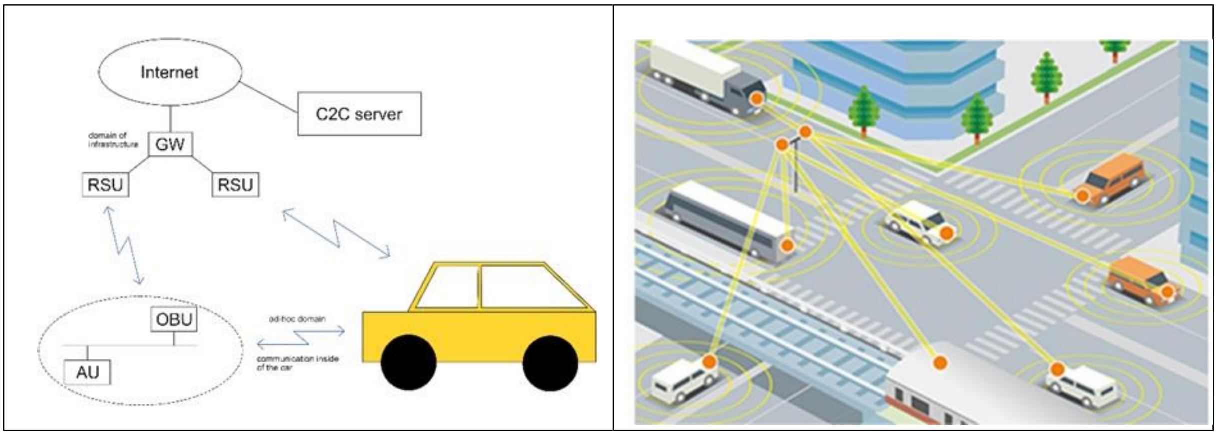


Figure 4.2.2: C2X communication

It should be noted here that each vehicle that will be integrated into the Car2Car system will have to include a set of mandatory sensors that will provide information on:

- the position (GNSS receiver), • the vehicle speed,
- the direction of travel, • the switching on of the warning lights,
- braking power (deceleration of the vehicle),
- ABS, ESP and ASR status.

4.2.1.2 Public transport preference / emergency vehicle preference

The Public Transport Pillar is explained in detail in chapter 4.4. Public transport preference is one of the key features of smart transport and mobility in the cities and it is the way how to decrease the number of individual car traffic in the city centres. The main purpose is to decrease the travelling time of public transport vehicles by decreasing time of waiting for the green in intersections and make it more reliable. In cases of separate bus lines the good preference can save a lot of time in favour of vehicles of public transport.

Public transport preference is a process in which the green signal for public transport vehicle is included as soon as possible after the request has been received. The level of preference and its impact on the traffic of other vehicles depends on the method used. The methods used include:

- **Passive preference** - these are only detection points without additional vehicle information
- **Simple active preference** - allows to distinguish the vehicle type
- **Active preference** - allows to pass on additional vehicle information, such as:
    - Physical location (according to GPS)
    - Logical position on the line (according to stops)
    - Time deviation from the schedule in real time
    - Operating status of the vehicle (ride, stay, door)

In case of active preference, the traffic controller can handle each second of the signalling plan:

- assigns a preference to the vehicle that is currently in use
- distinguishes in detail between vehicles, lines, driving directions, etc.
- respects a locally established hierarchy of preference rights
- works with all locally available data
- minimizes the delays of all vehicles before traffic lights
- optimizes the necessary time of green light for public transport vehicles
- does not give unnecessarily green light if there is no vehicle
- insulated branches open only for real transit of the public transport vehicle
- allows to ensure other traffic control functions dependant on public transport operation

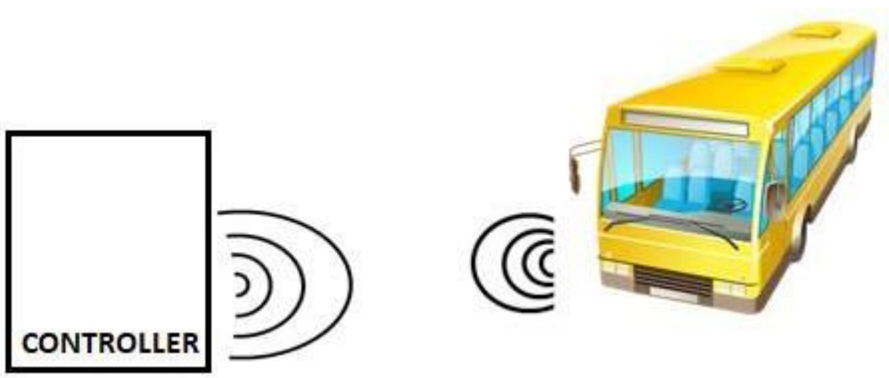


Figure 4.2.3: Public transport communication

The public transport preference use **RSU – road side units** which are connected to the controller and are used for logging in of public transport vehicles before intersection and for logging out when they cross the intersection and **OBU - on board units** which are installed in the vehicles and can be applied both **locally** and **centrally**.

In a **local - direct** communication the vehicle communicates directly with the traffic light controller (fig 4.2.3). For communication can be used:

- Radio direct connection
- Radio central connection
- C2X

This type of communication ensures the fastest delivery of the data packet to the traffic light controller and therefore the most accurate preference function.

With **central preference** (fig. 4.2.4) the vehicle communicates with the central server and tells it the GPS position. Based on this information, the central system evaluates and sends data to a specific intersection. The disadvantage of this solution is the possible delay of the packet due to possible latency in the network. Because the data packet can be delivered later, the MHD preference may not work properly.

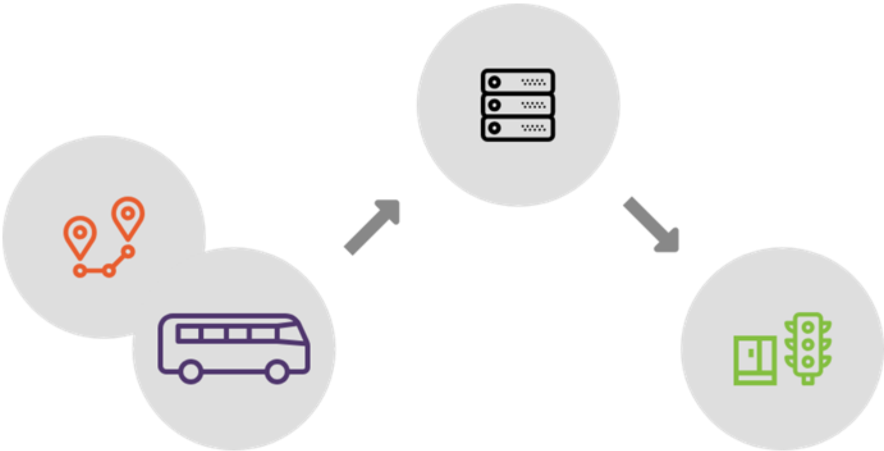


Figure 4.2.4: Public transport central preference

With the **combined** public transport preference system (fig. 4.2.5) the system combines the advantages of both previous types of preferences and uses modern data transfer technologies. The disadvantage is higher acquisition costs, however, they are redeemed by the system's readiness for future technology expansion.

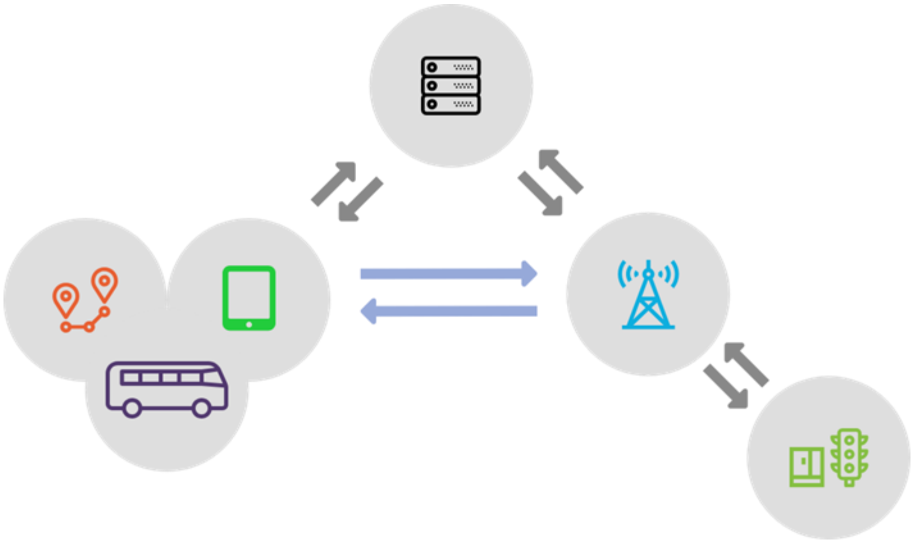


Figure 4.2.5: Public transport preference – combination

The **preference of integrated rescue system vehicles** is very similar to the public transport preference, but with the difference that the allocation of preferences is absolute for the vehicle. This means that it takes place in the shortest possible time that the control algorithm allows. This shortest time is usually given by the split times of the greens for a particular intersection, so that vehicles that are just inside the intersection can safely leave it.

General V2X requirements

V2X – intersection
The RSU for V2X communication is directly connected to the controller at the intersection.

The RSU unit for V2X communication connected to the controller should be minimum have as the following functions:

- Broadcasting CAM messages.
- Receiving CAM messages and aggregating them into short and long-term operation statistics.
- Support of forwarding messages as per the Geonet protocol.
- Broadcasting and receiving DENM messages including their generation.
- Broadcasting and receiving IVI messages – the source is typically C-ITS Back Office.
- When connected with an intersection controller unit, it uses MAP messages to broadcast a map of the intersection (stored in the unit or in the controller) and SPT messages to broadcast a signal plan.
- ES preference via CAM messages when the unit is connected to a controller unit.
- MPT or ES preference via SRM and SSM messages when the unit is connected to a controller unit. We do not recommend MPT preference via CMA messages – there is no feedback channel for vehicles.
- Secure communication support (integrated HSM module).
- Possibility of connection to C-ITS BackOffice – by using an embedded LTE modem or cable connection.

The units that are installed on a column are the “all in one” type and they constitute one mechanical set containing the unit itself, antennas and all the needed converters so that their installation and connection to a controller unit are as simple as possible. If possible, these units are placed in the middle of an intersection to cover all its parts with signal. The unit is equipped with high performance antennas and if needed also with a communication adapter to ensure fast communication with an intersection controller unit (ethernet, standard RS 485).

Table 4.2.1: Example of the properties of V2X RSU units for intersections

General properties of the RSU unit:	
Operation temperature of surroundings	from -30°C to 65°C
Power Supply	from +10 V to +32 V
Consumption	typically 8 W, max. 15 W
Measurements (W × H × D)	260 × 180 × 90 mm
Installation on infrastructure	Anchored to a traffic lights column by a bandimex
Weight	2 kg
Antenna connection (connector type)	All antennas are integrated in the unit: 1) 2x V2X – 12 dBi 2) LTE 3) GPS
Hardware parameters of the RSU unit	
Processor	frequency1GHz, two cores, 1 extra core 240 MHz
RAM (dynamic memory)	1 GB – DDR 3
Data storage	16 GB internal flash disk
Basic communication interface	V2X (ETSI ITS G5), LTE, Ethernet, RS 485
Auxiliary interface	RS-232,one-bit inputs and outputs
LTE	800 / 900 / 1800 / 2100/ 2600 MHz
V2X	2 channels 5,9 GHz, dual channel or diversity mode, supporting HW security (HSM module)
Reach V2X	In a build-up area about 300 m, in open terrain up to 1,5 km
IP Code	IP 68
Other communication parameters	
LTE – Transmission speed	Up to 150 Mbit/s downlink, up to 50 Mbit/s uplink, diversity option, up to two independent modems
Ethernet – Transmission speed	1x 1Gbit/s, 1×100 MBit/s
Communication with a controller unit	Directly via Ethernet or by using a converter for two conductors. The converter is integrated in the unit.
Wi-Fi	Based on choice, up to 3x3MIMO 802.11ac
One-bit I/O	Up to 8x input, up to 6x output, switched to the ground
Complies to norms	set of standards ETSI ITS G5, IEEE 802.11 a/b/g/n/ac, IEEE 802.3 10BaseT, IEEE 802.3 100BaseTx, IEEE 802.3u

V2X – vehicle funtion description

- Vehicle V2X unit is designed as to serve as a central communication unit (called On-Board Unit – OBU) in various types of vehicles, be it a vehicle for public transport, emergency vehicle or a vehicle of a road operator.
- Vehicle-to-vehicle and vehicle-to-infrastructure communication (V2X) V2X. Communication is an emerging set of standards, which will enable the vehicles to communicate with each other and also with transport infrastructure equipment. Such communication can increase both safety and efficiency of traffic. OBU unit fully complies to ETSI norms, including security and signature generation or validation. The V2X communication can work in an antenna diversity mode or in a dual concurrent channel operation. Fast mobile internet connection The built-in LTE modem provides a fast internet connection. Except for internet access for passengers it allows long-range connection to the transport infrastructure, making the unit a so called "hybrid unit". The internet connection is also used for V2X certificate renewal and can be used for fleet monitoring.
- Fast mobile internet connection
- The built-in LTE modem provides a fast internet connection. Except for internet access for passengers it allows long-range connection to the transport infrastructure, making the unit a so called "hybrid unit". The internet connection is also used for V2X certificate renewal and can be used for fleet monitoring.
- The whole unit can be mounted on the rooftop and for communication it will using its internal antennas.
- The unit is provides a plenty of wired communication interfaces: 2x Ethernet (1x1Gbit, 1x 100Mbit), USB, CAN, RS-485, RS-232 and one-bit I/Os. Wi-Fi creates a very powerful access point (up to 3x3 MIMO) and the unit can also behave as a GNSS server for other vehicle devices.

4.2.1.3 Coordination of intersections

The coordination of traffic lights is a great possibility how to make the traffic management more effective and increase the capacity of traffic network. The principles of coordination consist in calculation the right offset of green time beginnings between more intersections equipped with traffic light controllers. The precondition for creating coordination between intersections is maintaining the same time on each controller. This is usually done by GPS, or connection to NTP server as part of UTC software. The right offset reduces the number of stops between the intersections and improves the fluency of traffic flow. With the combination of dynamic traffic management changing the green times in different stages in real time based on the traffic situation is it the suitable combination how to improve the fluency and capacity of the traffic network.

4.2.1.4 Central control system

The need for the traffic urban control centre is caused by increasing volume of the traffic in the city. Modern traffic control centre is a sophisticated structural element of a municipal traffic light system. It should be easy to control, provide an overview of the whole traffic light system and allow on-line data collection from the city traffic network.

Control centre therefore should offer features for traffic monitoring, supervising and control as well as quality management and reporting features and meets different requirements of large urban areas. Strategic control of intersections makes travelling in the city easier and faster.

Central control system should be an optimal platform for modern and efficient traffic control in urban areas, and **it should feature modular and open architecture ready to interact with third-party systems and software**, what is the most essential aspect of implementing complex ITS solution in already existing city infrastructure. Control centre should be able to be extended by other smart city platforms, which gathering all the relevant data generated by the city systems creating interoperability and bringing smart city concept alive (see fig. 4.2.6).

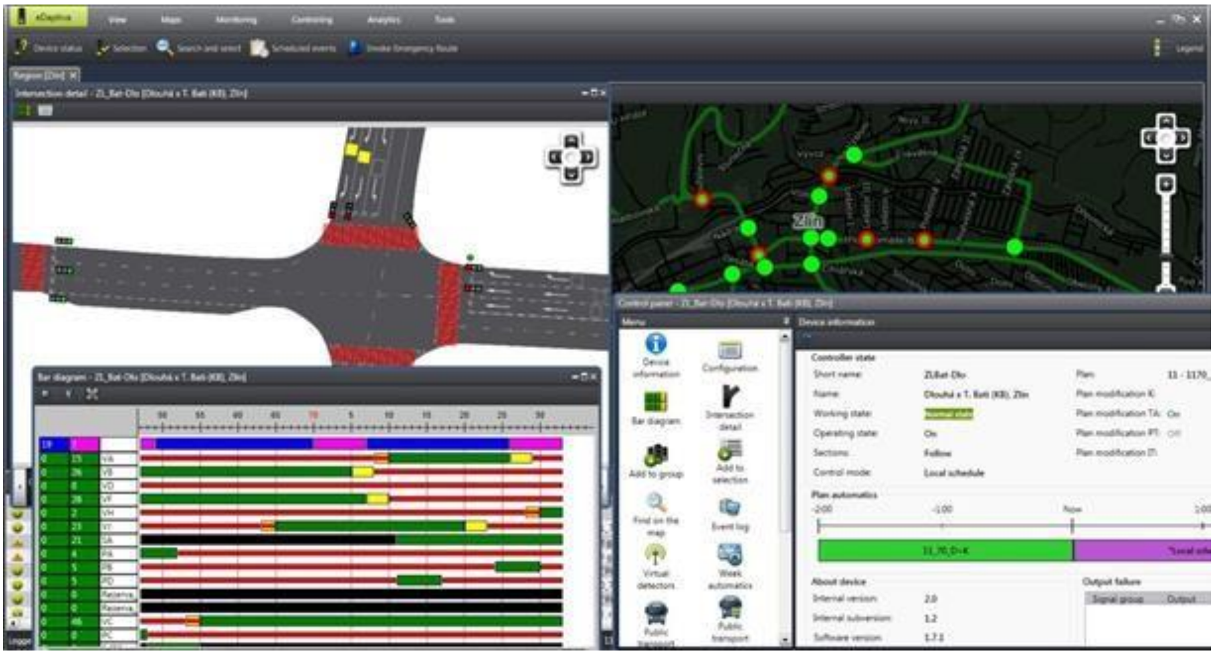


Figure 4.2.6: GUI

Central control system should have following attributes:

- real time monitoring of the operating status of intersections;
- transmission of the actual control courses in the form of bar diagrams in real time;
- control based on information from individual controllers in real time;
- collection and displaying of information on the number of vehicles (from detectors);
- hanging of the intersection operation mode; either individually or in groups for prioritizing of public transport vehicles;
- route setting of vehicles with the right of way at isolated intersections as well as on coordinated routes live monitoring and controlling;
- setting of automatic scenarios
- grouping of controllers with functionalities for launching (automatically or manually) various control strategies;
- real time bar diagram view (signal group and detector status) for more controllers at the same time;
- user access to the program with the use of access rights
- connection of third-party applications

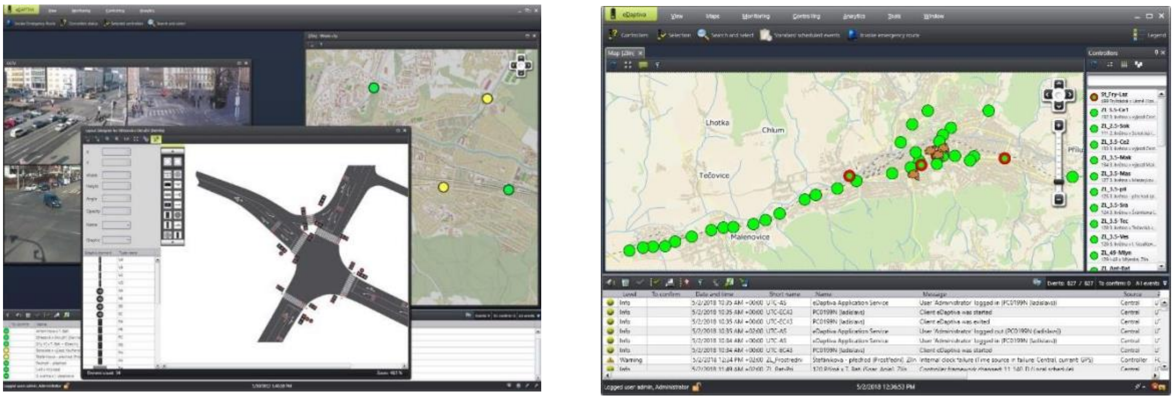


Figure 4.2.7: Multi windows system monitoring

4.2.1.5 Traffic counters

Traffic counters are special type of traffic detectors used for measuring traffic information such as number and classification of cars and density of traffic. This additional telematic equipment is very useful for area control and traffic management on the area level. It is suitable to place the traffic counters on the approaching street from the suburban areas.

Based on the collected data it is the possible to set automatic mechanism to the traffic control centre and to launch created traffic management scenarios in the right time (fig. 4.2.8).

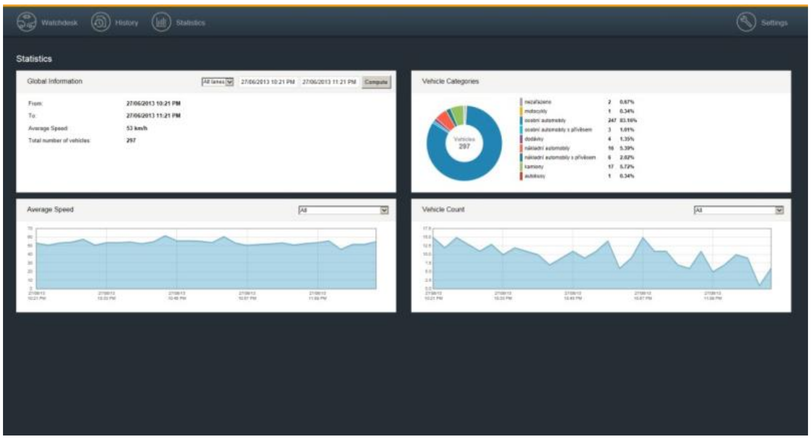


Figure 4.2.8: Traffic counter interface and analytics

4.2.2 Parking System

There must be 2 types of parking systems need to be installed. On-street parking with the parking terminals directly on the street. Second application is off-street parking for parking slots especially in the spots where is good connection to the public transport. In these location the tariffs must be integrated with the public transport and these off-street parking must be used for the park and ride application. The Parking Pillar is explained in detail in chapter 4.3.

4.2.2.1 On-street parking

Automatic payment terminal has been developed for automatic payments for parking in paid on-street areas. Also, it can be used separately as a parking meter with coin changing from tubular bins. Payment is only possible with coins or bank cards. Terminal subscription contactless cards could be used. Payment amounts are analysed. Based on a barcode parking ticket, which is issued by the parking system, the automatic payment system communicates with the control computer of the parking system.

According to the received cash with the possibility of correction of the payment amount or time when the terminal is used as a parking meter.

4.2.2.2 On- street payment terminal configuration

The automatic payment terminal in the basic configuration in the parking system is equipped with:

- coiner for receiving coins and bins for 6 coin denominations
- stainless steel box for received coins
- parking ticket reader
- printer for tax documents and denomination splits
- software for communication with the car park control computer
- 230VAC power supply without backup

When used as a parking meter, it is equipped with:

- coiner for receiving coins and bins for 6 coin denominations
- stainless steel box for received coins
- printer of tax documents and denomination slips
- 230VAC power supply and 12V battery backup

In the extended configuration, the terminal can be supplied with:

- bank payment card reader
- subscription contactless card reader
- solar power supply for parking meter

4.2.2.3 On-street Terminal design

The terminal cabinet is mounted on a pedestal through which power and communication cables pass. Electrical devices are mounted on a special frame inside the cabinet. The degree of protection of the cabinet is IP 44. The entire equipment is fixed with screwed joints on a base frame which is installed into a concrete base. The fasteners and the steel components that are not protected by a bake-on coating are finished by zinc-coating. The standard cabinet is painted with RAL 5017 – transport blue and RAL 7021 – anthracite black. The embedded base frame is hot-dip galvanized. The cabinet is closed with a door with lock with multi-point locking and a cylinder-type safety lock. The automatic payment terminal is controlled by the TERM electronic unit.

The payment system must be placed in the area each 150 up to 250 meters. Drivers need to have opportunity to pay fast and to be able to fund the parking payment terminal. The fees can be modified in the mobile application or in the maintenance systems.

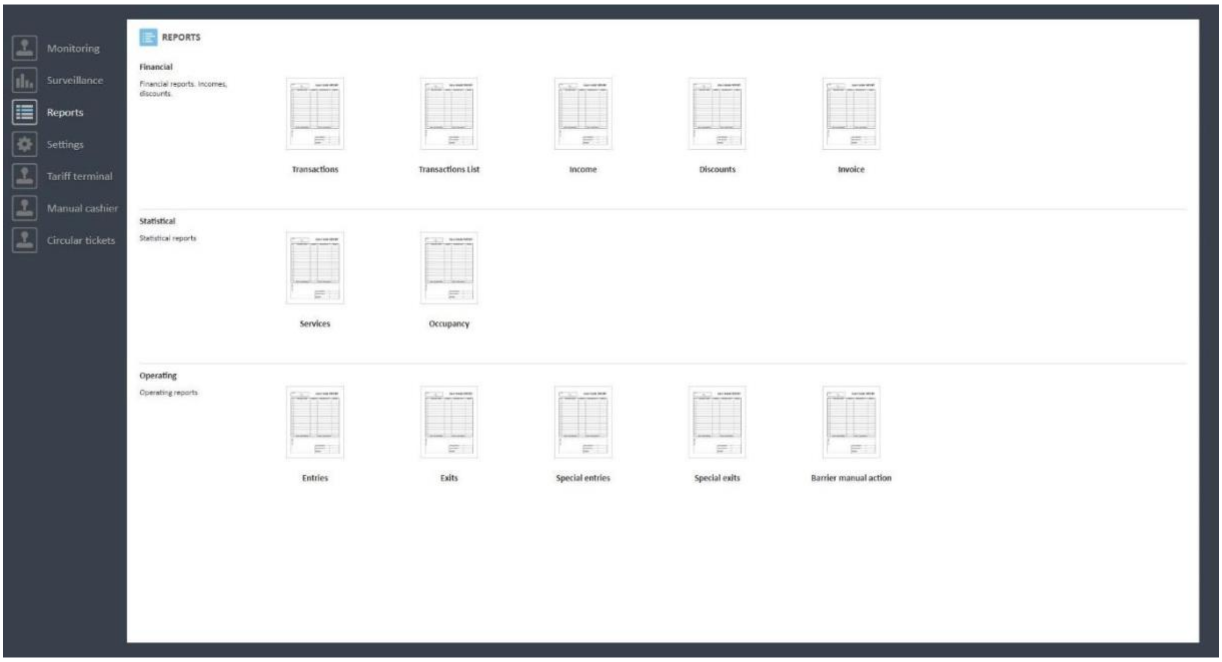


Figure 4.2.9: Parking system reporting

4.2.2.4 Off-street parking

The off-street parking systems (fig. 4.2.10) consist of various part such as entry terminals, gates, navigation systems and payment terminals. The kea feature is to have good overview about the empty places and this information deliver directly to the drivers via mobile app or navigation tables. It helps to reduce the time to find empty parking plot and reduce the traffic in areas where the drivers are searching for empty parking places.

Figure 4.2.10: Off-street parking technology preview

Navigation system (fig. 4.2. 11) as part of off-street parking helps the drivers with the navigation in the parking house and reduces the time needed for the movement in the It helps with cooperation of LPR cameras for residential parking and setting of right tariffs during the day and night time.

Figure 4.2.11: Off-street parking navigation system

4.2.2.5 Off-street parking terminal specification

The Automatic Payment Terminal (hereinafter referred to as the APTM) is a versatile item of equipment, which may be used for making cash and cashless payments, e.g. when paying parking fees within the system, for paying municipal charges within the CityPoint system, regulatory charges within the health care system, when selling tickets, transport tickets, etc.

The main advantage of the ATP terminal is its versatile interface, which allows to integrate third party software as well as to fully an APTM to the customer requirements, with touchscreen control.

In its basic configuration the Automatic Payment Terminal should be equipped with:

- a coiner used for receiving coins
- dispenser boxes for coins in 6 nominal values
- a stainless box to hold the coins received
- a bar code card reader
- an industrial computer installed inside the cash box

In the advanced configuration, the cash box may be supplied with:

- a banknote acceptor and a banknote box
- a banknote dispenser handling banknote in two nominal values
- recycler of banknote
- a bar code card printer
- a payment card reader
- an RFID card reader
- a registration printer - fiscal module

The APTM cabinet is mounted on a base, through which the supply and communication lines pass. All the APTM technical equipment is fitted in a special frame inside the cabinet. The cabinet is protected to IP 52/20. The entire assembly is bolted to the foundation frame, which is fixed to the ground. All steel parts and the connecting material used are zinc coated. In its standard configuration, the cabinet is provided with a RAL 9007 and RAL 9006 coat. The foundation frame is hot-dip galvanised. The cabinet closing door is fitted with a lock and a multiple-point locking device and a security cylinder.

4.2.2.6 Mobile app and monitoring system

Mobile application gives the city citizens good overview about empty parking places and tariffs. If the mobile application is part of the system it helps to reduce needs for payment systems on site (fig. 4.2.12). It’s very useful to link this application with other traffic information into one system and deliver it as one product to city citizens.

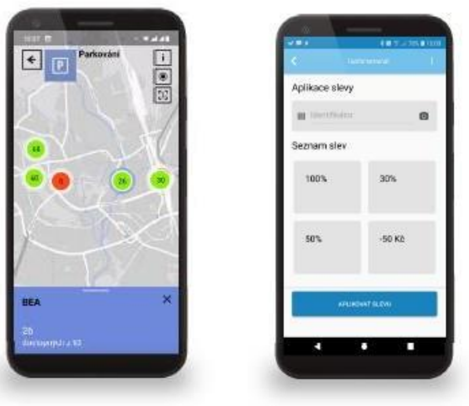


Figure 4.2.12: Mobile application for customers – navigation and payment systems

The system for off-street parking must be equipped with monitoring and maintenance system (fig. 4.2.13) in web interface, where each part of the system can be configurated.

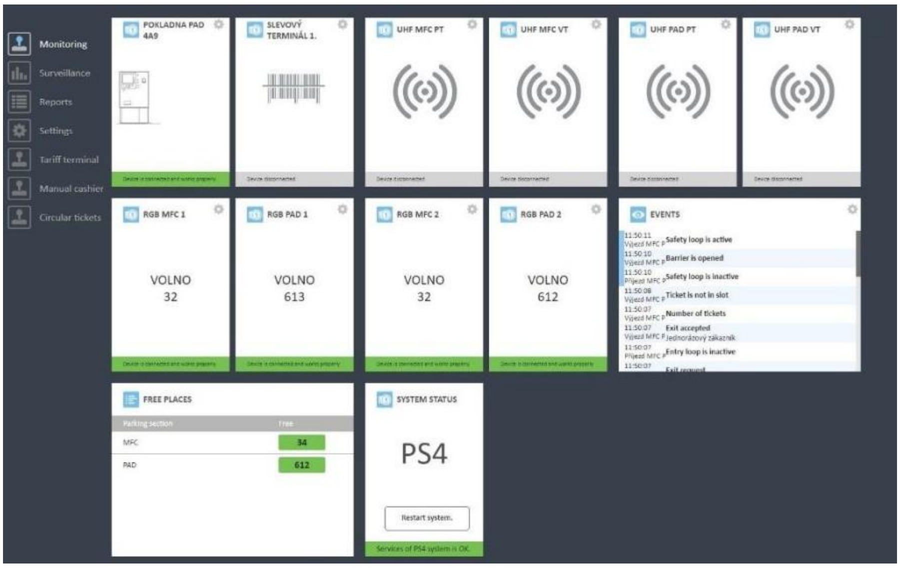


Figure 4.2.13: Monitoring of parking system

4.2.3 Central ITS system – Integration platform

An integral part of every ITS project is the central system, which, unlike the individual vertical subsystems, covers them horizontally and are referred to as the Integration Platform.

In a modern approach to ITS systems, the Integration Platform is responsible not only for the interconnection of individual devices and their monitoring, but mainly fulfils the control functions of the all system and ensures interoperability between the connected subsystems and devices.

The integration platform is also the main operator tool within the Traffic control centre (fig. 4.2.14). Its purpose is not to replace the full functionality of integrated individual subsystems, but to ensure interoperability between subsystems to achieve maximum integration synergy and optimal use of data obtained from subsystems.

Over the last ten years, Central ITS systems have evolved with respect to new IT technologies, which have affected conceptual changes and the architecture of Central Systems. The original application software central solution connected with inflexible communication, demanding for the needs of ITS integration with the help of ESB (Enterprise Service Bus), storage and work with data only within relational databases is replaced by systems based on WEB technology with architecture designed for work with BigData, non-relational DB and integral communication layer. At the same time, emphasis is placed on the openness of systems, high scalability, easy integration of subsystems, including the import and export of data to other central systems.

The current Central Systems should cover both the urban transport network, transit and circular urban arteries, as well as suburban and extra-urban roads connected to the urban transport network (including the management of transport hubs). As part of their functionality, they should provide data exchange between individual Central Systems of interconnected communications and also enable Line traffic control within the artery.

Figure 4.2.14: Example of traffic control centre

An example of an ITS system that meets a modern approach is the ITS system of the city of Izmir in Turkey (fig. 4.2.15), which covers the entire metropolitan area and adjacent roads.

Currently, the system integrates over 4000 devices and 14 subsystems.

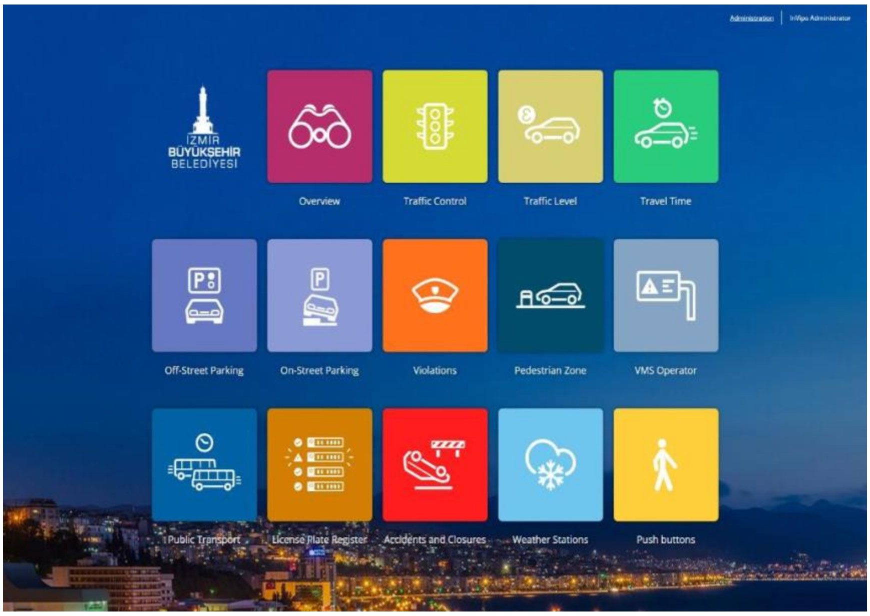


Figure 4.2.15: Izmir operators' dashboard

From the city's point of view, the Central ITS system should be the basis for the implementation of the Smart City concept and the interconnection of non-transport systems, which will lead to the creation of the Smart City Platform (fig. 4.2.16).

Figure 4.2.16: Example of traffic control centre

4.2.3.1 General requirements for the Central Integration Platform

The Integration platform should be a fully modular system within a hierarchical structure of the traffic control system with a clearly defined function of the individual subsystems ensuring cooperation and mutual support to ensure a high level of efficiency and reliability.

The integration platform provides the operator with the ability to control all requests for ITS systems within their functionality.

The integration platform should correspond to the ITCDI concept:

I – Infrastructure

The platform is capable of working in wired as well as wireless networks. In private networks (organizational), local (metropolitan) and also public (Internet).

T-Technology

The integration makes it possible to combine with a "smart" devices, as well as other hardware with help of the communication software.

C-Control

Each device can be a platform controlled either directly or mediated access by operator of service end system. All activities are recorded in the operator's log and all the activities can be tracked back. The platform also respects the work processes and is able to fully adapt to them.

D-Data and their presentation

The platform is processing large amounts of data each time which is stored in various online and offline databases. The complete communication must be processed, nothing can be lost. Data are presented across platforms in a unified, user-interface also respects the concept of schematic views on transport routes.

I-Intelligence

Collecting data from integrated devices leads to their immediate validation and processing. On the recorded events platform can respond by notification to dispatcher or evaluate the situation and affect the operation of associated equipment. All collected data the platform also visualizes and presents in graphs. Platform represents a comprehensive and flexible tool to integrate terminal devices across transport projects.

The platform is primarily intended for software integration, monitor and control various technologies and systems installed on roads.

Furthermore:

- Connects various traffic technologies and systems independently on vendors and providers
- Collects traffic data into Big data warehouse for further analysis
- Centralizes technology access
- Processes all traffic data in real time
- Provides unified command & control capabilities
- Provides smart scenarios for traffic optimization

- Provides analytical, reporting and notification tools
- Opens data and integration API for 3rd parties

4.2.3.2 Platform layers

The platform should be built on three basic layers – data, interoperability and presentation, in short DIP (fig. 4.2.17). The pillars define platform from the functional perspective, the characteristics and the vision it is heading towards.

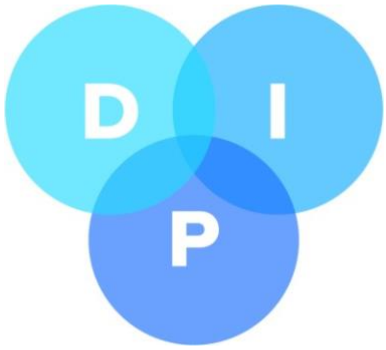


Figure 4.2.17: DIP principle illustrates how data, interoperability and presentation relates to each other

Data layer means interconnection between technologies and systems, their data harvesting into one platform and consequent validation and segregation of the data. Thanks to such centralization and data placement the end users achieve many advantages. The end technologies and systems are integrated via open API.

Interoperability layer enables interconnection of all technologies and systems among themselves, execution of smart scenarios and use of smart applications for smart device control. Such interoperability results in management logics and smart road control.

Presentation layer means unified look & feel enabling the use of central and intuitive user's interface by all users. The user does not need to switch from one interface to another. The unified presentation also means that the operators will see all the information in one place, on interactive dashboards and module interfaces.

4.2.3.3 Technological requirements for the Central Integration Platform

The modern Central integration platform should be preparing handle thousands of concurrently connected subsystems and devices without any delays in communication, data polling, data storage, data processing, and data publication.

Horizontal and vertical scalability, allowing simple expansion of the city users, technologies, subsystems and devices.

Principle proven event-driven ensures optimal functionality of the Integration platform. All the data acquired from individual technologies or used for interoperability data exchange shall be communicated and transferred as general events.

The platform must allow the integration of new technologies without changing the core of the system. All integrations should be system core independent connectors (modules) easily replaceable, upgradable allowing new system integrations without impacting the production system's stability.

To ensure interoperability between systems and control functionality, it is necessary that the platform includes a tool for creating control scenarios. The rule-based engine (Rule Engine) for the capability to define custom rules and rule sets for handling different scenarios. The platform must utilize real-time data processing to automate delay-sensitive automation scenarios (traffic control, priority management, etc.).

With regard to the architecture designed to work with BigData the platform must provide a non-relational database suitable for storing and processing real-time data. Export from a non-relational database to standard SQL database systems must be supported.

The platform shall define universal data envelope for storing all operational information about the Item, such as its current operating status or events that have occurred.

Horizontal and vertical scalability, allowing simple expansion of the city users, technologies, subsystems and devices.

Additional technology recommendations for the Central Integration platform to ensure maximum functionality, minimize system requirements, and optimize the process:

- shall operate operating system-independent (support Microsoft Window Server and Linux operating systems),
- shall be utilizing PaaS (Platform as a Service) concept and running as Docker containers,
- shall be divided into separate modules/applications that shall communicate and share information via Message Broker,
- data storage shall store any additional metadata for already stored records without specifying their structure in advance.
- user interface shall be based on the web access supporting all mainstream web browsers. Users should not require to install any software client for operational functionality.
- The Platform must not require to use any of 3rd party plugins, like Adobe Flash, Java Applet, or any other plugin.
- must provide a standardized interface allowing connection to online data services such as GoogleMaps, BingMaps, OpenStreet Maps, Mapbox and others to utilize the map content and operating in the WMS standard, eventually real-time traffic data provided by such platforms. Publishing own transport data information to such platforms shall be supported as well,
- must provide fully documented REST API and JSON data format to integrate third-party applications in a citywide context.

4.2.3.4 Central Integration platform highlights (RESUME)

Solution architecture (fig 4.2.18)**:**

- Centralized system
- Module based architecture
- Web-browser support (all applications runs in web browser)
- Flexible and open connector system
- Traffic scenarios and dynamic rule management
- On-line data collection and aggregation
- Big data NoSQL database storage
- Web portal and mobile application for drivers
- Three tier architecture (database – business – presentation)
- Big data warehouse
- BI analysis
- Open API for integration
- Real-time data processing
- Connector for each technology
- Modules with GUI for road/technology operators

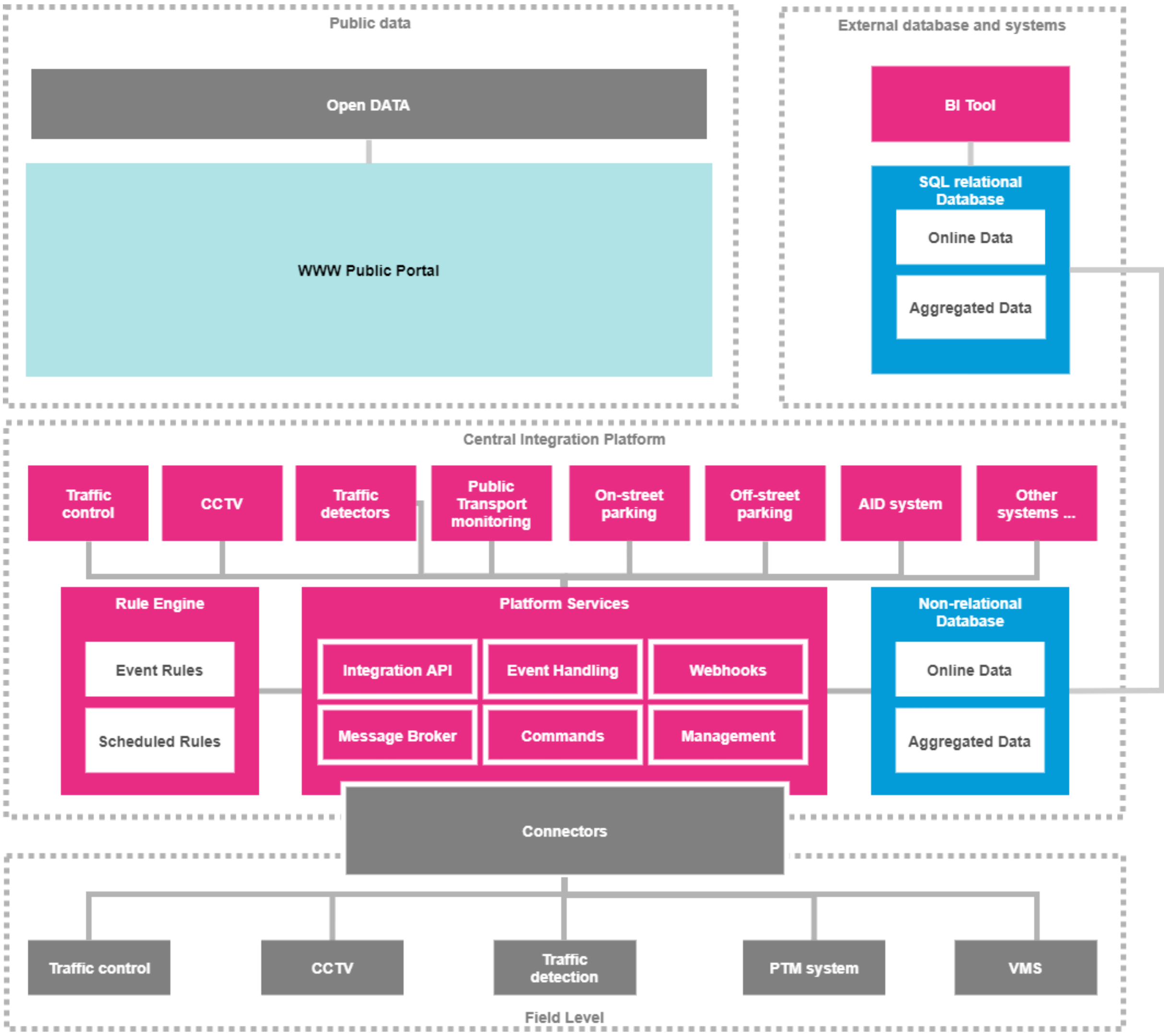


Figure 4.2.18: Example of Scheme of Integration platform architecture

Integration

In the integration model, four components will take part – technology (device or system), connector, core (Platform Services) and module. The main actor in the integration process is connector, which communicates with technology on one side, and interacts with the platform core on opposite side (fig. 4.2.19).

Figure 4.2.19: Example of interoperability between subsystem – automatic scenarios

Connector and Services

- Communicates directly with equipment
- Synchronize items with services
- Collects actual data from equipment
- Gets current equipment status
- Executes control commands on equipment
- Registers status of connector and equipment into the services
- Registers malfunctions to services
- Provides connector with interface for item synchronization
- Provides connector with interface for status registration
- Provides connector with interface for event registration

Rule Engine

- Smart Scenarios
- Rule Engine Designer
- Predefined traffic and smart scenarios
- Realtime evaluation and control

Realtime information

The Integration platform communicates with equipment in two modes - online and offline. The mode and the way of communication depend on the technical capabilities of the connected technology. An online way of communication, i.e. data acquisition and real-time control, will be always preferred.
On-line communication and real time data acquisition:

- The user can monitor the status of the device in real-time
- The platform displays the currently measured data from the device
- Control and control requirements are delivered to the device without delay
- The platform can perform real-time smart scenarios

The Integration platform supports big data collection. The data is either through the API interface of each platform module or through the Services and then stored in a unified Big data database.
The basic storage system is the multi-platform no-relation document database. It ranks among the NoSQL databases and provides fast data access and large data management. Accompanying system is the SQL database that is used to store aggregated data, which can then be used, for example, when creating reports or statistics (fig. 4.2.20).

Data that is stored in the central database:

- evidence of connected technologies and systems
- events (system and non-system)
- users, user rights
- smart scenarios
- aggregated data
- Events from communication
- supporting evidence
- logs

Unified data storage:

- Instant context between data
- Ability to further analyse and search for relations between datasets
- No information is lost (raw data remains in the system)
- Ability to transform raw data into special
- Simple exports to other databases or formats

Figure 4.2.20: Example of interoperability between central systems

4.3 Parking Pillar

The fact is that the key to urban mobility management is in parking management. Virtually every motor vehicle ride ends in a parking space. Therefore, the management of parking spaces influences the demand for driving and traffic congestions. Compared to other transport policies that deal with the use of cars, parking has two obvious advantages:

Parking management usually does not require large investments, such as new roads or additional public transport extension, so it can be implemented in a relatively short time;

We can already find a certain type of parking management in almost all smaller and larger cities in Europe. Thanks to this, the acceptability of parking management by the public is much better than new ways of managing car traffic, such as the congestion charge system or toll systems.

Public space has high value and should therefore be charged if used for parking. Each parking space takes up 12 to 20 m2 and the average motorist uses 2 to 5 different parking spaces per day. In densely populated European cities, an increasing number of people are beginning to question whether the use of valuable public space for car parks should be part of reasonable social policy and whether it was a good idea to support the construction of parking spaces altogether with newly built buildings (Kodransky and Herman, 2011, IDTP). In the figure below (Fig. 4.3.1) you may also see a very interesting comparison of both the costs of parking and costs of city property put into corelation. It is important to understand just how valuable public space is.

Figure 4.3.1: Price comparison of city parking and city property costs (euronews 2016).

Like many other rare collective goods, this space should be price-managed. Research has shown that for example the creation of greenery in a given area can have bigger positive impact on the value of a town house than the provision of parking. So, in general, no public space should give way to vehicles parked for free in city centres. A survey in Graz, Austria, which concerned the usage of public space for static traffic, showed that 92% of this space is used for car parking (private car parks and garages are not included!). Only 2% is used for parking bicycles, 3% is used by pedestrians (including benches, street cafes, etc.) and 3% is intended for public transport (including public transport stops and train stations). This survey has shown the enormous privilege of car parking in the usage of public space in relation to the actual share of each transport mode (fig. 4.3.2).

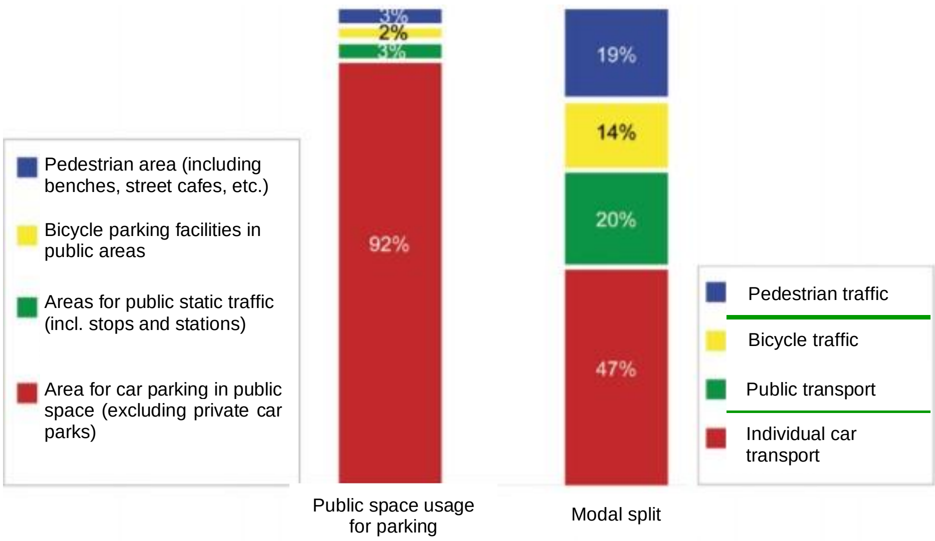


Figure 4.3.2: Comparison of parking requirements in public space with the share of individual car traffic in total traffic (modal split).

Parking regulation means introducing several linked organizational, community and technological tools, which on the one hand will help to implement uniform rules and supervise their compliance, and on the other hand will consist of more than just a CCTV surveillance system. The aim is to support sustainable mobility, not to induce individual transport even more through the construction of parking garages. The smart approach should be based on the principle of using existing possibilities (capacities), i.e. deploy appropriate technologies so that existing parking spaces are used as effectively as possible (both paid and unpaid).

A parking system based on the concept of smart parking should meet the following requirements:

- increasing the efficiency of using existing parking spaces
- informing drivers about the count of free parking spaces in the given parking areas
- navigation of drivers to free parking spaces in real time
- information about the situation in the monitored car parks will be freely available to any driver (in the form of variable traffic signs, website or mobile application)
- The system will be also used as a parking load data collection tool by cities
- The system will offer information on the technical condition of the smart parking hardware itself

- The system will allow further expansion of smart parking
- The project will be affordable and effective for the city

Smart parking management is a solution that can bring common benefits to the council and users.

4.3.1 Parking space occupancy management, assumptions of parking

Parking regulation is a fundamental part of the transport policy of every major city. As the intensity of car traffic does not decrease in the long term, the task of parking a vehicle close enough to the destination of your journey is becoming increasingly difficult and should not be taken for granted.

While dealing with off-street parking, the usual management recipe or ideas of various Prague districts is to increase parking capacity by building new surface parking spaces or collective garages (parking houses). This may not be met with enthusiasm in some central localities of Prague (unlike the peripheral parts, where P + R car parks with sufficient capacity are necessary) and on the contrary, due to the increase in parking spaces, the situation may lead to increased traffic intensity and partial public transport users transfering to individual car transport.

For the above reason, it is necessary to find a different strategy and means for solving the problem of static traffic, worthy of current modern pace and focused especially on the near future. In the short term, Chisinau should solve its parking policy with modern systems, specifically the so-called smart parking system. It is one of the basic transport principles within the so-called smart cities and nowadays it is becoming an effective tool in the world for driving the change in the regulation the regulation of static traffic, especially in city centres. The advantage of this principle is the reduction of traffic congestions. Specifically, it prevents drivers from driving unnecessary kilometres on the street network in an unsuccessful search for a vacant parking space, as they obtain an information on occupancy before arriving at their destination. In the Republic of Moldova, this is not yet established, each subject deals with its parking problems on his own. Quality static traffic management, which, in addition to sharing parking spaces, also works with variable coefficients to determine the number of (retaining) parking spaces, can bring significant savings in the use of public space and the cost of building parking infrastructure.

An important aspect for the proper functioning of any system is the control of compliance with the established rules. This control has to be regular and of sufficient frequency and with appropriate penalties to prevent breaking the rules from being profitable.

The benefits of parking management from the users perspective:

- *Ease of use* - if smart parking is associated with a paid lot, often the payment for parking at this place is made via the application. This payment can be made remotely, i.e. without the need to return to the parking meter.
- *Intuitiveness* - thanks to the parking lot occupancy detection technology, the payment of the paid parking lot can be adapted to the user. If the payment tariff allows it, it is possible to adjust the software of the payment machine for measuring the parking time. When the user arrives at the parking space, the sensor measures its standing time and, according to the tariff, presents the price for the actual length of stay. Payments are thus fairer for both users and operators.

- *Social advantages* - a municipality that operates smart parking lots can change the payment conditions or the parking rules of certain parking spaces over time. If the parking meter is adapted to recognize different types of drivers (for example by user cards), different rules may also apply to different drivers. The city is thus able to give a reduced payment rate to residents or allow them to use free parking lots. Non-residents will pay the determined fee according to the tariff. Parking spaces for people with disabilities can be distinguished using this approach. Parking regulation is thus much more flexible.

The contribution of parking management from the perspective of municipalities:

- *Economical benefit* - after the integration of the payment system into smart will result in economic benefit, according to general research. Revenue can be increased up to 60%. This is because users cannot easily bypass the smart paid parking system. The system itself recognizes whether the participant has paid an adequate amount for parking or whether the amount he has paid agrees with the time of his parking stay.
- *Advantages for city councils and mobility* - The administrator or management, which deals with mobility in a certain area, obtains detailed information that helps him get an overview of transport and parking over time. Problematic sections or time may be identified and find out which groups of residents and users are affected by these events. It also motivates the development of more efficient urban mobility and traffic plans.
- *Benefits for police officers* - thanks to data from the system, police officers can better identify vehicles whose drivers have not paid for parking. Another advantage is that by collecting data over time and comparing to historical data, they can better identify areas to focus on. This will increase their efficiency and the city can better monitor the use of parking services.
- *Social benefit* - Thanks to the possibility of distinguishing users of parking spaces, individual groups of target users can be favoured.
- *Data utilization* – data has been the driving force of many innovations in the past few years and will likely remain so. A large and complex enough data set has a potential for great optimization (learning from past experience) and should, therefore, be cherished and sought after.

The need for parking management is not a new concept (see fig. 4.3.3), it is however, still evolving. A crucial part is keeping up with the newest approaches. Perhaps the hardest challenge is that of a politician who needs to persist and brave through the changes and opposition.

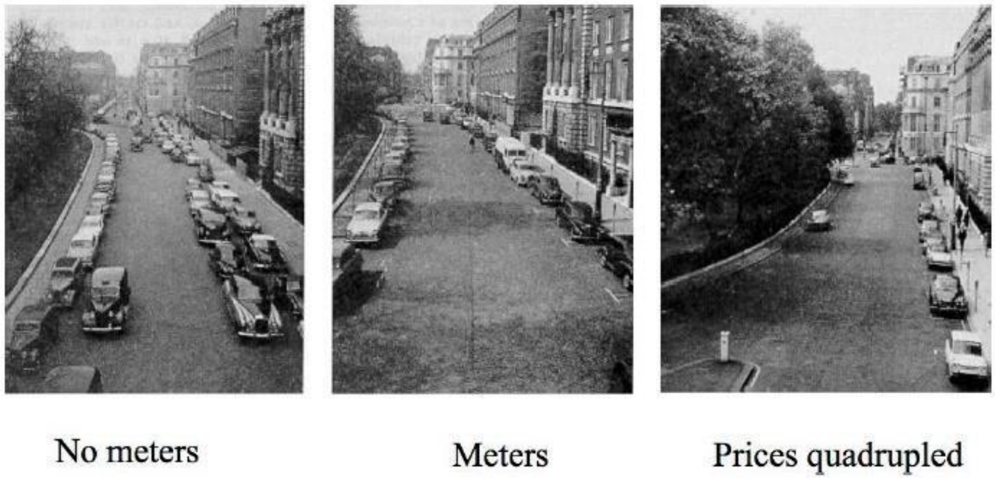


Figure 4.3.3: Grosvenor Square in London – applying changes (On-street parking management, an international toolkit, 2016).

4.3.2 Pay-to-Park zones

Virtual parking meter

The virtual parking meter is part of a digitized parking system, which serves to make the payment of parking fees via a web application (available at mpla.cz/praha – a good example of a virtual parking management and payment system prom the city of Prague) simpler and more effective. When using for the first time, the user sets license plate number of his vehicle in the application, payment method via payment card or CCS card, security password and e-mail, to which a confirmation and a link for the parking extension will be sent.

When parking in the Pay-to-Park (PtP) zone and using this method of payment, it is necessary to precisely define the given section. We have two options for this step. For the purpose of clear identification, there will be a code located on the vertical traffic signs or on the parking meter, which will be entered into the application manually or by scanning a QR code.

There is also a second option – determination by using a mobile phone and GPS. The application will offer the nearest sections in the area. Then the driver will select the appropriate license plate in the system, the required length of stay and the payment method. The user will be then prompted to enter the security password he had chosen when using the application for the first time. A cash receipt and a link to a possible extension of the parking period will be sent to the user by e-mail afterwards.

The advantage of this system is that there is no need to place a parking permit (including a parking ticket) behind the windshield. This solution simplifies the whole process for drivers, as they don‘t have to return to the vehicle with the purchased parking ticket. Thanks to this online application, users also can extend their parking at any time up to the maximum time allowed in the section without having to return to their vehicle.

Mobile application

There is currently no official mobile application for the PtP system. There are several applications available (not only) for the territory of Prague focused on parking, such as eParkomat, zaparkuju.cz or Parking, which, among other things, allow payment for parking in the PtP system. However, they always include a link to the above-mentioned web application.

Figure 4.3.4: MPLA web application.

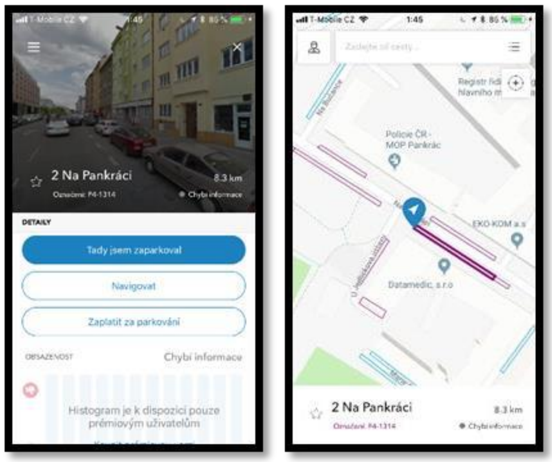


Figure 4.3.5: Mobile application eParkomat.

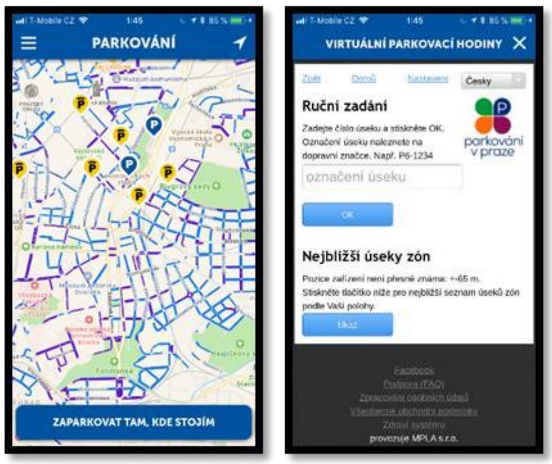


Figure 4.3.6: Mobile application “Parkování”.

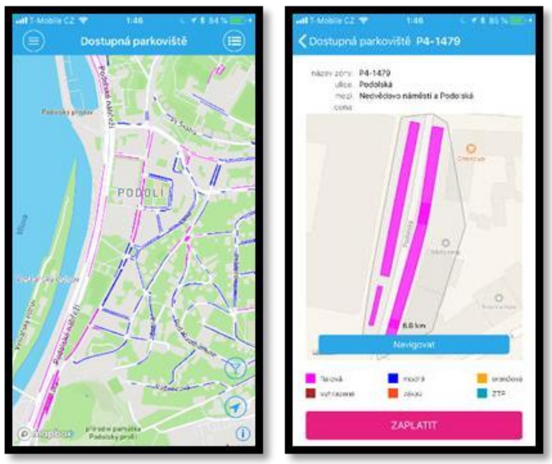


Figure 4.3.7: Mobile application “zaparkuju.cz”.

Identification of parking sections

Each section has its own unique identification code, which is used for orientation and particularly for payment. The code is in the format: P3-0109.

The first number represents city district and the four-digit number after the dash is a unique code within the district.

Automated parking payment control system

In 2016, in addition to new operational technologies, the Capital City of Prague began to use new technologies for monitoring Pay-to-Park zones. A new and unique program for controlling the entire data collection process has been developed. The data collection tool is a special vehicle equipped with a camera adapter. The vehicle (fig. 4.3.8) has four special cameras on the roof for reading license plates (two for front view, two for rear view) and two surveillance cameras, which are designed for taking surveillance photographs and monitoring traffic signs. The monitoring system is a closed automatic system of data collection. The data are securely transmitted to the central information system of the capital city of Prague, which integrates all processes related to the regulation of parking in the Pay-to-Park zones.

Figure 4.3.8: Monitoring vehicle.

4.3.3 P+R - Best Practise Examples

When talking about the need for parking capacity for regularly commuting drivers, especially from outside the Capital City of Prague, it should be emphasized that the Capital City of Prague has a very high-quality public transport system. For proper functionality in combination with commuting drivers, it is necessary to have a sufficient capacity of P + R retaining car parks (located near public transport stops with sufficiently attractive service). However, the capacity of car parks in this regime is currently significantly insufficient.

Fig's. 4.3.9 and 4.3.10 below show the available P + R car parks in the territory of the Capital City of Prague.

4.3.3.1 Prague

This chapter summarizes the strengths and weaknesses of the current parking system in the Capital City of Prague.

An important part of the proposed concept is the parking solution in terms of technology and organization. The basic idea is that there should always be one "account" (smart card, username in the application, ... etc.) to which one person (from Prague / outside Prague) and a vehicle will be registered. If the person in question had another vehicle registered, the price for related services should be several times higher (eg 5 - 7 times) for all fees. There is also a possibility for connection with public transport payments (card “Lítačka”).

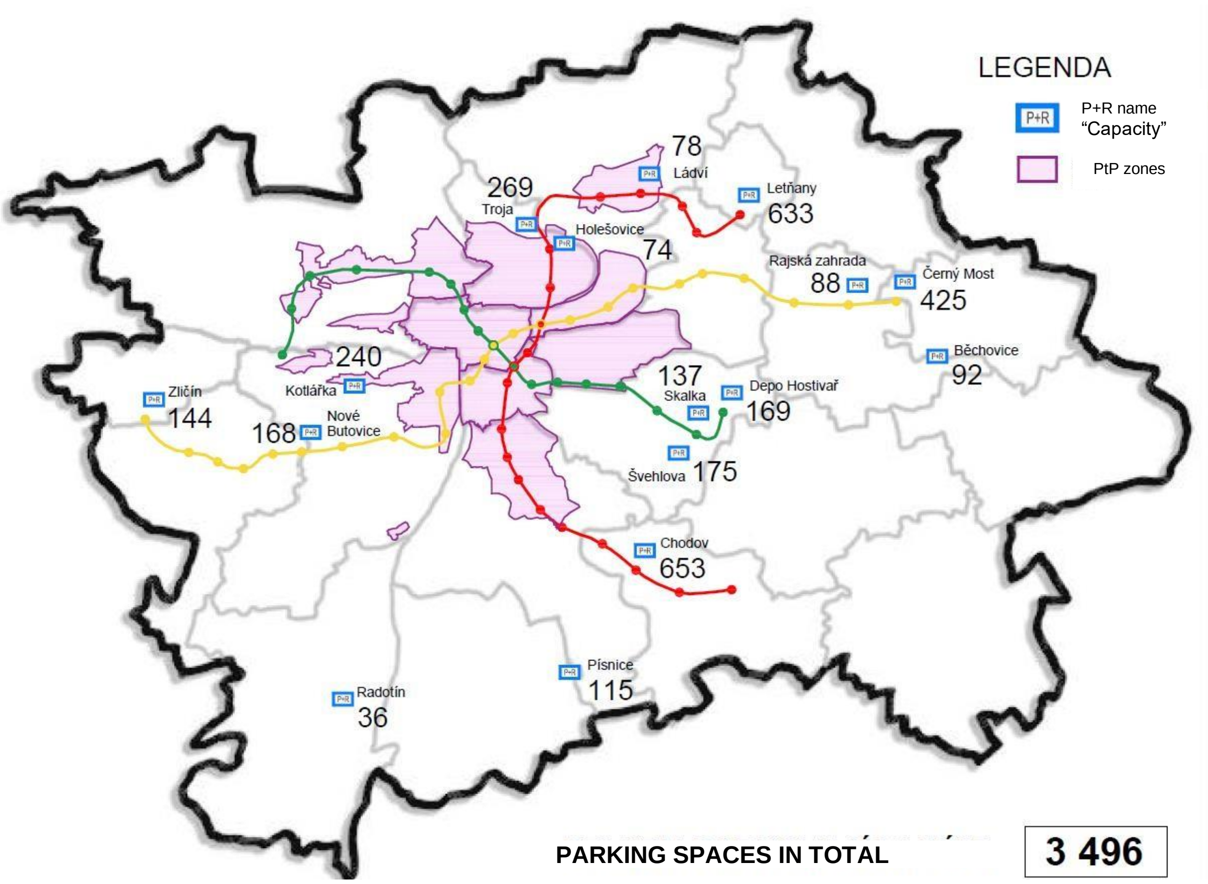


Figure 4.3.9: Map of P+R retaining car parks in Prague with marked capacities.

Name	Surveillance	Station / metro	Max stay	Capaity
Běchovice	No	Railway	12 h	92
Černý Most I	Yes	B line		294
Černý Most II	Yes	B line		131
Chodov	Yes	C line		653
Depo Hostivař	Yes	A line		169
Holešovice	Yes	C line, railway		343
Kotlářka	No	Tram stop	12 h	240
Ládví	Yes	C line		78
Letňany	Yes	C line		633
Nové Butovice	Yes	B line		168
Písnice	No	Bus stop	12 h	115
Radotín	Yes	Railway		36
Rajská zahrada	Yes	B line		88
Skalka I	Yes	A line		63
Skalka II	No	A line	12 h	74
Švehlova	No	Public transport	12h	175
Zličín I	Yes	B line		83
Zličín II	Yes	B line		61

Figure 4.3.10: Basic data about P+R retaining car Parks in Prague.

Monitoring the occupancy of parking spaces

As part of the new mobile application, for the purpose of monitoring the occupancy of parking spaces in the area, it would be appropriate to somehow force drivers standing in a given parking section to register and after leaving the parking space (or just before leaving it) to log out. On check-in and check-out basis, it would also be possible to charge a parking fee based on the actual parking time, which would be a change from the current system, where drivers buy parking fees for a certain time in advance.

The situation is more complicated with the option of an annual subscription. In this case, it would be appropriate to motivate drivers to check in and out (of course without any additional payments) in any way. One of the possibilities is the so-called positive motivation, where drivers would be rewarded for this information, e.g. with discounts on payments or other benefits. Such a method would certainly have a higher popularity among drivers, but at the same time certainly lower efficiency than in the so-called negative motivation, when drivers would be directly obliged to register and check out, and if they did not, it would be considered as illegall parking.

The monitoring could then take place in a similar regime and on the same principle as now, using the same special vehicles.

The issue of marking parking spaces using HTS

It has been debated whether HTS (horizontal traffic signs) has any effect on the maximum usability of parking spaces. Anti-marking opinions state that marking places with HTS reduce the capacity of parking areas, because ineach vehicle have different width and especially length. In the case of marking places with HTS according to ČSN 73 6056, it often happens that some places are not sufficiently used (in terms of area), especially in the case of parallel spaces. The second opinion, on the other hand, says that marking has a positive effect on the capacity of parking areas, when in particular there is no creation of larger gaps between vehicles (for all types of parking).

The authors of the study conducted a survey in the territory of the Capital City of Prague, which mapped 40 parking lanes or stripes in 17 different locations within the current PtP zones in Prague. These were parallel, perpendicular and angled parking spaces, which were not marked with HTS (horizontal traffic signs). The selected areas were mostly occupied, the condition for the implementation of the survey was a maximum of 2 free spaces next to each other, in order to be possible to calculate the capacity, with the current distribution of vehicles. This value was always compared with the theoretical capacity when marking parking spaces using HTS (horizontal traffic signs) according to Czech standard (ČSN 73 6056). The results of the survey speak quite clearly against the use of horizontal traffic signs (see Table 2). Only in 3 cases did horizontal traffic signs appear as a means of increasing capacity, in 30 cases it was the other way around, and in 7 cases the capacity was approximately the same for both options. This fact is not altered by the fact that relatively large space reserves between vehicles were often noted in the survey, as can be seen from Fig. 4.3.11 – 4.3.14.

Figure 4.3.11: Spatial reserves between vehicles identified during a survey of 17 localities in the Capital City of Prague - angled parking.

Figure 4.3.12: Spatial reserves between vehicles identified during a survey of 17 localities in the Capital City of Prague - angled parking.

Figure 4.3.13: Spatial reserves between vehicles identified during a survey of 17 localities in the Capital City of Prague - longitudinal parking.

Figure 4.3.14: Spatial reserves between vehicles identified during a survey of 17 localities in the Capital City of Prague - longitudinal parking.

4.3.3.1.1 Strengths

As part of the implementation of the new PtP zones concept in the Capital City of Prague, the web presentation parkujvklidu.cz was launched. In one place, citizens will learn important information for the use of PtP zones system, there is available information about each section within PtP zone and, last but not least, a direct link to the so-called Virtual Parking Clock, which is used for cashless parking fees payment.

Possibility to pay for parking by credit card

Although it seems likes a platitude nowadays, in the original PtP concept, it was not possible to use a payment card as payment option for parking tickets machines (see fig. 4.3.15). Today's machines (see fig. 4.3.16) already allow this payment method, it is also possible to make a contactless payment.

Possibility to pay for parking online, including localization

Another simplification for drivers paying for parking and As well an alternative to parking ticket machines is the possibility of payment via an Internet application, the so-called Virtual Parking Clock. Another useful feature of this application is the localization (after enabling it) of the user, so there is no need to enter the zone section number manually. It is only necessary to check or select some of the adjacent sections for which the driver wants to pay.

Figure 4.3.15: Original type of parking ticket machine.

Short term parking option in blue parking zones even for non-residents

The current PtP concept allows short-term parking (max. 3 h) even for drivers who do not have a parking permit valid in the area. The price is always the maximum possible within the given tariff zone (I. zone - 80 CZK, so about 3 €; II. Zone - 60 CZK, so about 2,20 €, III. Zone- 40 CZK so about 1,50 €) and it is possible to pay only by the Virtual Parking Clock application, because there are no parking ticket machines in the blue zones. Even before, it was possible to park in the blue zones for non-residents. However, it was necessary to have special scratch cards, which had a limited distribution and a minimum of people knew about this possibility. The practical usability was therefore almost zero.

Figure 4.3.16: Original type of parking ticket machine.

Automated parking payment control system

As already mentioned in Chapter 4.3.2, in 2016, the Capital City of Prague began to use new technology for monitoring Pay-to-Park zones. The data collection tool is a special vehicle equipped with a camera body (see fig. 4.3.8), which provides data to a closed automatic system (CIS), which integrates all processes related to parking regulation within the Pay-to-Park Zones. This has significantly reduced the number of staff checking each vehicle for valid parking tickets behind the windshield.

4.3.3.1.2 Weaknesses

Residents of the Capital City of Prague are not favored in the system

In the current PtP system, the inhabitants of the Capital City of Prague are not favored in any way. In practice, for example, a resident of the Capital City of Prague with a permanent residence outside the tolled area cannot obtain a parking permit in any tolled part of the Capital City of Prague and pays the same parking fee as drivers of vehicles commuting from areas outside the Capital City of Prague. In general, the resident card in one area does not in any case apply to free parking in another area, which disadvantages Pragues living and working in the territory of the Capital City of Prague in various city districts. With the current setting of the tariff policy in combination with a significant lack of capacity of retaining car parks, drivers commuting from outside of Prague in particular do not have an motivation to avoid PtP parking areas wand thus have a significant share in the occupancy of PtP parking space.

Absolutely insufficient capacity of P + R car parks

Considering the number of vehicles entering the territory of the Capital City of Prague every weekday (based on an analysis from available sources it is more than 300,000 vehicles per day), the current insufficient capacity (3,500 P + R parking spaces) of P + R retaining car parks clearly emerges. It is thus around 10% of the optimal state (at least 30,000 - 35,000 of these places are needed).

Unclear tariff system, including PtP operating hours

There are 3 tariff zones in the territory of Prague, but these determine only the maximum hourly rate for parking (and at the same time the rate for non-residents in all blue zones). However, the tariff for mixed and visitor zones is not further unified in any way, each city district determines this itself, the same applies to the operating hours of individual zones. The tariff is supposed to have a regulatory function in particular, which it does not meet at all with the current setting of fees. There is also a lack of significant edification for the current PtP system.

Absence of smart technologies (ia for localization of free capacities)

Widespread implementation of PtP zones is a necessary condition for the application of technologies identifying or predicting the occupancy of parking capacities. Nowadays, however, with few exceptions, this does not work, not even with use of the data from monitoring vehicles. Based on various studies, it has been reported that, on average, the driver travels up to several extra kilometers when searching for a parking space. This, of course, has a negative impact both on the drivers themselves (loss of time, fuel consumption) and on the area (increased traffic intensity, noise and emissions in the area).

Absence of a mobile application

Today, there is no official mobile application for the PtP system. Only a few applications focused on parking are available, but at least in the area of parking payments, they always refer to the above-mentioned internet application.

User-unfriendly payment in parking machines

Here are some observations that make the existing parking meters (see fig. 9, fig. 10 and fig. 21) not user-friendly.

- The parking meter has a colour display and a large keyboard below it, which does not have a classic layout like the computer one
- However, the dispay doesn't contain touch screen, which may confuse the user
- There is not stated to which parking section the machine belongs
- It is not possible to manually enter the parking section in which the user has parked, which can also be confusing
- When selecting the parking time, it is not possible to enter the time directly, but it is necessary to set it minute by minute, resp. half an hour

4.3.3.2 Vienna

Vienna regularly holds the top positions in the world's metropolises quality of life rankings, so it is a good inspiration also for finding solutions in the field of static traffic. It has already completed the period of two transport "master plans" fulfillment and is currently preparing a third one. Vienna has been connected with Prague both evolutionary and culturally in the past and therefore is probably the closest city in terms of the spirit among other European capitals nowadays. It is also close to Prague in terms of area (415 km2 versus Prague's 496 km2) and population (approx. 1.7 million, Prague has 1.3 million). The ratio of car to public transport is similar to Prague. Vienna has a ten percent higher rate of non-motorized transport, than the described Prague.

The Vienna underground transport system has five lines with 101 stations and has been developing rapidly for a long time (16 new stations since 2000). The annual public transport ticket was recently reduced to 365 € (146 € in Prague), a single ticket costs 2 € (1.3 € in Prague). In Vienna is available an annual subscription to P + R at cost of 550 €; in combination with an annual public transport ticket it costs less (468 €). It is not possible to buy an annual P + R subscription in Prague, a daily parking fee is worth 0.80 € here. Vienna city centre with adjacent areas is covered by parking zones. Bicycle transport makes up about 6% of all journeys and is constantly rising.

Parking Zones in Vienna

There are short-term parking zones in Vienna city centre and adjacent districts. Parking time is limited, the beginning of the zone of the relevant district is always marked with a traffic sign and in short-term parking zones the driver must pay for parking.

The first Pay-to-Park zone in Vienna was established in 1993 and was gradually expanded to Vienna city centre and adjacent districts. In the following years, the zones were extended to districts 6 to 9 (1995), 4 and 5 (1997) and 2, 3 and 20 (1999), covering the entire area of the true city centre. In 2012 and 2013, there was another significant expansion into district 15 and parts of districts 12, 14, 16 and 17.

The main difference from the Prague system is that Vienna does not distinguish between parking lots for residents and visitors. Residents and visitors can park in the zones anywhere (with some exceptions). There is no need to implement horizontal traffic signs (blue lines) or to define places for different groups of users. Vienna is divided into only two large zones, in which slightly different rules and pricing policy apply.

For visitors without permanent residence in the defined area, the parking time is limited to a maximum of 2 hours in the city centre, in the adjacent area to 3 hours. It is possible to pay by a mobile application called "Handy parken", or by parking tickets (for purchase at post offices, news stands, etc.). There are no parking machines in the streets, which leads to economical and public space savings. It is possible to stop anywhere for free within 10 minutes, but even in this case it is necessary to fill in a parking ticket.

Figure 4.3.17: Vertical traffic sign for a short-term Pay-to-Park zone (so-called "Kurzparkzone").

The following table 1 summarizes parking conditions for visitor within the parking zones. It is obvious, how clear and unambiguous the system is. The price for 30 minutes is 1,05 €.

Table 1: Parking conditions for visitor within the parking zones.

Districts	MO – FR	SA – SU, Holiday
1 – 9 and 20 (red)	9^{00} – 22^{00}, max. 2 h	Free of charge
12 and 14 – 17 (blue)	9^{00} – 19^{00}, max. 3 h	Free of charge
Stadthalle (yellow)	9^{00} – 22^{00}, max. 3 h	18^{00} – 22^{00}, max. 2 h

Residents pay 120 € per year in the central area (red), 90 € per year in the adjacent districts (blue). The given authorization is always valid for the city district in which they reside, plus the so-called overlapping zones on borders of the particular district.

A special parking card can also be obtained by employees or tradesmen without permanent residence in the defined zone. However, the applicant must prove that they can't travel to and from work by public transport and that car travel is essential for them. Exceptions are also granted to companies which will prove that running a company vehicle several times a day is necessary for their business, especially for the transport of material.

Control of the functional system is provided not only by the city police, but also by employees of the Vienna City Hall. They are competent to mete out a fine for violating the Pay-to-Park law. This frees the city police's hands for more demanding activities and thus reduces the cost of controlling the system.

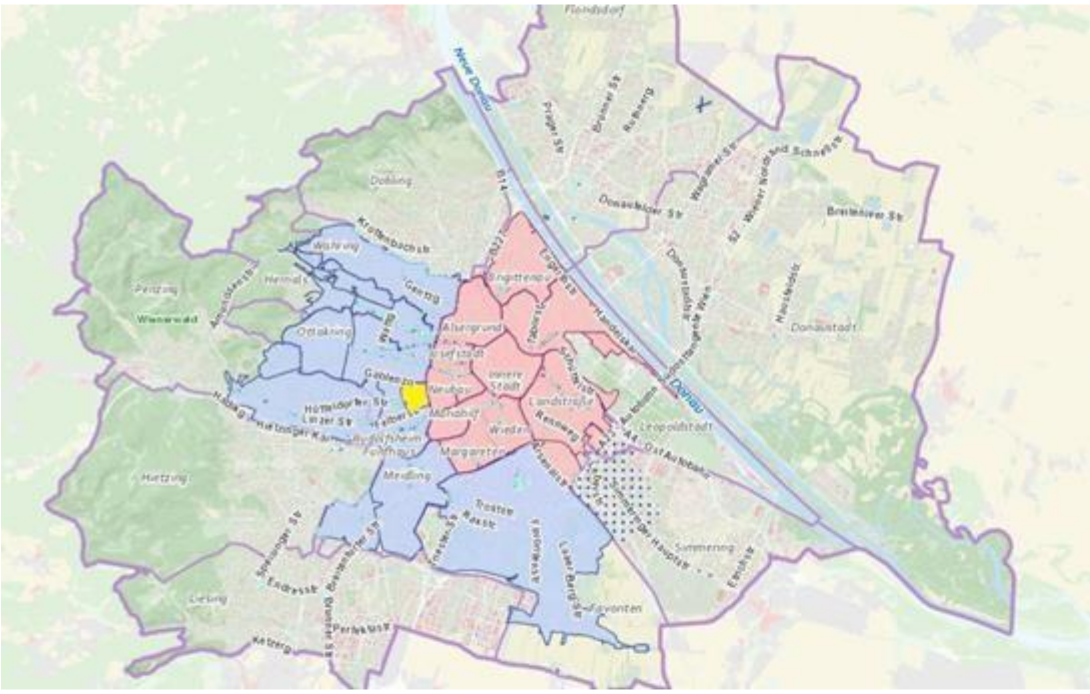


Figure 4.3.18: Parking zones in Vienna.

Retaining P + R parking in Vienna

Vienna also has a sophisticated system of retaining P + R car parks on the outskirts (fig. 4.3.19) of the city, but also beyond its borders (mostly in connection with a railway). The price of all-day parking is 3.40 € (0.80 € in Prague). The total capacity of P + R car parks in Vienna and its closest surroundings is 16,271 lots, of which 10,419 is in the city of Vienna. It's obvious that a significant part of the car park capacity is located outside the city boundaries with a link to railway transport stations (with the provision of adequate public transport service). Even such capacity is not optimal and Vienna still has a parking capacity shortage. Nevertheless, the situation is better compared to Prague, not only in terms of absolute numbers, but also relative ones. In Vienna, there is one parking lot in the P + R car park for 28 commuters, while in Prague for 53 commuters. Car parks with a larger capacity can be found in Vienna. The average size of the P + R car park is 850 lots (only 169 in Prague), the largest P + R car park in Vienna has 1,800 lots (Erdberg), in Prague it is Chodov with 653 lots.

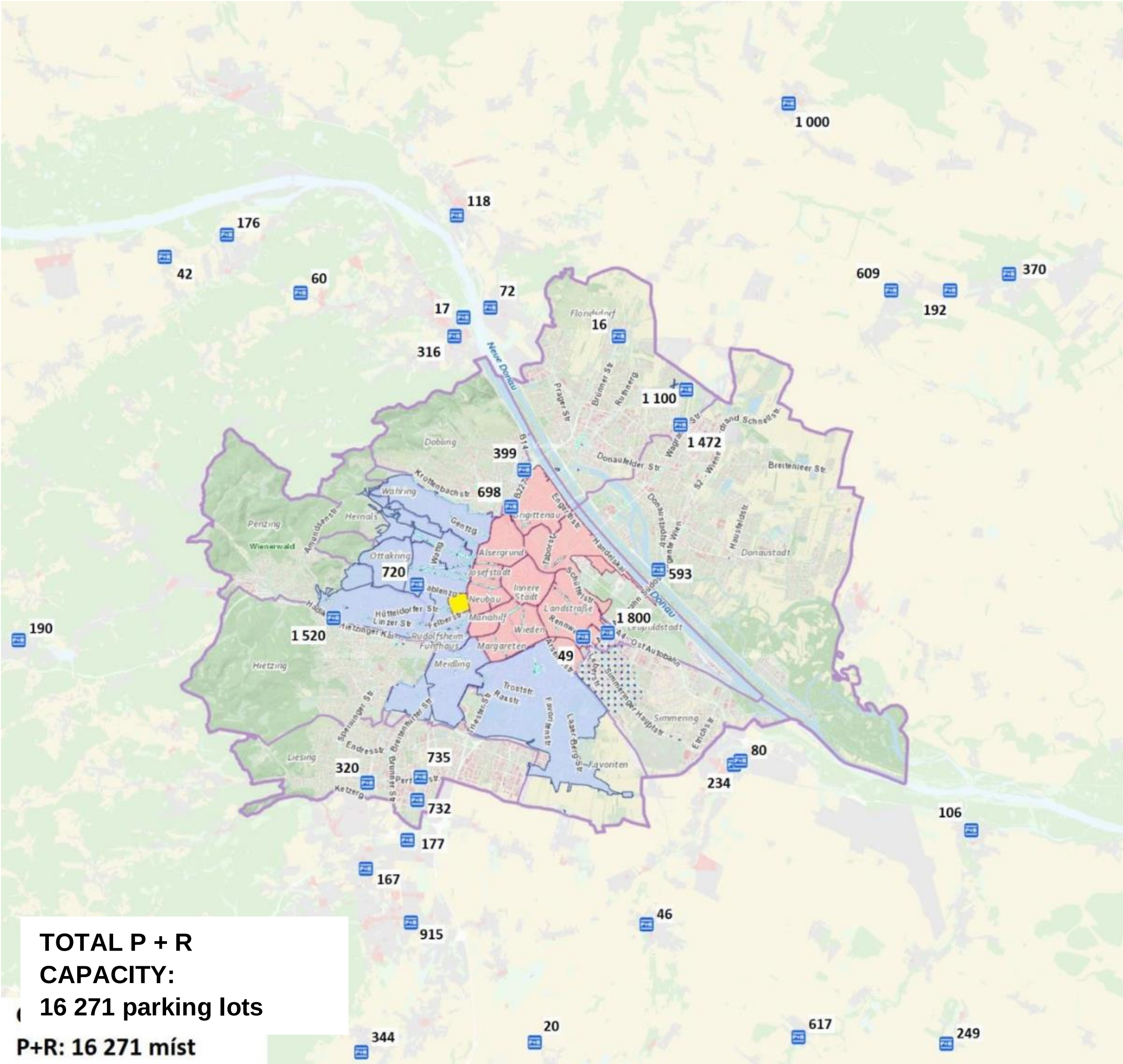


Figure 4.3.19: P + R network in Vienna.

The most fundamental impacts of optimizing the static traffic organization in Vienna:

Districts 1-9 (red colour):

- Reduction of the average parking lots occupancy in the morning from 109% to 71%,
- Reduction of the average parking lots occupancy in the early evening from 108% to 89%,
- Reduction of the unauthorized parking ratio by 86% (morning), resp. 76% (evening)
- Reduction of traffic intensity (by 26% due to reduction of traffic when looking for parking lots),
- Increase of free parking spaces for residents from 46% to 67%,
- Reduction of parked vehicles commuting from outside of Vienna by 66% (in the morning).

Outer districts 12, 14, 15, 16, 17 (blue colour):

- Reduction of the average parking lots occupancy in the morning from 83% to 60%
- Reduction of the average parking lots occupancy in the early evening from 88% to 79%
- Reduction of the unauthorized parking ratio by 72% (morning), resp. 13% (evening)
- Reduction of parked vehicles commuting from outside of Vienna from 20% to 3% by 66% (in the morning)

In order to reap the benefits of static traffic regulation, it was important to use follow-up precautions, such as sufficient retaining parking capacity, adequate city garage capacity, sufficient capacity and high quality of public transport, increasing short-term parking fees, or reducing the annual public transport ticket price to 365 €.

4.3.4 Proposal of a New Basic Concept of Pay-To-Park Zones in Chisinau

4.3.4.1 PtP Zones

The basic idea of the newly proposed concept of PtP system is the division into only 2 zones, the so-called "Primary" and "Secondary" (or Core and Surrounding), with the fact that Paid Parking Zones should be intended for use primarily by residents of the Capital City of Chisinau and they should therefore be favored by this system. Also, these 2 proposed zones are not dependent on the boundaries of urban areas. Among other things, the authors were inspired by the concept of paid parking zones in Vienna, where a similar principle has been operational successfully for several years and has brought positives both from both drivers and especially the city's inhabitants.

The proposal of the above-mentioned 2 Pay-to-Park zones is as follows:

- "Primary zone" (blue marked in the map in fig. 4.3.20)
  - uniform for the whole area,
  - it is mainly the city centre (based on amenity and building distribution),
  - if the zone boundary is confined by a street, the street section belongs to the "Core" zone.
- "Secondary zone" (red marked on the map in fig. 4.3.20)
  - based on higher density building distribution,
  - the goal was to avoid the problem of users parking few meters away from the zone and thus only moving the problem further away,
  - the zone needs to be large enough to encompass all problematic areas (or possibly problematic areas),
  - it is possible to change the area of red zone based on future experience (should problems arise just outside of the zone, it needs to be modified to include new problematic areas until there are none left).

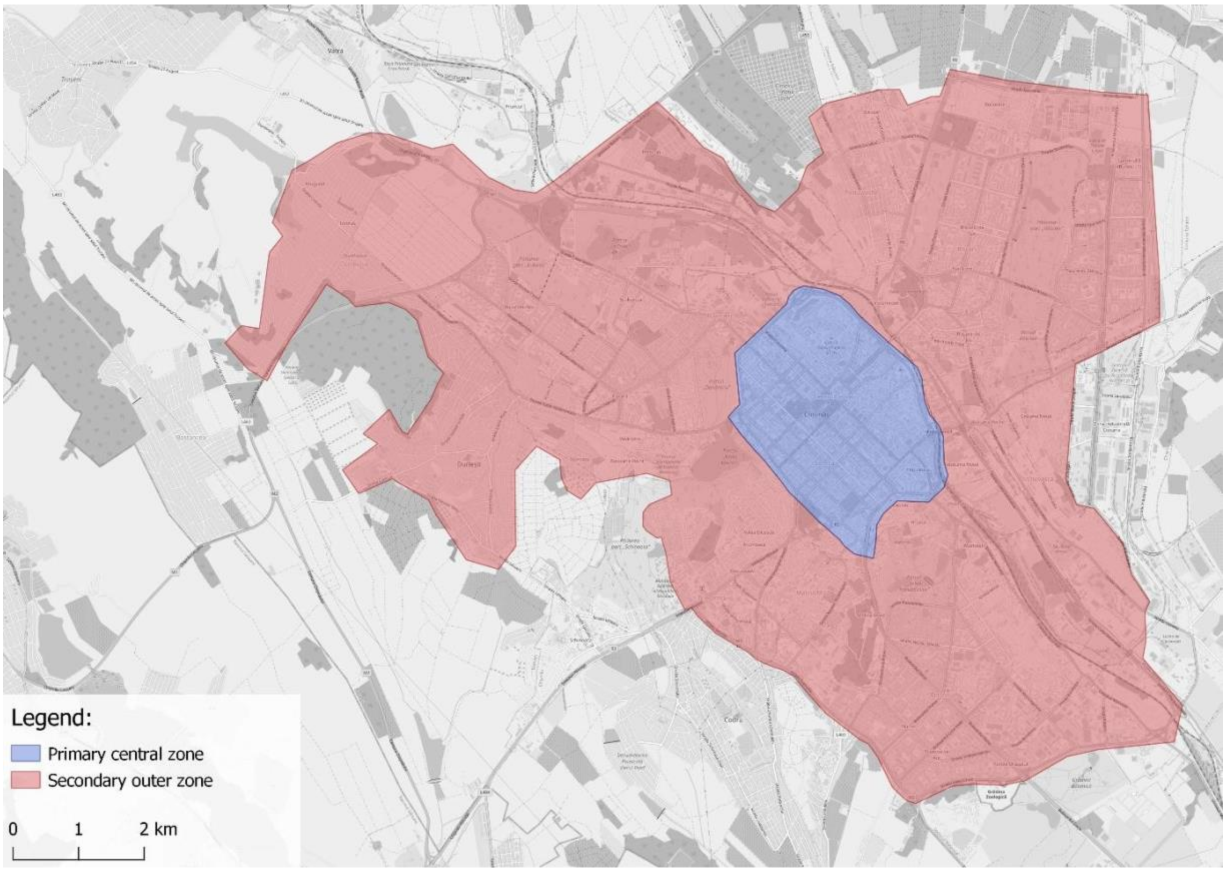


Figure 4.3.20: New PtP zones proposal in Chisinau (blue „Core" zone; red „Surrounding" zone).

4.3.4.2 P+R parking lots

The main feature of the retaining car parks should be a multi-storey layout, which would make possible to significantly increase the capacity while using existing areas. Any significant increase in the capacity of parking lots will significantly and positively affect the issue of parking in the Capital City of Chisinau. In comparison (by area, number of inhabitants and traffic load) with the city of Vienna the capacity of retaining car parks is five times higher there (see chapter 4.3.1.2).

Some capacity reserves are shopping centres, which often have a parking capacity of hundreds of places and are located on the outskirts of the city within easy reach of public transport stops (especially subway). This offers cooperation between the city and private entities in order to use these areas at least as a part of P + R car parks.

Another topic to consider is the involvement of Central Moldavian cities and municipalities in the system of P + R car parks, especially in connection with railway transport, including the attractiveness of this mode of transport for drivers.

The locations of proposed P+R parking lots is based on availability of free space and accessibility of public transport (with railways being favoured as it should be the load-bearing infrastructure in the future). The expected primary end destination is the city centre. But if the P+R parking lots are close to public transport, it offers more options to leave the car behind and move freely about the city. The proposal is on the map in Fig. 4.3.21 below.

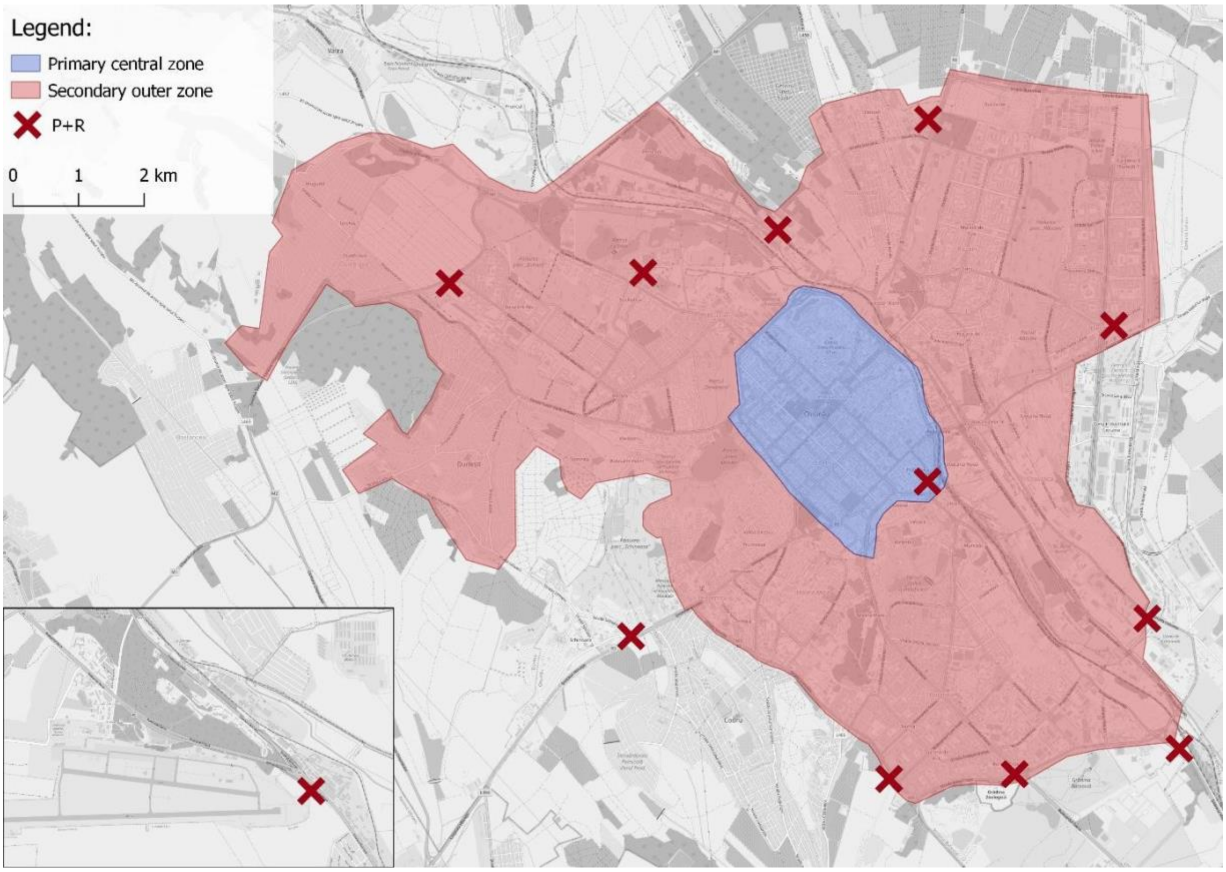


Figure 4.3.21: New P+R locations.

4.3.4.3 Navigation system and virtual garage

Should the P+R parking lots be equipped with technology capable of detecting current remaining capacity and forwarding such information, it is extremely beneficial to utilize this information fully. It would be recommended to equip the city with traffic signs that direct the drivers to particular close P+R parking lots with the additional information of how much capacity is left. Such navigation systems allows for diminishing the effect of users looking for free parking space increasing traffic flows and furthering the traffic problems in the city centre.

Such navigational system based on traffic signs should also be enriched by combining it with GPS navigation systems (this can be navigations in cars or in mobile applications). For example, if the user plans the journey using some currently available application such as Google maps, Waze, Sygic, TomTom etc., or possibly some future apps, it could already include the information about free parking space availability. It could even include historical data and predict possible free space availability for the time the user would reach the end destination.

It is important to view the city as a complex system of roads and parking lots. An illustrative analogy would be that of a complex parking garage with multiple floors and several connecting segments. Should one understand the entire city as such garage, it would be clear that easy navigation would greatly reduce the additional traffic. If one part of the city reaches its parking capacity, the system can redirect the traffic to another part of the city, close to public transport. This system shall be called the **Virtual Garage**. Naming it should prove to be beneficial when dealing with the public.

4.3.4.4 Pricing and tariff policy

In this study, the aim is not to determine the specific payment amount for parking, but rather the price ratio for individual zones and types of inhabitants. Therefore, only relative amounts are used in the following examples, where:

X the amount of the annual subscription in the "Primary" zone for persons residing in the "Primary" zone
Y full hourly rate in the "Secondary" zone

It is therefore sufficient to just set the price for X and Y and the rest should follow the ratios below. There is a table describing the pricing policy for the annual subscription (*table 1*) – the table or matrix determines the relationship between their residential location and the location the customer wants to park in. The second table below (*table 2*) sets the pricing policy for an hourly rate based on. The pricing policy was constructed in such a way to favour residents significantly.

Table 1: Pricing policy recommendation – annual subscription

Lives in… / Parks in…	Primary zone	Secondary zone	the city outside of zones	outside of the city
Primary zone	X	(5-6) • X	(7-10) • X	(9-12) • X
Secondary zone	3 • X	(0.6-0.7) • X	(4-6) • X	(9-12) • X

Table 2: Pricing policy recommendation – hourly rate

Type… / Parks in…	Full hourly price	First hour of parking	Customer with an active annual subscription (any zone)
Primary zone	3 • Y	1.5 • Y	0.6 • Y
Secondary zone	Y	0.5 • Y	0.2 • Y

Full hourly rate – any customer payment for each hour above the first hour.

First hour of parking – any customer who parks their car has a different charge for the first hour only, after the first hour a different rate sets in.

Customers with an active annual subscription (any zone) – any customer that has an active subscription of any kind (see *table 1*) has a reduced price for parking as it promotes usage of annual subscription. Customers from outside of the city may be excluded or the pricing policy can be shifted in favour of city residents.

It is important not to be afraid to test out new prices (higher prices) and see what effect it has. It is also possible to implement dynamic pricing policy based on current occupancy (the more cars, the higher price) ensuring there will always be a parking space available to those who truly need it. With the implementation of zones, it should prove easier to implement wide-spread changes in control and pricing policy. The parking can also be played not only per hour but per half an hour or quarter of hour to motivate customers for shorter parking times.

4.3.4.5 Parking digitization and Enforcement

Parking control can prove to be very demanding on the resources of the city. A sensible step is to fully digitize the agenda. This includes several individual steps:

- Implementing technology capable of connecting a database of registered vehicles (vehicle registration plates) and monitoring devices (optimally on a moving car or in the hands of policemen).
- Creating a system, where the police can go through listed offences and contact the owners.
- Crating a payment system, where users can fill in the register plate and play for parking at a specific location for a specific time period (or subscribe).
- Create sheltering SW (applications) that both enable the users to utilize the system to the fullest and provides data from the parking lots.

A good example of this system is MPLA in the City of Prague (this is only part of the system). Implementation of these steps can greatly reduce the costs of the regular control and increase the revenue that can be then used to further improve the public space.

4.3.4.6 Data utilization

Data of individual anonymized uses of the parking system should be recorded at all times. The addition of complete and thorough data from the entire city for a longer time period has significant potential for optimization. Not only does it provide the information of the current state, it also provides historical trends in public space usage and can be put into correlation with outer influences and analysed. Such analysis can prove to be beneficial for the users, as the system is made for the after all.

4.3.4.7 Data utilization Motivation, PR and leadership

Perhaps the most important aspect of the entire topic is political leader and public relationships (meaning communication of the agenda). Several parts of the entire chapter about parking (or static traffic if you will) can be rather problematic at first for the people to accept them. The simple truth is, we (as a society) have gotten used to the fact that car always has a right of way, that there is always a place for us to park our cars and so on. The painful truth is, there is not enough parking space in most cases and there never will be, unless we want our cities built over with parking lots and parking garages. Such city would not be a city to live in. Therefore, the people need to be explained, that the change will be a little painful for them in the beginning. But in the long run, this is all for them to feel better in the city where they live, work or commute.

This is all easier said then done. Unless there is a strong persona behind it all, the journey is going to be a lot more painful and lot harder. A political leader that can convince the people of the idea day after day is a must.

4.4 Public Transport Pillar

The analysis showed that the transport system in Chisinau is divided into many sub-subsystems, which are not mutually coordinated in the necessary way. This situation impedes the development of a synergistic effect and significantly decreases the performance of the transport system as a whole.

To create a quality and efficient transport system, it is necessary to solve its individual components and processes in a coordinated manner as a whole. The basic components of the transport system include:

- public transport (PT),
- individual transport,
- haulage,
- pedestrian traffic,
- micromobility,
- parking.

4.4.1 Integration of Public Transport

In the case of public transport, it turns out that the operation of individual modes of transport or the activities of individual carriers (operational integration) are not integrated. There is also a lack of integration of urban and regional transport (territorial integration) and a unified tariff system (tariff integration).

The transformation of the public transport system should consist in the introduction of an integrated transport system (ITS). This process includes the following basic steps:

- Appointment of an ITS coordinator and introduction of a three-tier model of the organization.
- Elaboration of ITS quality standards and methodology of their implementation.
- Strategy elaboration:
    - on the management and development of ITS,
    - on the system development of public transport priority,
    - on the development of the tariff system,
    - on fleet renewal and development
    - directional and time coordination of lines.
- Integration of railway transport into the established ITS.
- Construction and modernization of railway infrastructure (eg. construction of new stops and multimodal interchanges).
- Hierarchical arrangement of transport subsystems within a heterogeneous PT network.

<u>The Three-Tier System of the ITS Organization</u>

The top tier is the political tier, which consists of the political representation of the city. The political representation of the city is obliged to ensure quality transport services of the city in accordance with the approved transport policy and within the possibilities of the municipal budget. To ensure this task, the municipality will establish a professional organizational authority - the ITS coordinator, which forms the second tier of the organization. The ITS coordinator is responsible for professional solutions leading to the achievement of policy goals in the field of public transport organization. This role cannot be performed by the carrier, as more carriers participate in the operation of public transport in the city. However, ITS requires uniform coordination so as to ensure comprehensive service of the entire territory according to uniform rules while ensuring equal rules of competition among individual carriers. However, competition among carriers cannot take place in relation to passengers. The passenger must have a standardized quality of service, regardless of which carrier operates the service chosen by the passenger for his journey. Competition among carriers should take place in relation to the organizational authority (ITS coordinator) by the individual carriers trying to offer the provision of the service in the required quality at the lowest possible price. The carriers form the third tier of the organization and their task is to ensure the operation of the assigned lines in accordance with the requirements of the ITS coordinator.

Basic competencies of the ITS coordinator:

- defining ITS quality standards and checking their compliance,
- precise definition of transport performance:
    - creation of line management,
    - determining the operating parameters of lines (number of connections on individual lines, their exact time positions, transport capacity of individual connections).
- Selection of carriers on the basis of a tender, including the subsequent conclusion of contracts,
- ordering transport services,
- financing of contracted transport services from funds obtained from the city,
- conducting transport surveys,
- solution of public transport priority.

ITS Quality Standards

To guarantee a uniform level of quality of public transport throughout the territory served by ITS, regardless of which carrier provides the operation, it is an effective tool for standardization of some technical parameters and activities. At the same time, standardization will enable the implementation of an objective quality control of the system and compliance with the obligations given by the contract with individual carriers. For each individual standard, it is necessary to determine both the parameters that need to be met and the level of complexity of performance in percent (for example, compliance with the standard can be determined as acceptable in 80% of monitored cases). The basic recommended standards include:

Accessibility of Public Transport

The accessibility of public transport is represented by the maximum walking distance to the stops, which in a continuously built-up area should not exceed 500 m (approx. 6 min.). This rule should be met in at least 80% of the area served. In urban areas outside the continuously built-up area, the maximum walking distance to at least 80% of the area should not exceed 800 m (approx. 10 min.).

Use of Vehicles Transport Capacity

This standard should specify the use of vehicle transport capacity that can be taken into account when dimensioning the line's transport capacity. The maximum utilization of the transport capacity of vehicles must always be lower than the maximum transport capacity of the vehicle specified by the producer. This is necessary not only to ensure acceptable travel comfort, but also to ensure a reserve for demand fluctuations. Fluctuations in demand occur for several reasons:

- a normal fluctuation in demand is due to the fact that exactly the same number of passengers do not always wait for a specific connection,
- the lower the punctuality of operation on a given line, the greater fluctuations in demand will be recorded on individual connections,
- randomly increased demand may occur when traveling with larger groups of passengers (school groups, tourist groups, etc.),
- fluctuations can also be caused by the weather (for example, in summer near swimming pools),
- or various sporting and cultural events.

We recommend monitoring both the average utilization of transport capacity of vehicles, which should not fall below the set value (eg 20%) and the maximum utilization of transport capacity, which should not exceed the set value (eg 80%).

Operation Punctuality

With the help of the GPS system, for example, individual connections are monitored whether they travel on their route at times according to the timetable with a maximum of a certain permitted time deviation. This monitoring will, on the one hand, make it possible to obtain an overview of the quality of individual carriers' service and, on the other hand, it can help to identify critical points in the transport network. The detection of critical points in the network (places with the highest vehicle delays compared to the timetable or places with the highest traffic punctuality fluctuations) can be a good indication of which places or sections need to be prioritized when addressing public transport priority.

Filling Graphical Timetables

This standard makes it possible to check whether carriers actually operate all the contracted services. The level of complexity of this standard should be between 95-99%, with sanctions for carriers for lower performance of the graphical timetables would be a significant motivating element for its compliance with the required level of complexity. Compliance with this standard is very important for gaining passengers' confidence in the reliability of public transport.

Guarantee of Using Specified Types of Vehicles

This standard guarantees that carriers will always deploy vehicles with sufficient transport capacity on individual lines and low-floor vehicles on designated connections. Of course, the deployment of vehicles with a higher than specified transport capacity or the deployment of low-floor vehicles beyond the designated connections is not a defect in the fulfillment of this standard.

Technical Conditions of Vehicles

The carrier will be bound by the obligation to put into operation only vehicles meeting the specified technical parameters (without technical defects, with prescribed additional equipment in the form of approved information and check-in system, with uniform identification marks ITS, etc.).

4.4.2 Network Designing

The network of public transport in Chisinau does not have a sufficiently structured form corresponding to a heterogeneous system. The capacity of the backbone subsystem presented by rail transport is completely missing. Instead of a structured connection, trolleybus, bus and minibus networks overlap (without an obvious structure) and create the impression that they compete with each other instead of coordinated service. This impression is amplified by the current form of the tariff system.

The network design must ensure a sufficient supply of transport capacity in the entire territory that the ITS will serve (primarily in the entire territory of Chisinau) and at the same time the greatest possible synergistic effect of directional and time coordination of individual lines. To achieve these goals, we recommend the following focus:

- Coordinate all modes of transport.
- Include trains in the PT system. This will have the following effects:
  - a significant increase in transport capacity and thus public transport performance,
  - on increasing the average cruising speed of public transport and thus its competitiveness against individual transport,
  - to increase the level of PT priority and thus increase system reliability.
- Optimize line routes with emphasis on their straightness. This will have the following effects:
  - on the reduction of travel times,
  - to increase the share of trips without the need for a transfer,
  - on the release of part of the transport capacity of vehicles for its further use,
  - on reducing operating costs.

The creation of particular lines and their directional and time coordination belong exclusively to the ITS coordinator. Any in-service incidents may be dealt by individual carriers, but in the event of an emergency lasting more than 72 hours, these solutions should be subject to the approval of the coordinator. This system will make it possible to effectively coordinate individual lines across all modes of transport and all carriers, which is necessary to ensure the synergistic effect of the entire system.

Directional Line Coordination

Due to the potential of transport demand and the area, the public transport system in Chisinau should be conceived as heterogeneous with sub-subsystems in a hierarchical arrangement at least for the backbone and supplementary subsystem.

The backbone subsystem should have the following characteristics:

- decisive (at least more than half) transport performances,
- routing in the most loaded radial and diametrical directions,
- higher cruising speed compared to the supplementary subsystem,
- demand for transport composed of two components:
  - local demand in the perimeter of individual stops,
  - follow-up demand supplied by the supplementary subsystem at transfer points.

The supplementary subsystem should have the following characteristics:

- the lines of the supplementary subsystem follow in the radial direction the lines of the backbone subsystem,
- the frequency of traffic on individual lines is the same or several times lower than on the connecting lines of the backbone subsystem,
- routing in tangential and local radial or diametrical directions (in relation to local centres),
- demand for transport is formed from local demand in the perimeter of individual stops,
- the transport capacity of lines of the supplementary subsystem is equal to or less than the backbone subsystem lines.

Urban rail appears to be the appropriate mode of transport for the backbone subsystem. The connection of the municipal railway in the municipal transport system will significantly increase its transport capacity. Train connections also provide fast and reliable diametrical connections in the north-east-southwest relationship. In this context, it is appropriate to modernize the railway infrastructure, revise the location of stations and stops in the city. Railway stations and stops should be located in a continuous development at the intersections of important urban roads (arteries and collectors), in urban areas outside the continuously built-up area at the shortest possible walking distance from the local development. It is good to conceive railway stations and stops as transfer hubs for trolleybus and bus transport. In the south-eastern part of the route, it is appropriate to relocate the route directly to the airport terminal for the purpose of fast capacity service of the international airport. These basic steps will lead to the creation of a hierarchical structure of the system, which will allow a more efficient organization of the operation.

The backbone subsystem, together with the railway line, should form a network of trolleybus lines running along the main roads (arteries and collectors), ideally in dedicated lanes with terminal or diametrical connection to the railway line.

The supplementary subsystem should consist of tangential bus lines connecting at least two lines of the backbone subsystem. Furthermore, the supplementary subsystem should be co-created by regional bus lines with terminal connection to the backbone subsystem lines and local lines created from today's minibus lines again with terminal or diametrical connection to the backbone subsystem lines.

Creating Line Routes

For the creation of line routes, we recommend setting a set of general rules that will not depend on the specific transport measures implemented, will respect the network effect of the transport system and will lead to the application of the synergetic effect. These rules must be based on exact and demonstrable phenomena. They can be used for subsequent evaluations of the quality of individual proposals for transport measures. We recommend that you comply the following criteria in particular.

Respecting the Structure of the System and the General Directions of Routing

This means that the route of each line should be either radial, or diametrical or tangential. When choosing the general direction of the route of each line, it is necessary to follow the hierarchical arrangement of the system. Backbone lines should have either a city-wide radial or city-wide diametric direction, complementary lines should have either a city-wide tangential direction and connect at least two backbone lines, or a local radial or local diametric direction (relative to the nearest junction between the backbone and complementary subsystems). The local lines will therefore form the feeders of the backbone lines, resulting in a logical, uniformly structured system with the necessary directional offer, while the system will be very intuitive for users and therefore easy to use.

Rectilinearity of the Route

This criterion can be characterized by the following definition. If there are several route variants between two specific stops, the route is rectilinear unless another option is faster. It does not matter whether we can take an alternative route with another direct line or whether it will be necessary to use a combination of several lines. In addition to driving times, waiting times for connections must be included in the calculation of the length of the alternative route. Rectilinear routing of lines results in particular in these benefits:

- the average transport distance of passengers on a given line will increase, thus stabilizing the demand (reducing its fluctuations, which are caused mainly by short-distance passengers), which will enable a higher utilization of the vehicle's transport capacity,
- the average number of transfers per trip will be reduced,
- the total length of stay of passengers in vehicles will be reduced, thus reducing the demands on the total transport capacity of public transport,
- travel times will be shortened for passengers, which will increase the competitiveness of public transport compared to individual transport.

Ensuring Transfer Possibilities

At each point where the routes of public transport lines intersect or meet, it is appropriate to set up a transfer point to allow a potential transfer. Transfer points increase the efficiency of the network (shorten the transport time in some relations and reduce the number of necessary transfers among lines in the network). Ideally, the public transport network should form a planar graph. When deploying stops in the network, transfer points should have the highest priority, followed by stops at significant facilities and then other stops to ensure the area coverage.

Operational Parameters

Determination of the Standard of Utilization of Transport Capacity of Vehicles

See chapter 4.2 ITS quality standards. Furthermore, in this context, it is necessary to comply the rule that the transport capacity of vehicles of additional lines will always be the same or lower than the transport capacity of connecting backbone lines. By following this rule, it is possible to avoid congestion of backbone lines and uneven distribution of passengers in individual connections. At the same time, it is important for the efficient use of the transport capacity of vehicles that their transport capacity is the same for all connections during the entire operating day.

Determining of Line Intervals

Line intervals together with the transport capacity of individual connections should ensure compliance with the standard of use of vehicle transport capacity. Line intervals should respect the rule that the supplementary line must have the same or several times longer interval than the connecting backbone line. This rule, together with the previous rule on vehicle capacity, will narrow the appropriate combinations of interval lengths and vehicle capacity on individual lines. At the same time, the intervals within one transport period need to be constant.

4.4.3 Dimensioning of Transport Capacity of Vehicles

The operation of all three modes of transport (trolleybuses, buses and minibuses) in radial and diametrical directions indicates the fact that the dimensioning of the transport capacity of vehicles does not reflect the natural intensity of transport flows. Due to the different values of the intervals on the individual lines, it is obvious that in the individual sections there is an uneven frequency of connections, which must naturally have a negative effect on the occupancy of individual connections. The use of vehicle transport capacity is thus not efficient enough.

For efficient use of the transport capacity of operated vehicles (Fig. 4.4.1 - example), it is advisable to perform the following steps.

- Determine standardized values of vehicle transport capacity according to their length, regardless of the specific vehicle type.
- Divide differences in the transport capacity of individual vehicle types with lower sensitivity.
- Create reserves for cases of fluctuating demand and increase travel comfort.
- Use modern technologies (such as smart cards) to make accurate transport surveys.

Vehicles deployed on a particular line should have the same transport capacity. This will ensure a relatively even distribution of passengers on the individual routes, assuming an even interval within one transport period. This will make efficient use of the offered transport capacity. The specific transport capacity of the line can be achieved by various combinations of interval and transport capacity of vehicles. Vehicles with higher transport capacity have larger reserves in case of demand fluctuations. Assuming larger fluctuations in demand, it is therefore necessary to choose a combination of a more capacity vehicle and a longer interval. This combination is therefore suitable, for example, for longer routes, as a longer route has a higher potential for irregularity. For shorter routes, on the other hand, a combination of shorter intervals and lower capacity vehicles is more appropriate to make it worthwhile for passengers to wait for connections.

Figure 4.4.1: Several types of bus vehicles with the same standardized transport capacity 60 passengers in Prague

4.4.4 Accessibility of Public Transport

One of the basic parameters of public transport accessibility is walking distance to stops. Too long walking distances lead to an inappropriate ratio between walking times and time spent beeing on public transport vehicles. Too short walking distances means shortening inter-stop distances and slowing down public transport.

The analysis showed that walking distances to stops in the city are sufficient, but the low frequency of connections at some stops may actually mean that it is more advantageous for most passengers to use a more distant stop at the cost of a longer walking distance. In such case, the coverage of the territory is practically insufficient.

When optimizing the location of stops, we recommend emphasizing the following measures.

- Increasing the dispersion of inter-stop distances with emphasis on the service of important objects.
- Differentiation of maximum values of walking distances in relation to population density and distance from the city centre.
- Standardization of walking distances among platforms at transfer nodes.

It is recommended to set the maximum walking distance in a continuously built-up area at 500 m (approx. 6 minutes). In localities outside the continuously built-up area, this distance can be extended to 800 m (approx. 10 minutes). In the case of transfer nodes, it is recommended to establish priority transfer connections at the same platform. In case of necessity of pedestrian transfer between different platforms of the transfer node, it is necessary to pay attention to the shortest possible transfer connection up to a maximum of 100 m.

When allocating stops in the network, priority should be given to stops at interchanges. In the second sequence, it is necessary to add stops at significant facilities (schools, offices, medical facilities, shops, etc.). Significant objects generate the largest group of passengers using the stop. The location of stops to significant facilities thus significantly shortens the average walking distance of passengers to PT stops. In the third sequence, the remaining stops should be located to ensure standardized area service, with their specific location taking into account the local population density and should therefore be located as close as possible to the places with the highest concentration of inhabitants in the place.

The difference in the aggregate interval between the stop of the supplementary subsystem and the nearest stop of the backbone subsystem should not be greater than the sum of the value of the aggregate interval at the stop of the backbone subsystem and the time value of the walking distance between the monitored stops of the backbone and the supplementary subsystem.

4.4.5 Public Transport Priority

The analysis showed that the priority measures are gradually being implemented in the public transport network and are being solved by a special working group.

Public transport priority is a very important part of organizing a sustainable transport system. Its basic benefits are as follows:

- increases the cruising speed of vehicles,
- increases the reliability of public transport,
- increases the punctuality and regularity of operation,
- reduces unwanted fluctuations in demand among connections,
- increases the usability of the offered transport capacity,
- reduces operating costs,
- reduces the required number of vehicles and operating staff to ensure operation,
- increases the competitiveness of public transport compared to individual transport.

It is very important that PT priority measures are proposed conceptually in accordance with the directional coordination of public transport lines and the hierarchization of the heterogeneous system, and their effect is not limited to accelerating selected lines serving the city's residents. PT priority measures should also create motivating conditions for the combination of individual and public transport for the inhabitants of a suburban area. This will have the following effects:

- the intensity of individual transport traffic in the city will decrease, which will increase the speed and reliability of public transport,
- the demand for transport will increase, which will make it possible to shorten the intervals of public transport lines, which will further speed up travel time for the city's inhabitants,
- public transport will thus increase its competitiveness towards individual transport.

We recommend the following steps to increase the effectiveness of priority measures.

- Elaboration of a specific strategy for the development of PT priority.
- Emphasis on comprehensive transport solutions.
- Use of multi-criteria assessment of the selection of sites or sections suitable for priority measures. This will result in:
  - to increase the efficiency of site selection,
  - on increasing the effectiveness of priority measures,
  - a more visible effect of spending funds,
  - the origin of a synergistic effect.

4.4.6 Punctuality and Regularity of Operation

The available information showed that the punctuality and regularity of the operation is not systematically monitored, evaluated and does not serve to further optimize the system. We recommend that the punctuality and regularity of operation be standardized and become one of the basic evaluation criteria for the quality of public transport. We recommend the following measures.

- Develop a standard of operational punctuality and specify in it:
  - the average deviation from the timetable,
  - an acceptable deviation from the timetable,
  - by the level of demanding character (eg. at least 85% of connections).
- Continuously measure all connections of all carriers.
- Regularly evaluate the entire network and individual sections - one of the bases for priority measures.

The punctuality and regularity of operation, in addition to contributing to the quality and reliability of public transport, is also an important factor influencing the organization of operation. Data on the punctuality and regularity of operation can be used in the following activities:

- dimensioning of transport capacity of lines (the higher the punctuality of operation, the lower the reserve in case of fluctuation of demand we need),
- determination of the line interval (the shorter the line interval we determine, the higher the punctuality of the operation we need to achieve),
- solution of time continuity of line connections at transfer points (the higher punctuality of operation we achieve, the tighter time continuity we can set up and thus achieve less passenger delay).

4.4.7 Operational Traffic Management

The analysis showed that the public transport system does not have a central dispatching centre that would operatively coordinate the operation of all public transport lines and connections in the city.

Quality operational traffic management increases the reliability and quality of the public transport system. It makes it possible to deal with extraordinary events in transport and to replace traffic outages to specific sub-sections of the network, regardless of the carrier, type of transport or transport subsystem. It also enables the coordination and solution of transfers with controlled continuity and increase the reliability of transfers with uncontrolled continuity.

We propose the following measures to increase the possibilities of operational traffic management.

- Fusion of urban transport companies (PUA and RTEC) into one. This will simplify day-to-day processes and increase the interconnection of both modes of transport with comparable transport capacity.
- Establishment of a central control room for public transport, at least for trolleybuses and buses (ideally also for coaches). The central control room will enable:
  - for a more operational solution to emergencies,
  - a more operational emergency replacement of trolleybuses by buses if necessary,
  - on raising the awareness of operating personnel from both modes of transport about the actual situation in the network,
  - on the control of time succesions among trolleybuses and buses,
  - centralized data acquisition (from GPS, smart cards, etc.) and their evaluation.
- Replacement of dispatching stations at terminals by an automatic dispatching control system (with the possibility of monitoring departures from terminals electronically from the central control room).

4.4.8 Tariff System

The analysis showed that there is no uniform tariff system for public transport in Chisinau. Each mode of transport and each carrier has its own tariff system. This is very disadvantageous for both the municipality and the passengers.

The non-uniform tariff system does not allow the municipality to effectively manage the tariff policy and to introduce measures of indirect public transport priority through the tariff system. At the same time, the non-uniform check-in system does not allow for the systematic collection of data for the purpose of their subsequent evaluation. These data are an important source of information needed for the organization of public transport (it can provide information on the total number of transported passengers, demand for transport in individual transport streams, time distribution of demand, turnover of passengers at individual stops, etc.). The non-uniform tariff system is disadvantageous for passengers, as it does not allow for an efficient combination of different modes of transport, regardless of the carrier. This significantly complicates and makes the use of public transport more expensive and is a significantly demotivating element. The non-uniform tariff system significantly reduces the competitiveness of public transport compared to individual transport. Special attention should be paid to the reorganization of the tariff and check-in system and should be given the highest priority among all measures. We therefore provide a more comprehensive explanation of the principles with good examples from practice.

Opportunity for Interconnection of modern technologies for PtP zones and public transport dispatch

However, the possibility of using a smart (chip) card should be even more universal and not limited to the parking matter. The features of the smart (chip) card could be suitably used for other industries that are widely affected by citizens and tourists in the territory of the Capital City of Chisinau, mainly public transport dispatching and paying fares.

Major integrated transport systems principles in the Czech Republic

Brno

Integrated Transport System of the South Moravian Region (IDS JMK)

The Integrated Transport System of the South Moravian Region (IDS JMK) provides public transport in a comprehensive area in which several modes of transport cooperate. Passengers are offered a system of interconnected lines with a uniform tariff, transport conditions and regular intervals. IDS JMK includes trams, trolleybuses, trains, city and suburban bus lines and ferries on the Brno Dam (see fig. 4.4.2).

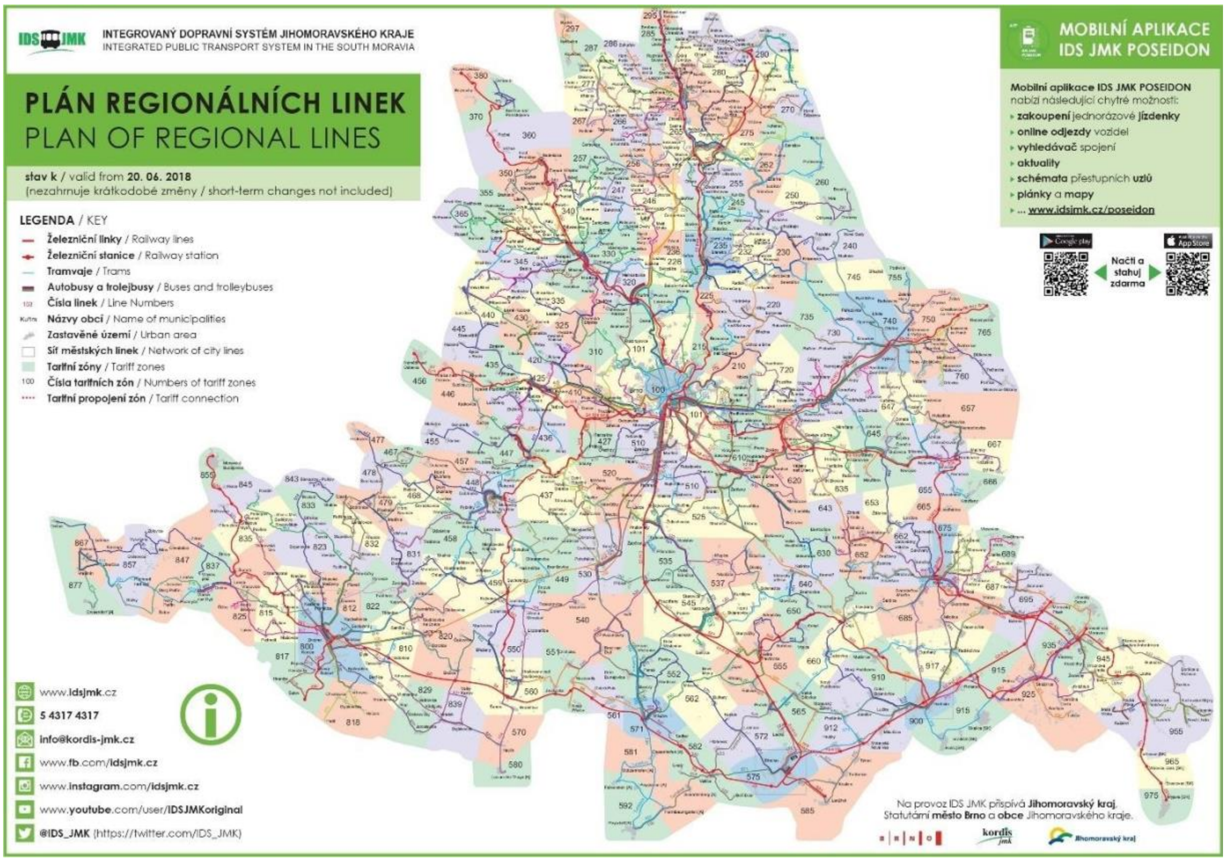


Figure 4.4.2: Line routing and zoning plan of IDS JMK (see https://www.idsjmk.cz/mapa/Plan-site-celek.pdf)

The whole system has been created in individual stages with the aim of its implementation throughout the whole region. The first stage was launched on 1st January 2004, when the system included 110 municipalities in the South Moravian Region, including public transport in Brno and Blansko, and one municipality each from the Olomouc and Vysočina regions. A year later, 112 municipalities were joined by another 73 municipalities integrated in the 2nd stage, which covered the Tišnov, Sokolnice and Zbraslav regions. Between 11 December 2005 and 1 September 2006, another 72 municipalities in the Slavkov, Bučovice, Vyškov, Ivančice and Židlochovice regions were included in the system as part of the 3rd stage. This stage took place together with changes in the management of regional bus lines, to simplify and streamline transport and to introduce a single fare. The lines were renumbered to a uniform operating designation and the new timetables were introduced, together with unified fare and transport conditions. From March 4, 2007, Boskovice and Náměšť nad Oslavou were included (4th stage), later supplemented by a part of Kyjov region. From December 14, 2008, the 5th stage extend IDS JMK to the Břeclav, Hodonín, Kyjov, Hustopeče and Veselsko regions. As of 1 July 2010, the last stage integrated the last part of the South Moravian Region in the Znojmo surroundings with 163 municipalities. So far, the last integrated city line was the line to Bystřice nad Pernštejnem marked with the number 370.

The above changes were caused by the ambiguity and uneconomicity of the original system condition. Due to the growing number of transport companies and the growing confusion about timetables and different prices, passengers were disoriented. Passengers then preferred to choose a car as a form of transport, which had a negative impact on the environment, but also on the operation of public transport. This results in a reduction of the number of passengers, which leads to a price increase for those who do not have a choice between individual car and public transport. The introduction of an integrated transport system should result in a simpler system with regular services and a uniform fare.

The integrated transport system of the South Moravian Region includes the entire territory and all inhabitants of the South Moravian Region. Passengers can thus use all tram, trolleybus and bus lines included in the IDS JMK, including passenger and selected express trains in the tariff-integrated sections of Czech Railways tracks. The territory of the region is therefore divided into so-called tariff zones. The IDS JMK has two tariff types, zone or time based.

Internet and mobile application Poseidon

The main advantage of IDS JMK is the Poseidon application, which is the official application of KORDIS JMK, a.s. (coordinator of the Integrated Transport System of the South Moravian Region). This application was created in order to provide information about IDS JMK and for the sale of the entire range of one-time and one-day IDS JMK tickets valid in all means of public transport included in IDS JMK. The easy purchase of a ticket is linked to the necessary information for traveling in South Moravia, such as current departures from the nearest stops, valid timetables (even in the off-line version) and a map with the location of the nearest stops together with the departures. Poseidon is designed primarily for mobile phones with permanent access to mobile data, both for the Android platform and iOS (Windows version is not supported due to the minimum number of users).

The application allows the user to deposit funds into his virtual account via a bank account and then buys more cost-effective tickets than at physical selling points (at sellers, a vending machine or by a driver in a vehicle). After the purchase, the ticket is paid from the credit of the user's account, which can be topped up by bank transfer. The purchased ticket is then valid 5 minutes after purchase for train connections and 2 minutes for other means of transport in all IDS JMK zones, in public transport, on trains and in regional buses. When buying again, you can save your favourite ticket and the next time you can buy it, you can buy it using just 2 clicks. There are two types of tickets - either you can buy a ticket for a specific route, or a so-called fast ticket, which is valid given number of zones (both types will cost the same). Tickets in the Poseidon application can also be purchased in groups, for up to 10 passengers at a time.

After launching the application, the user is taken to the home screen (see fig. 4.4.3), which is set to search for a connection. In the main menu (see fig. 32) you can choose from the following:

- current situation:
  - information on the current traffic situation and a table of lines indicating the situation
  - delays are divided into three colours - green (line without delay), yellow (line with a larger number of delayed connections) and red (line with a large number of delayed connections)
  - by clicking on a specific line, the information will be displayed, i.e. current location and delay rate
- search for a connection - the option to search for a connection and buy a ticket
- departures - displays the earliest departures from nearby stops (displays the name of the stop, the line number and its direction, remaining time until the time of departure and a note if the vehicle is barrier-free)
- timetables - a table of timetables in * .pdf format (off line version also available after downloading for viewing even without an internet connection, which reduces time to display)
- plans - schemes and plans of lines in the entire South Moravian Region (again, available off-line)

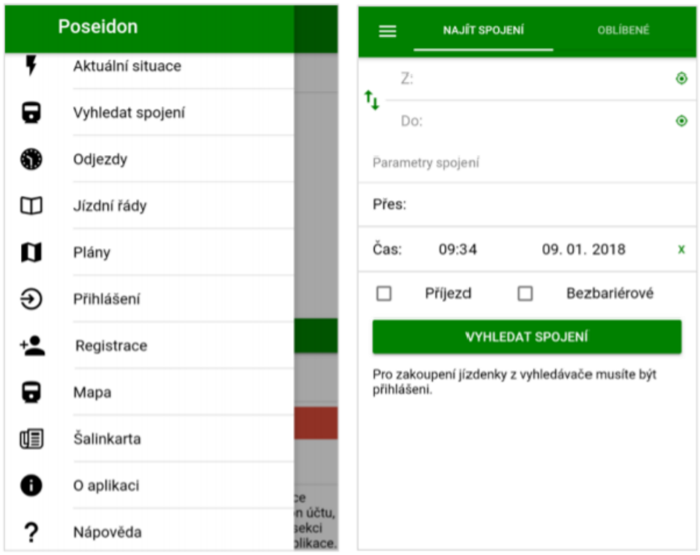


Figure 4.4.3: Home screen and main menu of Poseidon mobile app (see https://www.idsjmk.cz/idsjmkposeidon/manual.pdf)

- login + registration - the application can be used without registration, but it is not possible to buy tickets
- map - launch of the IRIS application showing the current position of all vehicles in the IDS JMK system (the position of the vehicles is transmitted using the CEDRIS and RIS traffic controlling and is updated approximately every 20 s)
- šalinkarta - for holders of electronic prepaid IDS JMK tickets for zones 100 + 101
  - displays a QR code for fast dispatching in trains and regional buses by drivers

<u>Prague</u>

Prague Integrated Transport (PID)

Prague has an extensive transport infrastructure, the main transport hub of public transport is the railway, but it is also the centre of long-distance and regional bus transport. Prague Integrated Transport (PID) includes backbone metro lines, tram and bus lines, the cable car to Petřín, the cable car at the Prague Zoo in Troja, railway lines and some ferries on the Vltava river. The system is gradually being unified with common transport and tariff conditions and a uniform transport solution (including coordination of timetables). It is gradually developing in the Capital City of Prague, in the former districts of Prague - East and Prague - West, including several former districts in the Central Bohemian Region with an emphasis on time, price, comfort, reliability and safety. The basic principle of PID is the preference of backbone rail transport, ie railways, metro and trams, with follow-up bus transport. The prerequisite is to enable the combination of passenger car transport with public transport in the form of P + R retaining car parks and places for short-term K + R stops (these are intended for carpooling, when the driver transports another person or persons to the public transport transfer). Another initial principle is a uniform tariff system enabling transfers, thanks to which the journey can be made on a single ticket, regardless of the selected mode of transport. This aims to the goal of preserving the necessary economic efficiency of operation while maintaining transport coordination and cooperation.

The tariff in Prague is zone and time based. The total number of zones in the territory of Prague is 4 (for the scheme of using tariff zones, see fig. 4.4.4):

- dual zone P (centre)
    - dual zone P is the largest within the PID and passengers in it can use not only train and bus connections, as in case of rest of the PID in the Central Bohemian Region, but also the metro, trams, cable cars and ferries
- zone 0 (area adjacent to the city centre) and zone B (suburban areas)
    - zones 0 and B include suburban bus lines and parts of railway lines in the territory of the Capital City of Prague
- in the Central Bohemian Region there are tariff zones 1–7 and form almost regular rings around Prague (see fig. 4.4.5)

Passengers must always have a valid travel document for all fare zones that they pass during their journey.

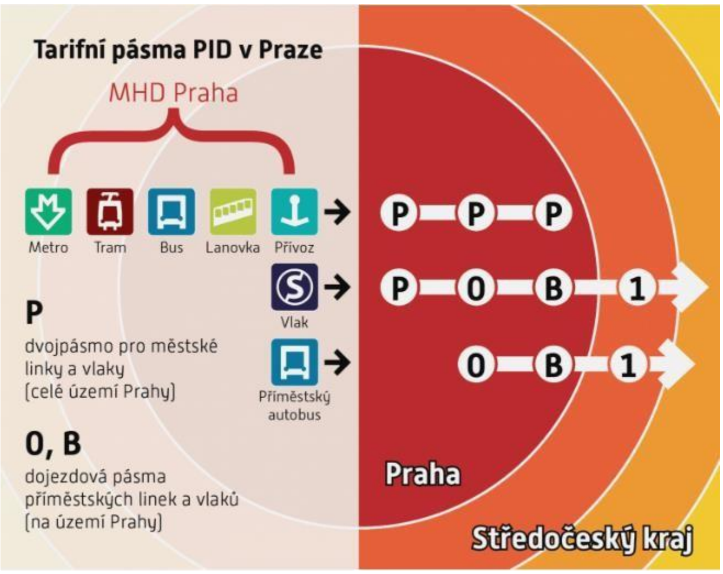


Figure 4.4.4: Princip fungování tarifních pásem PID (viz https://pid.cz/tarifni-pojmy/tarifni-pasma-pid/)

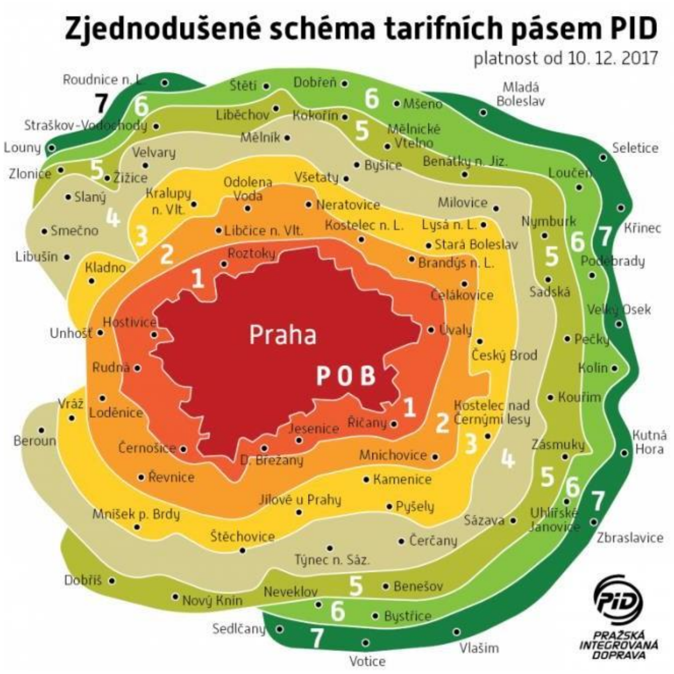


Figure 4.4.5: PID Tariff zones in the Central Bohemian Region (see https://pid.cz/tarifni-pojmy/tarifni-pasma-pid/)

Contactless chip card „Lítačka“

At present, a contactless chip card called Lítačka works for traveling throughout Prague. This card has been issued by the City of Prague since March 1, 2016 as the storage of all electronic coupons. The card replaced the original Opencard card (these are no longer issued and their use will end completely in 2020). In addition to carrying an electronic ticket, Lítačka also serves as a pass to the Municipal Library in Prague and the National Technical Library. The card does not allow use for a tourists, it can't be charged with a credit for a short time usage, for example, for public transport or admission. It serves only to residents or very regular visitors of Prague.

Figure 4.4.6: Contactless fare payment in tram in Prague (see https://smartprague.eu/projekty/bezkontaktni-platba-jizdneho)

In 2018, the function of the Lítačka should be extended to a user-friendly carrier, which also includes payment or partner cards (eg InKarta). This will support the joint integration and unification of dispatching rules in the territory of Prague and the Central Bohemian Region, which includes an e-shop for the purchase and management of travel documents without the need for a physical visit. The Lítačka city card should also be one possibility for the payment of parking fees (among other things, the Moje Praha mobile application is being developed, which will be connected to the Lítačka card virtual account). The map interface of the Moje Praha application already enables monitoring of P + R retaining car park capacities and navigation to a selected car park. This payment gateway will be used at P + R Letňans as a pilot trial. The benefit of this project should be to increase the comfort for P + R car park users and speed up their check-in. The system settings will allow the user to choose whether the payment for the given license plate should be manually confirmed every time or withdrawn automatically online after the end of parking. The payment will be made via the virtual account of the Lítačka card, which will be connected to the payment system.

This will ensure the simplicity of the system - the user will not have to re-enter the required information such as license plate and identification of the payment card to make the payment. At the same time, the transport company is preparing a modern form of fare payment through validators in trams, which will enable contactless payment (see fig. 4.4.6). This form of payment offers greater comfort to passengers when dispatching. Passengers will have the opportunity to upload the coupon to the Visa and MasterCard payment cards and pay with them contactlessly in the vehicles via validators.

Smart solutions in public transport in the Czech Republic

Kolín – smart keychain

Figure 4.4.7: Smart keychain for pupils of 6th Primary School in Kolín
(see http://www.kolin.cz/chytra-klicenka-bude-rozsirena-do-vsech-zakladnich-skol-v-koline)

An interesting project was created in the leading Czech city of Kolín, which is unique both in the Czech Republic and in Central Europe. The city s trying to implement modern technology into he urban ecosystem that works in the city. The smart keychain is a pilot project of the 6th Primary School in Kolín (fig. 4.4.7), where pupils attending this institute will be the first to test it in he school year 2018/2019. The distribution of he smart keychain was procured free of charge by the primary school itself (it is currently not possible to purchase this keychain by anyone else). The holders of the keychain will be the parents (legal representatives) of the studying pupils, who will provide it to the pupils for use.

The keychain has form of a plastic card, which intended to replace all the necessary cards, chips and keys to the lockers that each student uses in everyday activities. It is a functional tool that is able to unify all identification, access and payment cards, including a reader's card to the Kolín Municipal Library. It can therefore serve as both access and prepaid card.

Smart keychain features:

- reader's card for the Kolín Municipal Library
- chip for ordering, paying and dispensing lunches in the school canteen (replacement of the card with a barcode that is currently used)
- access to the bike storage and gym at the school
- prepaid coupon for Kolín public transport
  - in the case of occasional visits, it can also be used as a card with prepaid credit for the purchase of single tickets
- prepaid payment card
- opening of school electronic locks
- personal health book (electronic book that is accessible via Internet)

The task of the keychain is, in addition to simplifying everyday life, also to minimize the probability of losing or forgetting the necessary belongings associated with school activity, as they are all integrated into one. As a bonus, it introduces children to contactless payments and thus cashless payments. The keychain can be used as a prepaid Mastercard for receiving the pocket money, the transaction can be later verified online by the parents in the keychain transactions history. It is also possible to inform about the payment by SMFutureure vision is to prevent payments indecent to children and young people, such as the purchase of tobacco and alcohol, and to educate pupils on "Financial Literacy" etc.

Figure 4.4.8: Terminal in DPO vehicles – home screen (see http://www.buspress.eu/ostrava-spousti-nejmodernejsi-evropsky-system-placeni-v-mhd/)

Ostrava – the most modern payment system in public transport

Ostrava prevailed in the autumn of 2017 during the Smart Town Hall competition, which aimed to inspire and motivate municipalities to develop the smart cities concept. There were several project categories in the competition and Ostrava Transportation Company (DPO) won in the Public Transport category. DPO, in cooperation with Visa Europe, ODIS Coordinator, ČSOV, XT-Card and Mikroelektronika, broke through with a new option to pay in public transport. It is a contactless payment by bank card without the need for a paper ticket, this has been applied in Ostrava as in the second European city (for the first time in Europe, this system appeared in London). From 30th of June 2017, passengers have the option of purchasing a fare via the ODISka contactless payment card at the terminals (see fig. 4.4.8 and fig. 4.4.9), placed in all DPO vehicles. This is a breakthrough solution, thanks to which passengers will not have to carry cash with them, and they will not even have to find out in advance which type of ticket to buy for the trip:

- the passenger encloses the card to the terminal, which is at least one at each door, when boarding and then exiting the vehicle, and the intelligent system evaluates and calculates the optimal fare
- the fare is determined on the basis of transfers and time spent in the vehicles (if, for example, the passenger would use public transport throughout the day and the sum of individual tickets would exceed the value of 24-hour ticket, the system automatically charges a cheaper option)

It is therefore a fully automated system, in which the passenger does not choose between the tariffs or does not keep the paper travel document, all you have to do is enclose a payment card. The entire contactless payment system thus works with an electronic ticket, thanks to which passengers spare.

Figure 4.4.9: Terminal in DPO vehicles – card enclosure when exiting (see http://www.buspress.eu/ostrava-spousti-nejmodernejsi-evropsky-system-placeni-v-mhd/)

The dispatching system offers not only the convenience of obtaining a travel document, but also the security and protection of personal data. Communication with the bank is encrypted, personal data is not stored and he username or bank card number is not kept anywhere. After enclosing, the validator first evaluates whether there is enough credit on he card to perform the ride or whether the card is not blocked (see fig. 4.4.11), and then sends the information to the issuing bank.

Each user has the opportunity to register on he Internet interface, where, among other hings, they can print a tax document or esolve complaints. During the ticket nspector's check, the validators are switched o the ticket inspection mode (see fig. 4.4.10). f the passenger is asked to attach a card to he validator during the check, the inspector will see a list of registered enclosures of that card.

Figure 4.4.10: Terminal in DPO vehicles – ticket inspection mode (see http://www.buspress.eu/ostrava-spousti-nejmodernejsi-evropsky-system-placeni-v-mhd/)

Figure 4.4.11: Terminal in DPO vehicles – credit card evidence (see http://www.buspress.eu/ostrava-spousti-nejmodernejsi-evropsky-system-placeni-v-mhd/)

In addition to payment contactless card payment with constantly rising popularity, Ostrava has, for example, stops with an Internet Wi-Fi signal, technology damping noise and vibration from rail vehicles and SmogAlarm, which is used to determine the current state of the air.

Děčín – DPMD smart card

Within the framework of the smart cities concept, a smart DPMD card (Transport Company of the City of Děčín) was introduced in Děčín, as part of the innovation of passenger dispatching in public transport. The DPMD smart card (see fig. 4.4.12) serves as a contactless prepaid card, which can be used in the same way as a standard card in stores and on the Internet in the Visa network, but it is also possible to upload a coupon according to the DPMD tariff. The user charges a credit to the card from which he can later draw. Ownership of a bank account is not a condition, and thanks to this, even a person under 15 can buy a smart card. It can therefore be used to purchase a ticket in a vehicles, but also to assign a time coupon. Apart from DPMD vehicles, the smart card can be used in vehicles throughout the Czech Republic if they have a terminal for contactless payment. If the form of the payment card does not suit some passenger, it is possible to purchase a payment bracelet (see fig. 4.4.12). Checking the card report is enabled via the Internet interface.

Figure 4.4.12: DPMD Smart Card and Smart Bracelet (see https://www.matehromaduduvodu.cz/decin)

<u>*Opted foreign solutions for dispatching and tariff policy in public transport*</u>

Dispatching system „check-in / check-out“

All of the mentioned solutions for dispatching and tariff policy in the public transport (Singapore, Malaysia, Dubai) are a check-in / check-out check-in system. For this type of dispatch, the passenger logs in and out using a chip card on which the financial amount is prepaid (the principle of dispatch is therefore similar to the system operating in Ostrava - see Chapter on the side 67 for more details). A chip card check-in terminal is installed nearby all doors in the vehicle, at which the passenger is obliged to enclose a travel document upon boarding and subsequently on exit. The system then calculates the fare based on the transport work performed, i.e. it determines the fare according to the distance between the start and end stop. A necessity without which the journey cannot be realized is that the credit balance on the card is at least such that it is possible to purchase at least a single fare to the final station of the line to which the passenger enters.

The system will charge the passenger the fare to the final station, unless they check out when leaving the vehicle, which serves as motivation for proper check-out. Checking out of a vehicle can be considered as "harassment" of a passenger, but in fact it has the advantage of replacing traffic surveys. When passengers are motivated to perform a "check-out", the operator, resp. the city receives precise and above all real information about the movement of passengers.

<u>Singapur – prepaid contactless smart cards</u>

Singapore Mass Rapid Transit (SMRT) is a leading provider of public transport services in the city-state of Singapore. The backbone network consists of rail systems with the addition of bus lines and taxi services, thus fully integrating public transport. The following is used for public transport:

- EZ-Link contactless chip card
- NETS FlashPay contactless chip card
- single or return contactless chip card

The tariff of the electronic coupon is based on transport volume, ie. the final fare is determined by the distance between the start and end stations.

The NETS FlashPay card can be used to pay fees for public transport services (rail and bus), for payments for goods and services at selected merchants, for payments of electronic tolls and electronically paid parking lots. The credit can be loaded on this card via ticket machines (see fig. 4.4.13), special payment terminals, ATMs, at the branches of the transport company SMRT, at selected merchants or online. In addition to the prepaid credit system, passengers can also choose a prepaid monthly tariff for unlimited travel by public transport.

Figure 4.4.13: Ticket machines at Singapore subway stations where passengers can buy a "Standard Ticket" or charge credit to an EZ-Link card or NETS FlashPay card (see https://en.wikipedia.org/wiki/File:Cg1_expo_GTM.jpg)

There is also the option of a "Standard ticket" as well in the form of a contactless chip card that can be used for a single or return journey. When purchasing a Standard Ticket, the passenger pays a deposit, which is non-refundable if he / she does not use the coupon at least 3 times (maximum use is 6 trips within 30 days). This type of passenger fare is more expensive than a prepaid chip card, even if the same distance is covered.

For tourists, Singapore has a special contactless chip card, which the visitor charges with credit and in case the deposit is not used up, it will be returned to him within 5 days of issue.

In case of usage bus transport in connection with a metro journey, the passenger receives a discount on the fare, in which the fare for the bus is reduced.

Malaysia – universal prepaid chip card "Touch‘ n ‘Go"

In Malaysia, a prepaid “Touch‘ n Go ”chip card of the credit card size using contactless technology entered operation a few years ago. The user uses login ID and password to register online, and thus he has the opportunity to monitor all his registered cards and devices on his account. Of course, you can also view e-records, discounts, but also the history of transactions. This is a prepaid electronic card on which the user can charge a financial amount. This significantly increases the customer's comfort, as it reduces the need to carry cash. Therefore, if the user has a sufficiently large financial amount prepaid on the card, all you have to do is enclose the card to the terminal.

Using the "Touch‘ n ‘Go" card:

- when paying at merchants
  - in selected stands, restaurants and cafes, in shops, pharmacies and health stores, in entertainment centres, in hotels
- when paying for parking
  - - it is enough to have sufficient credit on the card to enter and exit selected car parks (in selected hospitals, shopping centres, airports, hotels, tourist places, shopping malls, street networks)
- when paying for public transport
  - Since 2002, 'Touch' n 'Go' has operated as a common cashless fare system for all rail and bus public transport routes in the Klang Valley (which is de facto the wider metropolitan area of the Kuala Lumpur agglomeration), where passengers can benefit from performance set tariff
- for the toll system on motorways and roads
  - the "Touch‘ n ‘Go" card can be used as the only electronic payment system on all Malaysian motorways marked TnG and roads marked SmartTAG (see fig. 4.4.14)
  - instead of manually issued tickets, 2 methods of toll collection were introduced - open and closed
  - in the case of an open system, the user must report to the toll gate by enclosing a card and the charged tariff is fixed regardless of the distance travelled
  - in the case of a closed system, users log in before entering the paid part and log out at the exit from the toll system, i.e. they are charged a fee based on the distance travelled in the entire paid section

Figure 4.4.14: Highway toll gate in Malaysia using a universal prepaid chip card „Touch 'n' Go"
(https://www.comparehero.my/blog/use-touch-n-go-card)

<u>*Dubai – 4 types of contactless chip cards "Nol"*</u>

In Dubai public transport, the contactless chip card "Nol" sized as a credit card has several functions. This is a prepaid card that the user can use for public transport fares and also parking payment. In public transport, it can be used on the Dubai Metro, trams and water and conventional buses, There is a travel volume fare everywhere, which means that passengers (as in Singapore and Kuala Lumpur) pay accordingly to the distance travelled between the start and end stops. Passengers dispatch at check-in and check-out again by inserting the card into the terminal. The system automatically calculates the cost of the trip, which it deducts from the credit on the card. The credit on the card must be prepaid before it can be used, which can be done online or at a ticket machine or sales office of the public transport operator. Users of "Nol" cards are charged a lower fare for public transport than passengers with paper tickets, which are still "surviving" here. The card can also be used to pay for a taxi (if they support the system). There are 4 types of "Nol" cards (see fig. 4.4.15):

Figure 4.4.15: Four types of contactless chip cards "Nol" used in Dubai
(see https://www.transportdesign.com/work/noltravelcard&id=172)

- red (anonymous)
  - for occasional passengers who can purchase the card any time in the vending machine
  - it can be charged to up to 10 individual rides
  - the card can be limited to a specific means of transport, i.e. only metro, bus, ... etc.
  - it is not possible to use the card to pay for parking
- silver (anonymous)
  - this card works as an electronic wallet, for which an amount up to approximately 30,000 CZK can be prepaid
  - the passenger may use the card in any means of transport within the integrated transport system
- gold (anonymous)
  - this card has the same functions as the silver card, but offers the holder privileged access to the so-called "Golden Avenue" of the metro
- personal (individual)
  - this type of card works similarly to a silver card with the difference that it contains identification data and a photo of the owner, so in case of loss or theft, a specific card can be blocked without losing prepaid credit (this card has about three times higher acquisition value compared to a silver card)

4.4.9 Proposal of Measures for Chisinau

Establishment of an Organizational Authority

The first step in the transformation of the entire public transport system should be the establishment of an organizational authority (ITS coordinator) and the establishment of a three-tier model of the ITS organization (see Chapter 4.4.1).

Processing of ITS Quality Standards

The organizational authority should define the basic quality standards of ITS, including the level of their complexity, and set deadlines in view of the real possibilities, when the required fulfillment of the proposed quality standards should be achieved. For example, in the case of vehicle equipment requirements, compliance with the relevant standard may apply to newly placed vehicles in service.

Introduction of a Uniform Tariff System

Appropriately set tariff system significantly contributes to the economy of operation and the attractiveness of the system for passengers. It is one of the basic tools of the indirect priority for public transport. We recommend the following adjustments:

- Introduction of a uniform tariff system for all modes of public transport and all carriers:
  - uniform types of tickets valid in all means of transport,
  - on the introduction of a time zone tariff in combination with a distance tariff,
  - to conceive all types of travel documents as transfer (even short-term tickets).
- Emphasis on subscription time tariff:
  - is the most motivating for using public transport,
  - is the safest and fastest fare income.

- Gradual increase of fares to the level of 25% of operating costs (eg. at annual intervals):
    - in accordance with social policy,
    - tactically compensate for the increase in price by always introducing an advantage (for example, a single ticket, then a transfer ticket for an individual trip, subscription for a longer period of time with a progressive discount, etc.).
- Supervising of compliance with tariff discipline not only by inspectors, but also by conscious public (for example, by means of an associated smart card function).

Inclusion of the Railway Line into the ITS

Next crucial step is the integration of the railway line into the ITS. Inclusion should take place in these basic partial steps:

- modernization of the railway infrastructure so as to enable the operation of electrical units with a high frequency of traffic (interval approx. 10 minutes),
- introduction of an intra-city line in the section Straseni - Parc Revaca (ideally the line should be supplemented by other connections from the region),
- gradual construction of interchanges at stations and stops of the railway line,
- construction of a transfer to the airport (relocation of railway section).

Change of Directional Coordination of PT Lines

Introduction of a structured heterogeneous system. Connect to the backbone railway line in the built transfer nodes backbone trolleybus lines running along the main roads (arteries, collectors) in radial and diametrical directions. The supplementary bus and minibus lines in city-wide tangential directions connecting at least two backbone lines, or in local radial or diametrical directions (backbone line feeders) join to the backbone lines (railway and trolleybus). Directional guidance and time coordination of individual lines should be based on the principles described in chapter 4.4.2. The basis for determining the intervals should be the interval of the backbone lines, the basic value of which we recommend setting to 10 minutes.

Public Transport Priority

In order for the priority measures to have a quick effect on as large a group of passengers as possible, we recommend setting them up preferentially on the routes of the backbone trolleybus lines, primarily those that will serve P + R car parks during their route. We recommend gradually setting up P + R car parks on the territory of Chisinau either directly in terminals at railway stations and stops, or in terminals at stops of backbone trolleybus lines with PT priority. Only fast and reliable public transport lines (consequently time-competitive) can be an incentive for citizens to use a combination of individual and public transport when traveling between the capital and the surrounding region.

Based on the experience with the gradual introduction of priority measures in Prague, the most effective is the combination of reserved bus lanes with subsequent dynamic control of traffic lights with phase priority for public transport vehicles. However, the establishment of reserved bus lanes can be significantly accelerated before the modernization of traffic lights, as the establishment of reserved bus lanes is significantly cheaper. PT priority can be supplemented even in less exposed places by organizing traffic at intersections without traffic lights by marking the main road (driving advantages) in the direction of the highest frequency of public transport.

4.5 Active Mobility Pillar

4.5.1 Adequate development of cycling infrastructure, safe corridors for cyclists and pedestrians

In the first phase, the city should focus primarily on completing a safe corridor for cyclists, and also a safe corridor for pedestrians (however, the issue of pedestrian safety is related to the goal of rehabilitating high-risk sites with regard to road safety). As part of the survey on the state of cycling infrastructure, a target state was proposed, among other things, to fill in places where adequate corridors for cyclists are missing (see figure below). This proposal complements the network of corridors for cyclists, where as the first step the city must schedule the phasing. Completion of this proposed network will ensure high-quality interconnections of all major transport cycling relationships (inner-city and wider).

Quality and safe corridors for cycling and walking are absolutely crucial in terms of promoting a healthy lifestyle. After the construction of adequate infrastructure, it is possible to focus on other activities related to the support of these modes of transport in order to make a more suitable transport modal split and reduce the share of passenger cars and this reduce environmental impacts and safety in public space.

As already mentioned, the existing network of bicycle roads in the city of Chișinău is not sufficiently interconnected and does not connect some important parts of the city. The city's priority should clearly be the completion of the backbone cycle paths. The current situation in Chișinău does not yet allow for full competition between bicycle traffic and passenger car traffic.

If building a dense network of quality and safe bicycle roads in Chișinău will be successful, then it is possible to see at least four impacts of this effect:

a) Perspective of mobility and transport in the area (safety – transport sesort):

It will make better use of the potential of cycling. The new paths will contribute to greater use of bicycles on everyday journeys for work, school, shopping, services or leisure activities. In addition, cyclists do not have such a problem with finding parking spaces, traffic collapses or congestion.

b) Perspective of cycling tourism in the area (tourism and leisure – local development resort):

The cycling market will bring a much-needed alternative and sustainable development of tourism, which is suitable for slowing down the pace and increasing the intensity of tourist experiences. Cycling support will provide job opportunities in various service areas around cycling.

c) Health perspective (active movement – health resort):

Half an hour's drive every day of the week is an excellent prevention against diseases of our civilization. Lack of exercise is just one of the main risk factors for cardiovascular diseases. The health benefits of regular physical activity can be summarized as follows: 50% reduction in the risk of coronary heart disease (i.e. a similar effect to non-smoking), 50% reduction in the risk of adult diabetes, 50% reduction in the risk of obesity, 30% reduction in the risk of hypertension.

d) Environmental perspective (environmental dimension – environmental resort):

A safe network of bicycle roads will automatically attract new cyclists, and this will have a positive impact on our environment. There is no pollution by exhaust gases during bicycle ride, while pollution by these gases from motor transport has increased in recent years (on the contrary, it has decreased for stationary sources). Increasing the share of bicycle traffic indirectly reduces noise in the area.

The construction of cycle paths without wider transport links should be exceptional and well justified. Also, a single section of a cycling route may not always be wrong, when there is a desired local traffic segregation for certain reasons. In practice, it is used, for example, in dangerous places or sections of otherwise safe roads.

For cycling infrastructure to grow and to be used, it must be continuous, direct, attractive, safe and comfortable.

Measures leading to the creation of a coherent road network for cycling must include the integration of cycling and public transport.

Cycling infrastructure segregated from other modes of transport is used by existing cyclists if it has at least the same direct connection and is attractive and saves time over other means of transport. Short connections, such as two-way traffic on one-way streets or access for cyclists where individual car traffic is prohibited, are therefore of great importance. Segregated routes are also suitable where they save time and avoid places with potential congestion.

Supporting alternative transport modes is a part of topics that are generally dealt with as a part of sustainable urban mobility plans. There is a growing demand for expansion of bicycle transport, whose utilization is currently insufficient.

Before the proposal of compart bicycle route network, safety inspection was made. This inspection divided dangerous localities according to the level of seriousness to three levels (see table 4.5.1). Evaluation of the dangerousness eases decision making for the administrator responsible for these routes on if and which problematic places to deal with, or in which order.

Table 4.5.1: Levels of risk and their characteristics.

Level of risk	Characteristics
High risk	If high risk is not going to be removed, there is a high probability of traffic accidents with health consequences. For example dangerous intersection, where important bicycle route cross themselves, intersections with high average daily traffic volumes etc.
Medium risk	Medium risk influences accidents with health consequences. For example improved conditions for easier orientation before continuing route.
Low risk	Low risk influences collision situations or increases subjective risk of road users.

4.5.2 Bike sharing

Bike sharing is a self-service system for short-term bike rental in public areas. This service for multiple target groups with network features allows one-way rent, which means users do not have to return the bike to the same location. Climate and the share of cycling in modal split are the main factors that determine the appropriate scale and which bike sharing system will be chosen. If individual cycle routes and cycle paths will be connected in Chisinau, this system could work.

One of bike sharing options is having fixed stations for bicycles, which requires a very carefully planned location of bike stations. Especially when it comes to large stations, which require earthworks.

Alternative solution is the concept of mobile stations. A flexible station means that users can leave bikes on the main nodes and inform the program, where they locked the bike. With the GPS bike tracking system, it is possible to automatically track the position of all bikes. The Rekola system in Prague and other cities is based on a similar principle. To rent a bike, you just need internet connection on your phone and quick registration for free. You enter the bicycle number into the application and you will immediately receive a code to open the lock. You then lock the bike in any of the pink areas marked in the app and mark it as returned. This idea has been working for 5 years.

Thanks to integration of bike sharing with other services, costs can be saved and at the same time attractiveness of the system can be increased.

Bike sharing in Chisinau has not been implemented up to this date. There have been some bike rentals, but these are too small and unorganized to consider. If bike sharing will be set up in the near future in Chisinau it is best to follow the examples of more developed cities. Some things to consider at planning stage:

- Bike sharing stations should be stationed in different areas of the city in order to facilitate commute and in this sense, further study and analysis is required so as to detect the most often used routes for work-commute by city dwellers; further study is required to understand how many of these work-commuters would be ready to switch from car to bike or from public transport to bike; this data collected should prove essential in choosing the locations for bike sharing stations.
- Bike sharing that will focus on leisure, could be set up at park entrances, but this would encourage people to use them just inside the parks. Later on, when parks are transformed into green corridors or transit bike lanes for commuters, there bike sharing stations may either be left there to be used by commuters or removed and installed in other places.
- Bike sharing need to function in conjunction with public transport. Ideally people that use bike sharing would also be bus/trolleybus users and in this case payment for bike sharing could integrated into the e-ticketing system so that users can make payments using the same platform. In order to prove the need for this integration, further study and analysis are needed and data would need to be gathered if there is such need from the city dwellers. If, not enough people need this service, the integration may not be worth doing from a technical and financial point of view.

- Bike sharing is weather sensitive and in case of snowy winters, the authorities must consider either removing the bikes from the stations altogether or finding a way to ensure that the snow is cleared from these stations and the bikes are ready-to-use. If a public-private partnership is concluded, this must be taken into account and it must be made a separate contractual clause.
- Collaborations must be sought between the authorities and companies. If several big employees' companies (i.e. Endava, Kentfort Complex, SkyTower complex, etc.) wish to contribute to the enlargement of the bike-sharing networks, the authorities must give these companies a chance to do it. The companies that wish to set up their own bike-parking and bike-sharing stations must be assisted and the administrative procedure for them doing so must be simplified. This would encourage more companies to become green-friendly and to freely pursue carbon-footprint reduction. This is especially relevant for big companies like Orange, that are subsidiaries of other EU and international companies.

Applications of bike sharing abroad:

France - Paris

Millions of kilometers are traveled daily on shared bikes. Vélo´v in Lyon, France, shows that bicycles replace 7% of trips for which cars would be otherwise likely used. With the start of the project, the number of bicycle rides increased by 70%. The system is based on information technology, where users identify themselves using smart cards.
Redistribution among bicycle stations is necessary in all fixed site systems and can generate significant costs and emissions. In Paris, for example, the redistribution of bicycles in the city is open 24 hours a day, but even so, the sites on the outskirts of the city are quickly empty after replenishing bicycles. Customer dissatisfaction can be balanced by providing information about the location of bicycles in his immediate vicinity. Another option is to provide another ride for free if the station is full.

Netherlands - Utrecht

In the city of Utrecht in the Netherlands, there is a project "Utrecht - we all cycle!", which considers cycling to be an important part of transport. Especially in recent years, the city has decided to invest money in the modification of main roads, construction of new bicycle paths, bicycle bridges, bicycle underpasses. These modifications had a goal to bring an overall improvement in the infrastructure to ensure safer movement for cyclists. Other plans included the construction of parking facilities. See image below.

Figure 4.5.1: The busiest path in Utrecht, used by 25 000 cyclists on a working day
[Source: bicycledutch.wordpress.com]

Great Briitain - Cambridge

In the city of Cambridge, they decided to be a part of the project „Green Transport Plan“. They wanted staff and students travelling between campuses to be able to use cycling.

Figure 4.5.2: An example of parking system in the UK, a smart card system
[Source: https://en.wikipedia.org/wiki/List_of_bicycle-sharing_systems]

The system worked on so-called “smart cards”, where a small amount of money was loaded. The card was then used in a kiosk, where the user paid and a certain stand was unlocked with the bike. This system was effective against vandalism.

4.5.3 Principle of network design cycle routes and its implementation

Based on the information from chapter 4.5.1, a solution for bicycle transport was proposed, i.e. the principle of basic routes in the Chisinau city (Fig. 4.5.3). The following map will help to show the growth of the bike network in Chisinau based on existing cycle routes, building and design plan of the cycle routes (planned by the city of Chisinau) and original design of main cycle routes. The following color-coded map will provide a better understanding of these three categories.

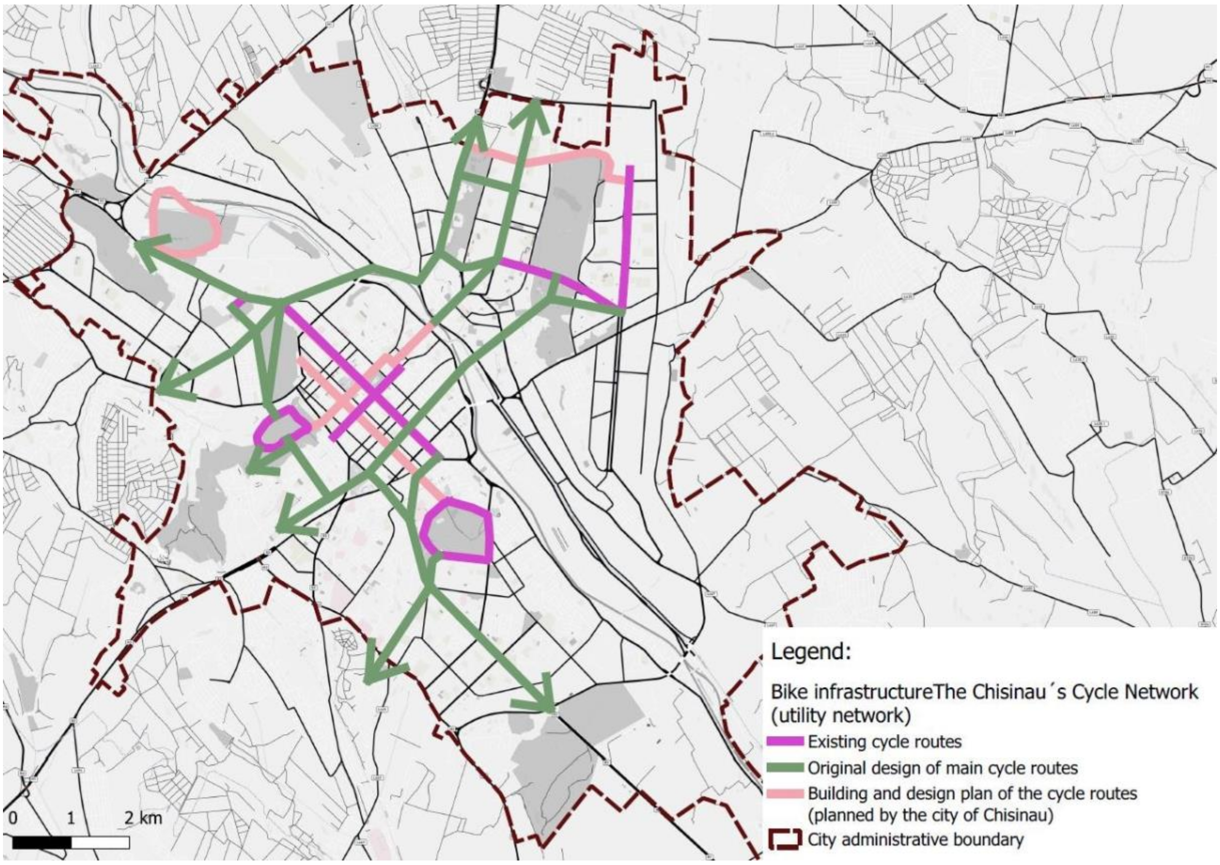


Figure 4.5.3: The main important connection of bicycle traffic in Chisinau.

The existing bike infrastructure in Chisinau started to be set up and built around 2014. It began very sporadically, not based on a network vision but rather it was built segment by segment. The initial designs were simply yellow lights on pedestrian tracks (Fig. 4.5.4).

Figure 4.5.4: The first design bike lanes in Chisinau - 2014.

In 2016, a slightly more successful project was initiated on Ștefan cel Mare street. Its execution is obviously flawed because it overlaps with pedestrian tracks again, but the biggest problem is that again the authorities did not design this bike lane based on a network vision. It is just one segment on one of the city's main streets (bd. Ștefan cel Mare).

Figure 4.5.5: The first design bike lanes in Chisinau - 2014.

In 2018, the most successful bike lane project was carried out. This is the Valea Morilor Park bike lane (Fig. 4.5.6). According to the data on the Mobile App, Strava, even up to this day, this bike lane is the most used of all bike routes in the city. Cyclists use this park circuit for leisure, sport training and even, rarely, to commute as a very inconvenient transit route. Despite the fact that again the public authorities do not have a vision for long term bike route network building, they accidentally built the bike track where people wanted to use it. Much later, in a study done in 2019, it was proven that data supported this choice of the authorities. Even so, at the moment of designing, data was not used.

Figure 4.5.6: The Valea Morilor Park bike lane.

Starting with late 2019 and 2020, the city authorities started to think more about building an entire bike network in Chisinau and designing bike lanes in accordance with modern street design principles[1]. In accordance with this guide and several other urban mobility planning documents developed in the last two years, a sort of vision for the city's bike network started to be developed. More and more the public authorities started to use data in decision-making about where to build bike lanes and more importantly – how to build bike lanes that will later on connect among themselves to form one whole network for the city. This means to prioritize bike routes that connect previously unconnected regions of the city and to avoid park circuit tracks that are only used for leisure and rarely for commute. If the city authorities are to nudge people into using bikes as a means of transport, they must build bike lanes that are utility-focused and not leisure-focused. This would encourage people to use bikes to commute for work or study.

This would encourage people to bike from one sector of the city (i.e. Telecentru) to another sector (i.e. Buiucani) daily for work in a safe and efficient manner. This could be achieved by potentially connecting Telecentru to the Park circuit track in Valea Morilor Park and later on with Dendrarium Park, transit, and later on connect to Buiucani sector. This would allow safe

[1] Chișinău Street Guidelines, published by the City Hall in 2020 with support from UNDP Moldova.

passage through a green corridor from one sector of the city to another. The travel time by bike from this sector to the other would be just as, if not faster, by bike than by any other means of transport including private car or public transport. This would further incentivize bike use by city dwellers.

According to a study[2] carried out in Oregon in 2014, people would cycle more if the bike lanes were designed to be safer. This is very important not just in the process of effective design, but also in the process of inclusive design. Ideally, we'd want for bike tracks to be used by women, teenagers, pre-teens, the elderly and all categories and not only men athletes. In the Netherlands we see a much more balanced distribution and we see all kinds of people using bikes and bike lanes including mothers with more than one child onboard their bikes. This is the ultimate sign that people perceive bike lanes as safe. This is what we need to aim for when designing a bike network in Chisinau. Secondly, green corridors or park transit routes are preferred by cyclists as opposed to bike lanes that are in very close proximity to car traffic. A good example of a green corridor and park transit route is Vondelpark in Amsterdam (Fig. 4.5.7 and 4.5.8).

Figure 4.5.7: Illustration by Mr. Amsterdam. [Source: https://www.mr-amsterdam.com/attractions-sights-vondelpark.htm]

The park combines pedestrian and bike tracks that help citizens move from one sector of the city to another. It connects the Leidsestraat-Leidseplein city center area with Amsterdam West area.

[2] Link to video presentation about the study: https://www.facebook.com/watch/?v=1929434607117416

Figure 4.5.8: Photo of a Vondelpark in Amsterdam.

In Chisinau, we have ideal conditions for setting up a similar park transit route. More so, the current Vice-Mayor Victor Chironda declared that there is a plan to connect all the City's parks into one single bike and pedestrian green network. Given the current infrastructural constraints, this is still possible and feasible. Data from the Strava Mobile App supports this with further evidence. Given the patterns of people using bikes in Chisinau, connecting all parks will prove to encourage biking in the city even more.

The fact that a country is more developed, does not automatically mean that they have much better bike infrastructure. The Netherlands is a perfect example but building bike lanes is a relatively new priority in urban development. In cities such as London and New York (Fig. 4.5.9), where traffic management is inherently more complex it is very difficult to add new layers of safe and inclusive bike lane networks and it is even more difficult to take advantage of green corridors in the best way possible.

Figure 4.5.9: Typical New York (Brooklyn) bike lane.

Cities such as New York have an incredibly hard time designing bike lanes that are inclusive and user friendly. See in the image above an example of a typical bike lane and this particular one is safer than others because it is on a one-way street. It often happens that bike lanes in New York are drawn on streets where cyclist often collide with public transport such as buses that frequently need to stop at stations. This very same situation happens in London. This constant conflict between cyclists and public transport shows that the urban development prioritized the comfort of car drivers and did so at the cost of both bus commuters and bikers. In this particular case, bikers are in the most danger because upon a collision with the bus, they are most likely to be injured.

This example of a constant conflict between buses and cyclists is very relevant to Chisinau, because the most recent bus-bike lanes that are planned to be set up in the city. So far, only Pușkin street in Chisinau has a bus-bike lane. According to the City Hall authorities, setting up more of these bus-bike lanes are planned for 2021. The streets where these will be set up are: Ștefan cel Mare (both ways); str. Mitropolit Banulescu-Bodoni and Bulevardul Grigore Vieru (both ways). It is important that authorities in Chisinau study the cases of London and New York when designing these new bus-bike lanes so as to avoid the mistakes that may lead to injuries and accidents. In essence, bus-bike lanes are not bad, but they need to be carefully designed. Injuries and accidents may scare people into using cars and public transport more often than bikes.

In the bike map above, green is the existing infrastructure and orange is the planned infrastructure. One such example is the 31 August street (Fig. 4.5.10), which will be turned into a Green Corridor by the end of 2021[3].

Figure 4.5.10: Render of the 31 August 1989 Street renovation project.

[3] https://www.md.undp.org/content/moldova/en/home/presscenter/pressreleases/2020/strada-31-august-1989-din-mun--chiinu-va-fi-reamenajat--devenind.html

The general principles applied:

- ***Commute is a priority***. People should use bikes as much as possible instead of cars or instead of public transport. If people use cars for commute and then use bikes in parks, that is not the effect sought by the public authorities. In order to cause a shift in the urban mobility trends, planning must focus on removing cars as much as possible. Cars are the main pollution source, so even one less car means less carbon footprint and healthier citizens. It also means, less congestion, less traffic and less need for parking spaces in the city in general.
- ***Connector routes are a priority***. If it is possible to connect two regions of the city i.e. Rașcani and Ciocana, this route development should be prioritized over a bike lane that simply traverses Ciocana and does not connect it with any other region. Intra-region is secondary as priority. This means that connecting Telecentru with Buiucani is a priority. Connecting Centru with Buiucani is also a priority and so on. This is the reasoning behind the purple line that extends from the City Center to Botanica sector. Currently there is no bike lane connecting these two sectors and no such lane is even planned due to the technical challenge of planning a bike lane on an existing car bridge (Viaduct).
- ***If park routes can be transformed into transit routes, they should be***. Firstly, this should be a priority because there are already some bike lanes in the city parks and it would be significantly easier to build new lanes in parks compared to the complexity of building bike lanes on roads or next to pedestrian tracks. Secondly, park transit routes are the safest bike lanes in the city for cyclists. The following parks are suitable to host bike lanes: Valea Morilor, Valea Trandafirilor, Parcul Alunelu, Parcul La Izvor, Parcul Râșcani, Dendrarium Park, Botanical Garden. As stated above, the authorities should strive to connect all parks into a single green network.
- ***Bike lanes should be interesting and attractive for cyclists***. Where possible and where funding permits, authorities should try to build attractive infrastructure. For instance, at the end of the 31 August 1989 Street, authorities have not yet foreseen a connection with the nearest park, because of the difference in altitude (Fig. 4.5.11). The purple line in this image shows the opportunity to create a bridge for cyclists that wish to enter the park above the car road or through a tunnel, beneath the road. In places where there are obstacles, architects must find interesting solutions for overcoming them. This can be observed in other countries such as Netherlands (Fig. 4.5.13), Belgium (Fig. 4.5.12), China and Denmark.

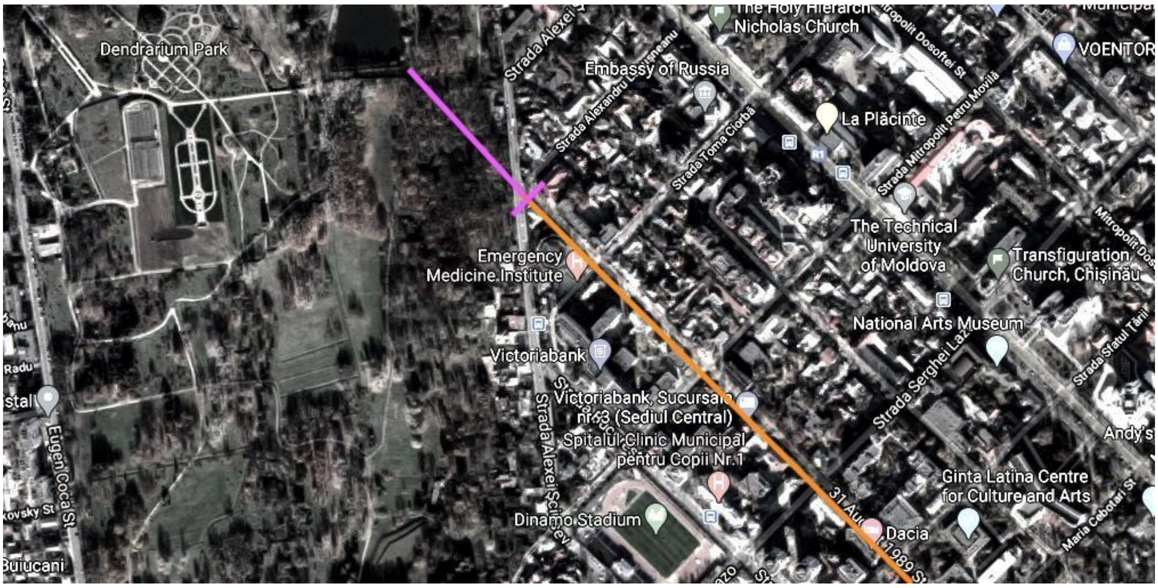


Figure 4.5.11: Building and design plan of the cycle route of the Strada 31 August 1989 street (planned by the city of Chisinau).

Figure 4.5.12: Belgium Forest bike track.

Figure 4.5.13: Amsterdam bike tunnel.

The long-term vision for Chișinău is to build a full network for urban bike traffic. In Amsterdam, 60% of all residents use bikes everyday.Certain estimations show that there are around 50,000 cyclists in Chișinău. If this could potentially mean 50,000 less cars in the city, then the authorities should aim to allow all of them to use their bikes in the city.

4.5.4 Pedestrian solutions - design principle

Regarding pedestrian tracks, in Chisinau there were up to 2020 very few projects that were meant to improve pedestrian flows, pedestrian comfort and to create better pedestrian tracks. The most recent and succesful project was carried out in 2020 on Puskin and Mitropolit Banulescu-Bodoni Streets (Fig. 4.5.14). The project aimed to remove on-street parking from 2 of the main city center streets. As can be seen, it was completed successfully.

Figure 4.5.14: Puskin Street in December 2020.

Figure 4.5.15: Mitropolit Banulescu-Bodoni Street in November 2020, after renovation with park benchces and green area. In some areas new trees have been planted.

In the near future, similar projects for renovating pedestrian tracks will be planned and carried out. The authorities aim to limit illegal parking in the city center and in an effort to do this, pedestrian tracks will be renovated and at the same time, slots for parallel parking will be set up so that cars do no impede pedestrian mobility.

The solution of pedestrian corridors is certainly a very important activity, however, the completion of safe corridors for cyclists is usually at a significantly lower level in cities than pedestrian infrastructure. That is why it is important to focus on cycling infrastructure in this regard. The city should decide for itself, depending on the time and financial possibilities, which corridors will be prioritized. It is also possible to address this issue directly with citizens. However, it is necessary for the city to define and plan exactly in what order it will deal with the proposed cycle paths. Fulfilment of this goal is ensured through the implementation of all recommended cycling corridors within the backbone network.

4.6 Road Safety

Road safety is mainly influenced by three main aspects DRIVER – INFRASTRUCTURE – VEHICLE (see fig. 4.6.1). Driver or the human factor is the most contributing factor to road accidents (93 % combined with others). Then there is the effect of the infrastructure and the surroundings (34 %) and the last is the vehicle (13 %).

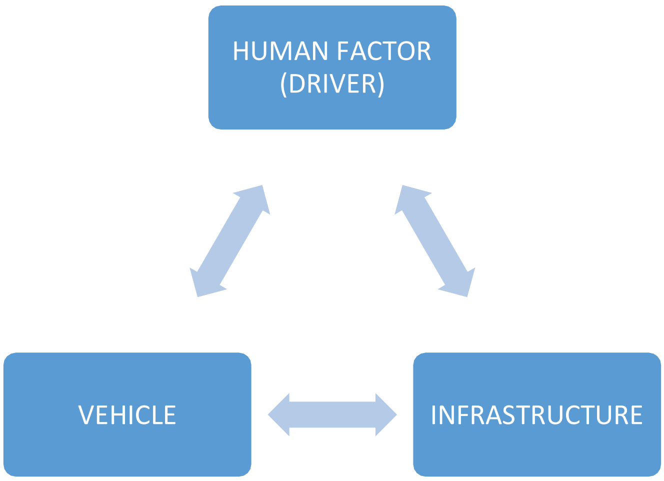


Figure 4.6.1: Road safety cycle

Human factor is all the mistakes the driver can make. That includes reaction time, wrong decisions, falling asleep, drinking, disregarding rules etc.

Infrastructure and the surroundings are the effects of the road geometry, surface quality, obstacles, spatial direction of the road etc., that can contribute to the effect of an accident, the risk of accident or can cause the accident on itself.

Vehicle means mostly poor condition, system malfunction or material failure that lead to dangerous situations. This depends heavily on the average age of cars in the country.

The actual distribution of contributing factors is shown on the figure below (fig. 4.6.2*figure 4.6.2:*). The percentages wrote above are combined from all factors. If we consider individual factors alone or different combinations, the percentages differ.

Beside the three listed factors, there can be others, such as Information (or rather ITS technologies) and integrated safety systems (emergency systems – firemen, ambulance and the police).

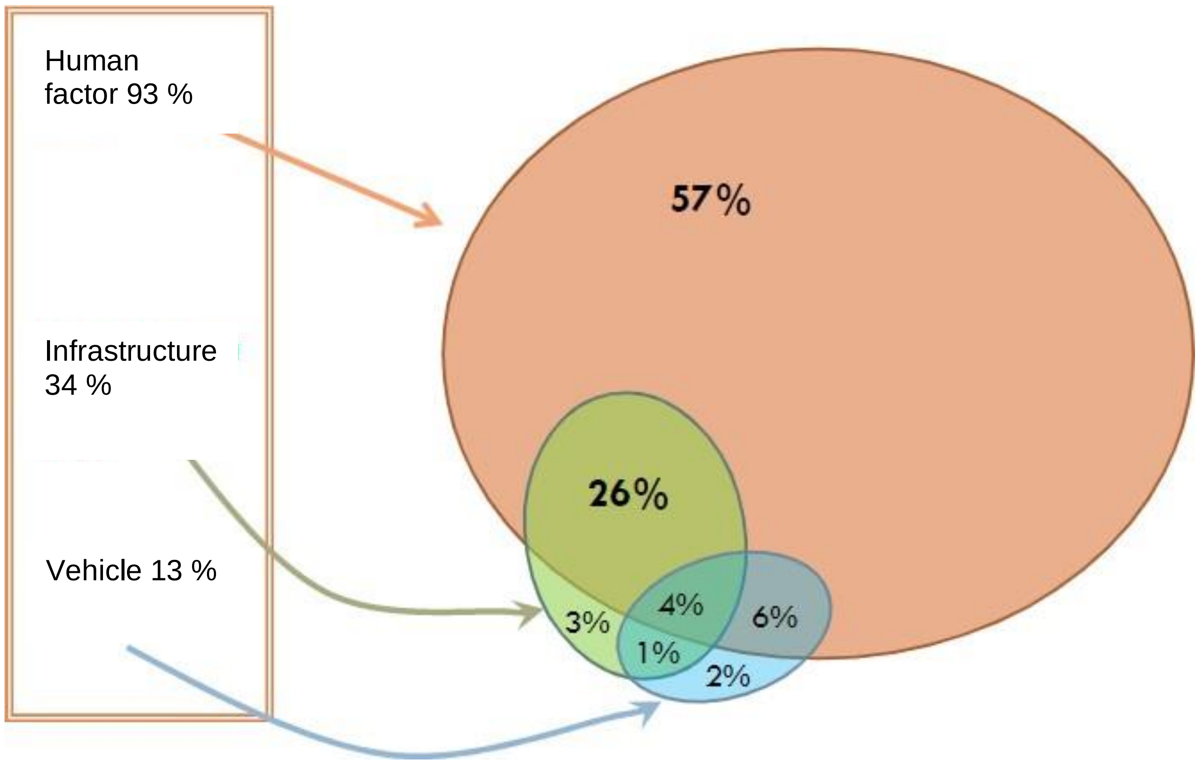


Figure 4.6.2: Contributing factors (CTU Faculty of Transportation Sciences, data from PIARC)

4.6.1 Infrastructure

According to PIARC (World Road Association) the infrastructure contributes to 34 % of road accidents. It is therefore imperative to implement such measures, that would decrease the effects of possible road accident, and decrease the chances for an accident to happen – increasing the overall road safety. Above mentioned PIARC is a good source of information and examples of good practise. In a five-year cycle there is an update of main documents, findings and policies. Beside PIARC, we should define the most efficient tools for a city or a country to employ, in order to reach a desired state of road safety.

There are three main options regarding infrastructure optimization are as follows:

- Road audits,
- Safety inspection,
- International Road Assessment Programme (iRAP).

Road audits are suited for road infrastructure that has not yet been built (projects) – be it reconstruction or entirely new infrastructure. In four phases, different experts (auditors) should evaluate whether the proposed infrastructure meets safety requirements (set by the state – legislation).

Safety inspection in contrast to audits is aimed at infrastructure already in service. The infrastructure is recorded on video recorder placed on a vehicle. The record is then evaluated by a team of trained experts. Individual road safety deficiencies are then defined and recorded. Not only are the deficiencies specified, but there is also a brief description of proposed changes to reduce the risk. Examples of the system employed in Czech Republic (used by the ŘSD – state road institution and others, developed by the Czech Technical University, the Faculty of Transportation Sciences) are shown on the figures below (fig. 4.6.3, fig. 4.6.4).

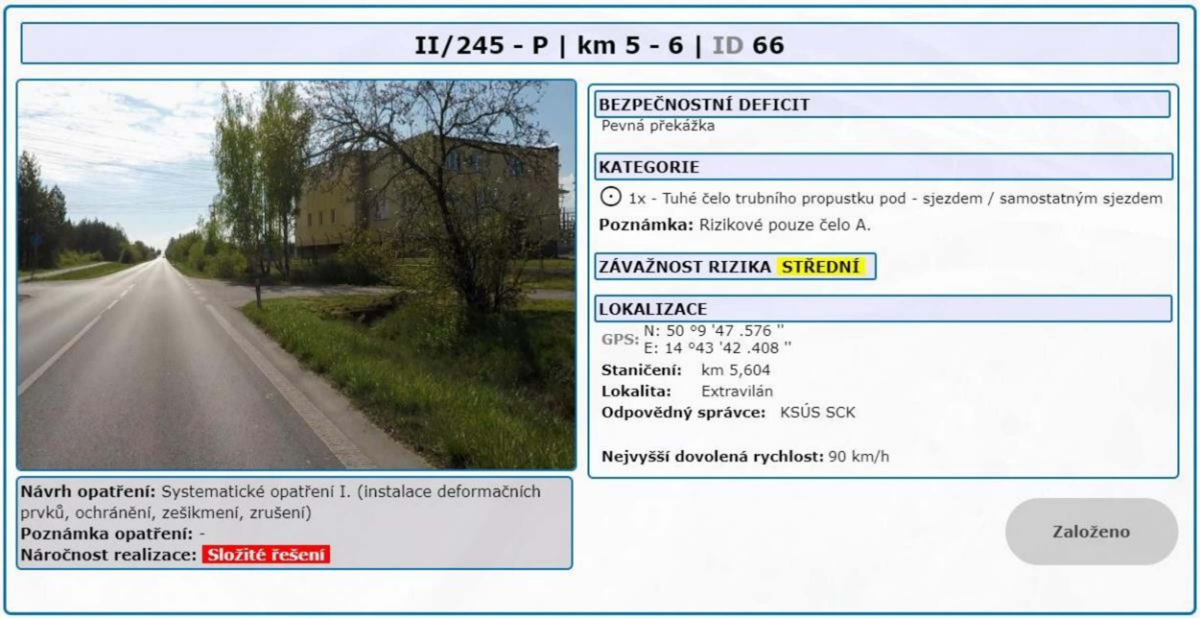


Figure 4.6.3: CEBASS record example

Figure 4.6.4: CEBASS map of records example

iRAP is an alteration to above mentioned Safety inspections, where one does not concern himself that much with individual road safety deficiencies, but rather evaluates an infrastructure (1-5 stars) based on the amount and severity of road safety deficiencies on segments with specified length. The infrastructure is recorded by a special vehicle and after that trained experts evaluate the record. The output is an infrastructure map coloured by the state of individual segments. The example of the system is shown in the figure below (fig. 4.6.5).

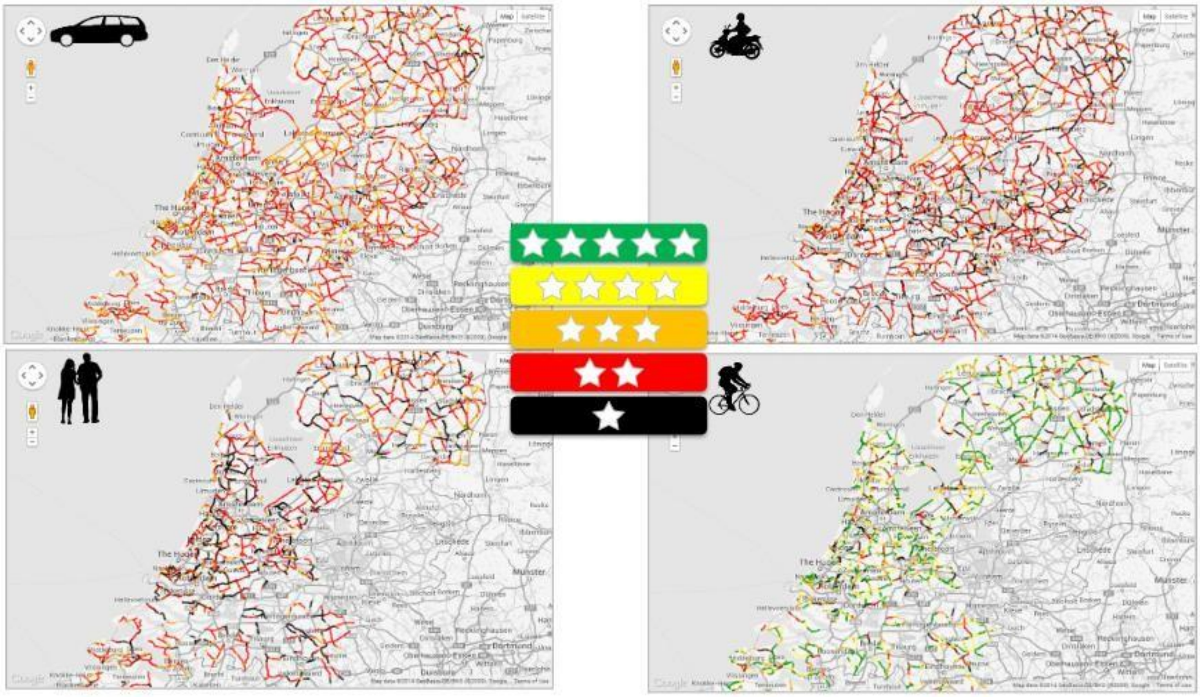


Figure 4.6.5: iRAP example from Interreg Danube Transnational Programme RADAR (1 star is the worst)

Other methods could revolve around investigating high road accident density areas and nodes. If there is an intersection, where road accidents happen on a regular basis, that is a good indication, something should be done. Cooperation with the police is a necessity here.

It is important to define what kind of infrastructure should be specified in legislation concerning road safety. At all times, a state or a city should strive to optimize costs, even when road safety is concerned. It would be near impossible to expect to go through all existing roads. Only the spinal infrastructure should be evaluated both in audits and inspections. And after that, if there is enough resources, lesser classes can also be included. For an example of the highest priority (both in the state and the city), the maps below show the proper most important roads (fig. 4.6.6 - country, fig. 4.6.7 - city).

Figure 4.6.6: Republic of Moldova infrastructure

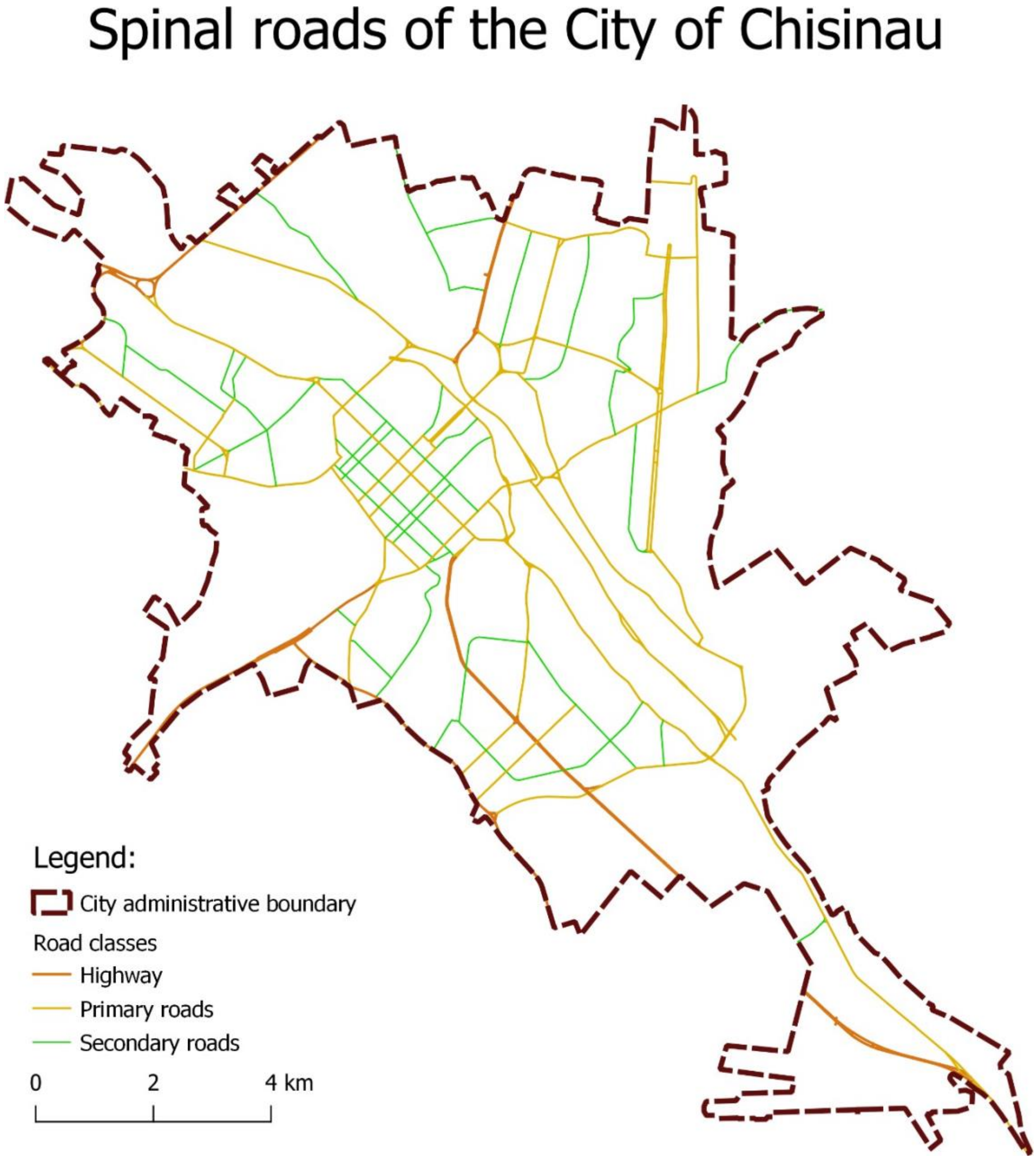


Figure 4.6.7: City of Chisinau infrastructure

4.6.2 Vehicle

To some extent, the effect of the vehicle is out of hands of the state or the city, as the main driver for the innovation and new safety measures and systems in the vehicle are the car manufacturers. But the legislation can be altered in such a way, that it can contribute to safety. For example, the legislation can set some minimum requirements for safety measures in the vehicle, the requirements for technical eligibility for vehicles etc. The state can also employ measures aimed at supporting the drivers and lower the average age of the cars – most easily through tax support for newer vehicles.

4.6.3 Driver

The driver behaviour and fitness can be influenced through legislation and edification. In **legislation** the physical fitness can be thoroughly described and set, so that unfit drivers cannot receive or hold onto their driver's licences. This needs to be supported by proper police enforcement (for improper behaviour and regulation disregard). **Edification** is however more complex and more interesting. It should start in ***I.*** early stages of life (school), ***II.*** after that supported heavily in the process of learning to drive and ***III.*** after that every citizen should be literally bombarded by road safety campaigns.

I. Road safety education for children

Children are very susceptible to any kind of education and edification. It is therefore imperative to start with road safety edification and driving education early in life. There should be driving parks available within walking distance for all schools (segregated from traffic) with real life traffic signs and rules, where children can learn to drive bike safely and function as an aware pedestrian (under the supervision of specially trained policeman and teacher). This should be a frequent addition to a regular curriculum for children. Not only the hand-on experience should be employed. There also needs to be classes aimed at distribution of information and conversing with experts and showing the effect of improper and unsafe behaviour. Children generally don't understand the consequences of their actions and they carry bad behaviour to later stages of life. It would be a good idea to consider creating special videos for children where there is an example of bad (dangerous) behaviour and the consequences it can have.

II. Driving school

All over the world driving schools teach us how to drive. But rarely do they teach us how to drive safely. How to better understand the dangers of driving a vehicle. How important it is to be seen as a pedestrian or cyclist/motorcyclist etc.

There needs to be a transformation in the system, so that people understand the driver's licence is no certainty, but rather a privilege. It would be optimal to utilise psychological testing of the potential future driver's preparedness for the roads (anger issues, mental instability etc.). Lager portion of the curriculum should be dedicated to road safety and the consequences.

III. Campaigns

Campaigns and proper PR handling of the issue of road safety can be the determining factor in overall effect of edification. The entire process, however, can take a long time to take effect. It is also a lot harder to convince the public and politicians, that such endeavour is financially healthy decision. Large scale campaigns that are "done right" can be extremely expensive. But the resources are well spent. The Ministry of Transport in Czech Republic is largely responsible in cooperation with BESIP (road safety institution) for road safety campaigns. The state should have a similar role in this respect in the Republic of Moldova as well. A campaign that was well received in Czech Republic was called "Nemyslíš – zaplatíš." (eng. "If you don't thing, you will play the price.") and there are other all over the world (Australian Transport for NSW, UK Surrey County Council and more). Some examples and sources are listed below.

Other People make mistakes. SLOW DOWN.

Short video:
https://www.youtube.com/watch?v=mrDeuzuIDqY&ab_channel=TransportForNSW

Nemyslíš – zaplatíš

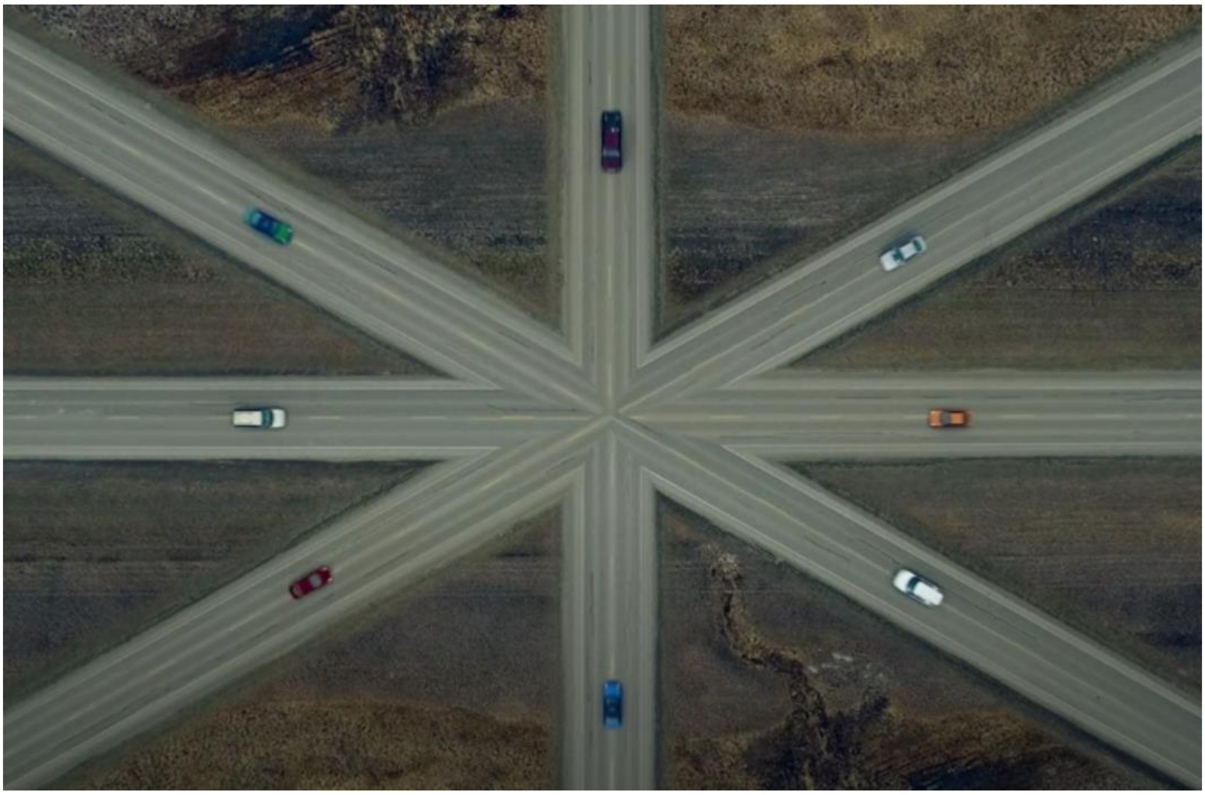
Short video: https://www.youtube.com/watch?v=otgH6sFECoM&ab_channel=Silc0

Road Safety Campaign Film HD - teen-anti speeding UK

Short video: https://www.youtube.com/watch?v=NjFnoU0IJrE&ab_channel=PhilTune

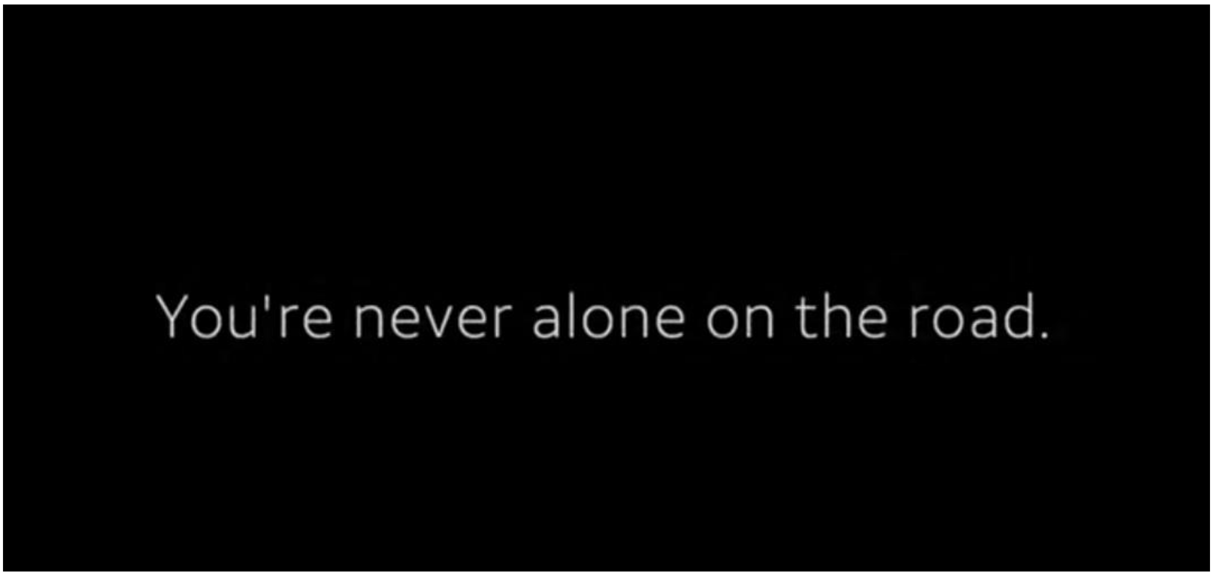
2016 SGI Road Safety Campaign

Short video:
https://www.youtube.com/watch?v=NFPM2for8ak&ab_channel=SGICommunications



ItCanWait

https://www.itcanwait.com



Just Slow Down

https://justslowdown.ca

Other campaigns dome by Fiat, Volkswagen, and other brands of automotive industry, government and other entities can be found all over the interned – an inspiration only waiting to be passed on.

People do not realise the consequences of their actions. You need to help them understand.

4.6.4 Other factors

There are two more main factors, that is **ITS technology utilization** and the employment of proper **Emergency service systems**. The ITS in this regard is connected to information –

sharing data and information can both prevent accident and save lives. It is closely connected to Emergency systems who benefit from quick and precise information the most.

Its is therefore important to invest in a compatible communicational infrastructure with the possibility of vehicle to infrastructure communication that can also provide data for emergency services. Spinal infrastructure should be considered primarily. Future project should take into account future networks for such technology and incorporate it in.