Push & Pull measures

Annual international markets overview

In the framework of project "PARKING GETS SMART – improved & digitalised parking management as tool to foster green and multimodal transport in the South Baltic Area" co-financed from European Regional Development Fund

Mateusz Olszewski
Tomasz Piernicki
Monika Graczyk-Raczyńska
Kacper Główczewski

April 2022

Disclaimer: the contents of this study are the sole responsibility of the authors and can in no way be taken to reflect the views of the European Union, the Managing Authority or the Joint Secretariat of the South Baltic Cross-border cooperation programme 2014-2020

Contents

Introduction

Rapid growth of population and increasing urbanization have a significant impact on all aspects of people's lives. It is estimated that the global population will increase to over 10 billions by 2050 [1], while urbanization will increase from today's 55% to 68% [2]. This situation will cause various challenges, of which many the world is already facing today. From degradation of environment, urban health and ageing, through overpopulation of some areas and social segregation, down to issues with mobility and provision of services.

The most visible mobility problem is the formation of traffic jams and, resulting from that, the increase of daily commuting time, especially for those living in and around cities. Since in many cities private cars are the primary mode of transport, another pressing problem, obscured at first glance, is the progressive pollution of environment. The majority of cars is occupied by only one person during a single trip – in 2020, car occupancy rate for commuting (i.e., mean value of occupied car seats during a single trip) in UK was estimated at 1.1 [3]. This puts a significant burden on the road network and related infrastructure. In addition, a large part of the valuable space in cities has to be allocated as parking lots, as cars are parked 96% of their time. Precisely, for 73% of their time the automobiles are parked at home, for 23% of their time somewhere else, and for only 4% of their time they are in motion [4]. This is one of the reasons why parking is one of the most important intermediate goods in the modern market economy, after money and credit cards [5].

In order not to aggravate this problem, there must be a change in the way people commute around the city. A switch from private cars to more sustainable and efficient modes of transport may be necessary. Thanks to this, air pollution would be reduced and space in cities would freed up for the people living in them. Reduced number of private cars in active use would partly solve problem of traffic jams, making commuting faster, especially during rush hours.

In order to bring about such a change, push and pull measures should be used. Push measures are intended to make cars less attractive in a direct manner. This, for example, results in making car utilization more expensive and less comfortable. On the other hand, pull measures are associated with a positive affect. They are focused on introducing alternative means of individual transport, such as bicycles, scooters, car-sharing and collective transport, and making them more convenient, faster and trendy. People are initially quite reluctant to change, but after proper introduction of reforms, they begin to positively perceive them [6].

This document is entirely devoted to push&pull measures (tab. 1). The most important of them have been described here, along with details, such as: when a given method makes sense to be implemented, what problems can be expected during its' implementation and what effects given solution brings. Additionally, there are examples of cities that introduced given methods and what effects they observed. Correlated pull measures are presented for each push measure, to indicate which methods should be introduced simultaneously, to achieve the best effect. Similarly, for pull measures, correlated push measures are presented. Finally, a few success stories are shown from the cities that have successfully implemented push&pull strategies.

Push measures	
Measure	**Sample implementations**
Paid parking zones	Krakow, Poland; Nottingham, UK; Balzers, Lichtenstein
Restricted zones	Krakow, Poland; Maastricht, The Netherlands
More space for pedestrians	Zurich, Switzerland; Copenhagen, Denmark
Parking standards for new investments	Zurich, Switzerland; Krakow, Poland
Mobility Contracts	Graz, Austria
Parking enforcement	Edinburgh, UK; Utrecht, Netherlands
Assigned parking spaces	Graz, Austria; Balzers, Lichtenstein
Pull measures	
Measure	**Sample implementations**
Improving bikeability and walkability	Victoria, Canada; Zurich, Switzerland
Information and promotion campaigns	Munich, Germany; Burgdorf, Switzerland
Shared mobility	Victoria, Canada; Moscow, Russia
Park&Ride	Strasbourg, France
Public transport improvement	Tartu, Estonia
Cooperation with private companies	Tartu, Estonia
Subsidizing alternative means of transport	Graz, Austria; Manchester, UK
Digital parking	Utrecht, Netherlands; Treviso, Italy

Table 1: Summary of push&pull measures described in the document.

Push measures

Paid parking zones

Paid Parking Zones are designated areas where drivers must pay parking fees directly for the use of the particular parking space for the desired period of time. They can include both on-street and off-street parking areas. It should be emphasized that parking is never free, and even if not paid directly by a driver using a certain spot, the overall cost of parking is covered indirectly, i.e. by various types of taxes [6]. Payments can be collected by parking managers using different methods – from on-site parking meters 1, through mobile-apps, to long-term parking subscriptions. The method should be chosen based on the parking managers and final users' requirements, making the process most accessible for everyone.

Figure 1: Parking meter in the city of Gdańsk. Accepts payment by cash or card. When license plate number is provided, there is no need to put the ticket under the front window of the car (source: https://www.trojmiasto.pl/).

Reasons for introduction

The introduction of charged parking spots is usually one of the first traffic reduction methods applied (either as an aid or prevention). It is usually introduced when there are problems with the availability of parking spaces in a given area, or when the access roads have insufficient capacity to handle the traffic from and to the parking spaces.

An essential motivation for introducing paid parking zones is the willingness to raise funds to develop alternative, more sustainable means of transport and discourage people from using private cars in those particular areas. Additionally, parking fees are being introduced to reimburse costs of the construction and maintenance of parking spots in the designated zone.

Implementation Problems

There are many issues associated with implementation of this measure that should be taken into account. Firstly, the method of payment for parking must be clearly defined (described in

more detail in the Digital parking subsection, together with other pull measures, since it can encourage drivers to act in a certain way). In order for the parking zones to be inclusive, it should be possible for drivers to pay using not only modern but also conventional methods, such as parking meters. However, since it comes with the installation and operation costs, it may create the need to increase parking fees, as well as result in decreasing cost-effectiveness of further expansion of paid parking zones.

When considering introduction of paid parking zones, it is important to remember about the issue of parking enforcement and its relation to the zone's infrastructure, including alternative means of transport, e.g. car sharing systems (Shared mobility). Additionally, depending on the cost of the chosen parking enforcement method, impact on the parking zones fees may be substantial. Different parking enforcement methods are further discussed in detail in subsection Parking enforcement.

It should not be forgotten, that the sole introduction of parking fees will have no effect other, than an increased budgetary impact. In order to obtain satisfying results of the aforementioned transformation, people need to be provided with other, more attractive means of transport. Therefore, it is necessary to investigate who are the people using certain parking spaces, and why they choose a car as their mean of transport. Only then, appropriate further push&pull measures can be successfully used.

Another issue to be resolved, is how to communicate the need of paid parking zones introduction to the residents of the chosen areas. There are many different ways it may be addressed – local residents may, for example, be exempt from direct payment for minutes of downtime, or they may be introduced with long-term parking permits on privileged rates. However, it should be clearly defined where they can park with such a permit, and how many such permits may be issued per each apartment, resident or area. Introducing paid parking zones, or increasing already existing parking fees, usually causes public dissatisfaction with the changes. Clear and honest information about the reasons for the introduced changes and the expected effects of the measures, should have a positive impact. In addition, it is always welcome to be transparent about how the money from parking fees is used.

Examples

Parking policies enabling new mobility solutions – results and acceptance (Krakow, Poland)
The main push measure in Krakow was extension of the paid parking zone. During the project lifetime, two new areas were introduced. As city council stated in 2021, a result of introducing new paid parking zones in Krakow, 40% of car users decided to walk and 32% started using public transport. Additionally, citizens now rate better: life quality and spatial organisation, public space attractiveness, accessibility of systems, and bicycle network. From 2020 at least 69% of revenue from parking fees are reinvested in financing sustainable mobility and green areas. Other measures were implemented as well, e.g. new park&ride facilities. [7]

Workplace parking levy (WPL) (Nottingham, UK)
In Nottingham, UK, parking fee for employees, business visitors and pupils was applied. Target group are the employers who provide at least 11 parking spaces for their employees. Levy is self funding, and only 5% of the income is used on the system maintenance. Remaining funds are invested into development of public transport and implementation of other measures. [8]

INFICON AG–parking management at the work place (Balzers, Lichtenstein)
INFICON AG company introduced parking fees for their employees tlo push them use different commutation modes. Before the measure was introduced, effort was made to measure employees possibilities for transportation. Parking fee was based on given employee mobility options. Throughout years 1999 to 2007 13% employees switched from individual motorized transport to collective public transport. The amount of employees walking or cycling to work remained unchanged [9] .

Correlated measures

Push measures
Restricted zones; Parking enforcement;

Pull measures
Improving bikeability and walkability; Shared mobility; Park & Ride; Public transport improvement; Subsidizing alternative means of transport; Digital parking.

Restricted zones

Another method of limiting traffic is the introduction of zones with restricted access for motor vehicles, with possible exemptions for suppliers or emergency automobiles. Such zones are created in a small space in urban areas, usually city centers. The mere introduction of traffic limitation does not involve high direct costs. Still, it is crucial to provide car-parks in neighbouring districts and convenient alternative means of transport, which can be expensive.

The introduction of such a zone has many benefits. First of all, there are more citizens and tourists on streets where only pedestrian traffic is available, positively affecting the surrounding businesses, such as restaurants. Next, the absence of car traffic makes the are quieter and more relaxing for inhabitants. Creation of a restricted zone causes smaller pollution due to lack of cars.

Reasons for introduction

There are several reasons why restricted areas are introduced. For each place taken into consideration, individual reasons may be pointed out. For old cities with historic heritage, presence of cars may blur their beauty. On the other hand, this measure can be used as a tool in process of transformation of places with industrial character, into more tourist welcoming and curiosity arousing areas. In both described scenarios, restricted zones boost image and identity of city zones, e.g. city centers.

When the reduction of air and noise pollution in particular district is intended, introduction of low/no traffic areas should be taken into account. Moreover, this solution is freeing-up public space allowing freedom of movement for pedestrians and cyclists. Reducing congestion in selected city districts is a good reason to introduce restricted zones.

Implementation Problems

There are a few challenges associated with the introduction of restricted zones. First of all, cars are being dislocated to areas neighbouring with the restricted zone. This implies that parking spaces on the border of the closed areas should be provided. Those car-parks should be prepared to serve an increased amount of clients compared to prior to the introduction of limits on traffic. Creation of such facilities may be both a financial and a logistic problem. As a counterweight to a financial burden, parking spots may be paid, and the additional money used to develop more infrastructure. When city's layout is dense, an underground parking may be considered as a solution.

Another expensive challenge is to provide proper accessibility to the closed part of the city. Access, that was earlier provided by private cars, should now be replaced with public transport, i.e. busses and tramways. They all must be approachable and adjusted to being used by disabled people. Commercial cars, like taxis, may also be allowed in the restricted area to boost the accessibility for disabled people. A trendy mode of transport is bikes. There should be an effort put on establishing safe and efficient cycle paths. Integration of such, into the landscape of the city, would reduce the occupancy of public transport entities.

Next problem to solve, is traffic reorganization. Since reduced traffic zones are usually created in city centers, some crucial communication lines may cut through them. During implementation process of a restricted zone, mobility in the whole city should be taken into account and addressed properly.

Lastly, negative public opinion may be an arising problem. During the introduction process, implementers should be ready for an outcry in communities of local citizens and drivers. Effort on education of those citizens should be made, as restricted zones in short-sight seem to be off-putting, but in the long term boost both, the speed of communication in the city center, and the overall public satisfaction.

Examples

Implementation of new access restrictions and parking management schemes in Krakow (Krakow, Poland)

In Krakow, three restricted access zones were introduced: A, B and C shown in figure 2. In zone A, only pedestrians and cyclists are allowed, zone B is open for residents and deliveries. In zone C, parking fees are being collected. Implementation of restricted zones in Krakow reduced the traffic intensity by 20%. In a public pool almost 50% of citizens found the city less busy after the implementation of this measure [8].

The Master Plan 1990-2000 and the role of parking in Maastricht (Maastricht, The Netherlands)

In Maastricht, squares and parks were inscribed in the city's long tradition. To emphasize those during city's development there was a strategy created and implemented. In the city center, a restricted zone was created with car-parks on its borders. The character of the city center was refreshed, making it more cyclist and pedestrian friendly. In 2010, after the policy introduction, there was an increase in sales of floor surfaces from 78,000 m^2 in 2000 to 110,000 m^2 in 2010, which proves the economic growth in this area [8].

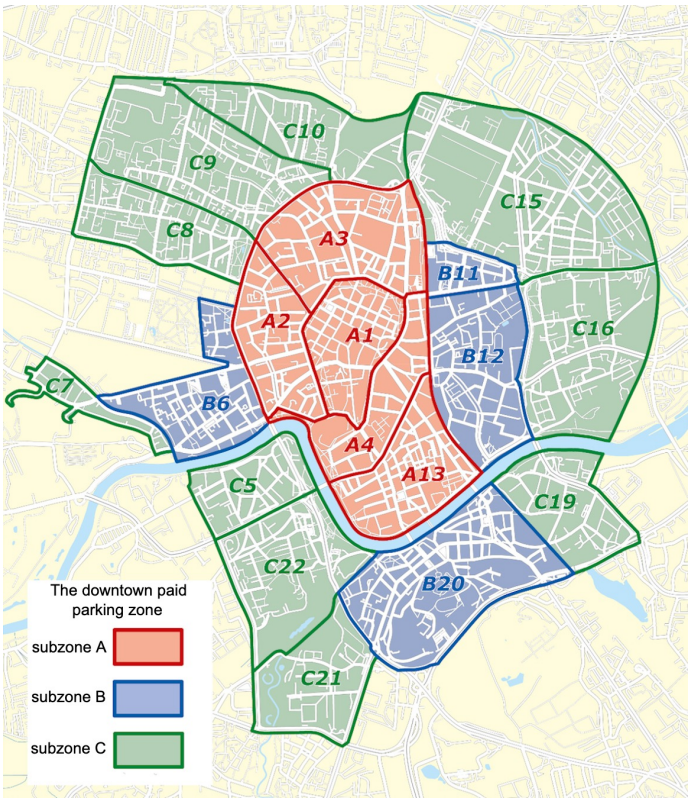

Figure 2: Map of paid zone, with distinction of subzones A, B and C in Krakow. (source: https://zdmk.krakow.pl)

Correlated measures

Push measures

Paid parking zones; More space for pedestrians; Mobility Contracts; Parking enforcement.

Pull measures

Improving bikeability and walkability; Information and promotion campaigns; Park & Ride; Public transport improvement.

More space for pedestrians

In cities, a vast majority of space is reserved for automobile traffic. In city centers, where all facilities are close, traveling by foot may be the fastest mode of transport. Pedestrianisation is a process of creating more space for walkers, usually by reorganising traffic and reducing number of on-street parking spots. Reduction of car-parks in certain places allows to turn them into beautiful squares and plazas. It is important to reduce the number of on-street parking spaces and to create off-street parking spaces simultaneously, keeping overall number of parking spots untouched.

Reasons for introduction

If the goal is to free up space for pedestrians and bicycles, this measure should be taken into account. Turning car-parks into pedestrian friendly areas, results in more green and environmentally balanced areas. When there is a need for upgrading the city's cycling paths network, additional space may be mandatory. During the process of city pedestrianisation this matter can be taken into account and addressed.

An important reason to create more space for pedestrians in the city, is changing it's initial look and aura. Reduction of parking places can be used as tool to: restore historical character of given place, make area more green or turn postindustrial zones into more tourist and citizen friendly.

Implementation Problems

First problem, that must be taken into account, is an already small number of parking spots in the city. Hence, the count of parking places in a given area should remain untouched after measure implementation. City manager should provide substitute parking places, by building them or renting them from private owners.

It is important to keep common sense during implementation of the changes, as clash of interests between businesses and inhabitants can arise. Businesses want more parking spaces for employees, while citizens want their living space to be quieter and less crowded. Still, some citizens drive cars, too. During implementation of this measure, opposition can be met from both groups. Transformation tends to become popular after the implementation, so a proper educational effort can me made.

Lastly, there should be a clear system of choosing parking places to be reduced. In most cities there is a variety of them, serving different tasks. During the development of a plan of the city transformation disabled parking space, taxi stands, spots for citizens, tourists and deliveries should be taken into account. None of these groups should be omitted.

Examples

Zurich parking supply cap (Zurich, Switzerland)
In the city of Zurich, there was a "Historical Compromise" established between interests of citizens and tourists. It allowed to reduce the number of on-street parking spots by over 900 across seventeen years. At the same time, overall number of parking spots in the city increased by almost 180. The main idea of the compromise states, that developers are not allowed to build new parking spaces, unless city removes corresponding number of on-street parking spots. Free space was used to create parks and squares[8]. One of the transformed squares in Zurich is shown on figure 3.

Case study: Copenhagen (Copenhagen, Denmark)
Copenhagen management has gradually changed the priorities of modes of transport in the city center. There was a reallocation of road space executed and access for through-traffic was restricted. Now 80% of journeys in the city center are made on foot, and 14% them by bicycles [10].

(a) Sechseläutenplatz before implementation of changes - serving as a public car-park.

(b) Sechseläutenplatz after implementation of changes - serving as a square open for pedestrians.

Figure 3: Sechseläutenplatz before and after implementation of "More space for pedestrians" measure [8].

Correlated measures

Push measures
Restricted zones;

Pull measures
Improving bikeability and walkability; Information and promotion campaigns; Public transport improvement; Cooperation with private companies;

Parking standards for new investments

Parking standards for new development regulate how many parking spots developers must provide. Standards apply to apartments, offices and commercial buildings. There are minimum and maximum restrictions, that imply the number of parking spots to be created. They are established in relation to number of apartments, offices, shops, workplaces, and the size of the investment.

Reasons for introduction

About 80% of the journeys begin and end at home [11]. Therefore, by lowering the number of available parking spaces at home, the overall number of car trips should also decrease. First of all, it discourages possession of cars. Nevertheless, even if someone still wants to possess a car, it may not be parked right outside the building, so there is an increased likelihood of taking different means of transport. The car is often the first choice when it is the closest means of transportation.

Additionally, if there is no need to build so many parking lots, there is more space for other utilities for residents, or just more green space. The amount of space that could be saved by lowering the number of parking spaces is visualized on fig. 4. It should be noted, that once a

car-park is built, it is challenging to convert it for other purposes, this is the case especially for off-street car-parks.

To encourage cycling, it is recommended to introduce minimum standards for bicycles [6]. Several countries already have such regulations on a national level: Bulgaria, Cyprus, France, Hungary, Lithuania and Slovenia [11]. It is possible to distinguish two types of bicycle parking spaces: long-term parking with enclosed spaces, e.g. sheds, security controlled area and bicycle rooms; and short-term parking with public and easily accessible areas. The second option for encouraging cycling and creating space for parking bicycles, is allowing fewer minimum car-parking spaces if entity provides adequate infrastructure for cyclists.

Following this trend parking standards for other means of transport, like car-sharing, e-scooters or motorcycles, can be taken into account.

Implementation Problems

The main problem to overcome is setting appropriate limits. They can be set as constant quotas related to, e.g. number of flats or inhabitants. The second option, is to create a more intricate model which takes more data as input.

For example, in Zurich, a model which calculates the a threshold of allowed traffic generation per each location. Calculations are based on utilisation of the property, accessibility of public transport, pollution limits, and local environmental law [8] [11].

Examples

"Fahrtenmodell" Trip Contingent Model for Parking Standards Policy (Zurich, Switzerland)
A dynamic model calculates traffic volume that is allowed for a given area. The calculations for the amount of short and long term parking places are dependent on the land use at the location of the parcel. Based on that calculation, a threshold of allowed trips-per-day for area or facility is designated. If the amount of traffic exceeds allowed threshold, the developer is bound to implement other push&pull measures to reduce it. Cameras are used for traffic monitoring. As an example, Sihlcity shopping mall shows that 27% of shoppers use their cars to reach the facility [8].

Implementation of new access restrictions and parking management schemes in Krakow (Krakow, Poland)
One third of the city is covered with local development plans. In areas covered with the plans, there are standards introduced. Measures used are parking-space-to-unit and per-inhabitant-ratio. Areas excluded from the plans do not follow any standards for new investments [8].

Correlated measures

Pull measures
Improving bikeability and walkability; Shared mobility; Park & Ride; Public transport improvement.

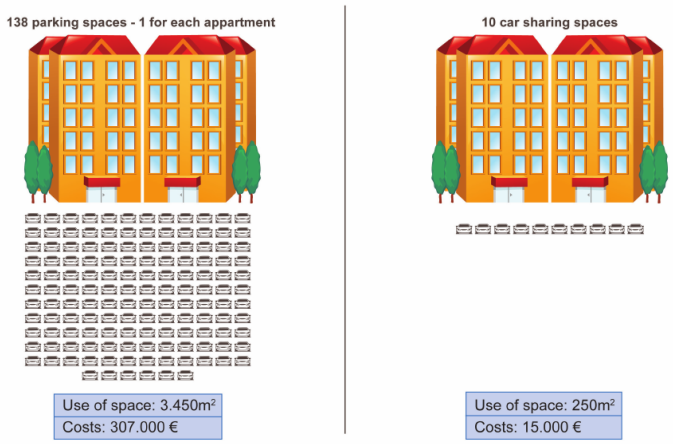

Figure 4: Use of space 25m^2/parking including space for maneuvering [6].

Mobility Contracts

A mobility contract, originated in city of Graz, is a contract between the city and the developers. The aim is to reduce number of cars present in the city, by lowering the number of parking places planned in upcoming investments. Number of parking places in such buildings is regulated by the law. By signing a mobility contract, the developers can reduce this number and save money.

Reasons for introduction

This measure is a tool to avoid overwhelming automobile traffic in the city. With every new investment, new parking spots are created. Main reason for introduction of mobility contracts is to reduce the number of additional cars present in the city as a result of new constructions being finished.

Implementation Problems

For such a contract to be interesting for the developers, there must already be a sufficient and working communication system in the city. Without the availability of public transport, the residents of upcoming investments would be left without a proper way of commuting around the city.

This measure puts additional effort on the developers. With lack of cars, bicycles may become the main mode of commute. This requires the developers to build additional high standard bicycle parking facilities. Moreover, bike paths should be constructed. To make usage of public transport easier, the developers must put an effort in creating additional electronic information displays.

Examples

Mobility contracts (Graz, Austria)
In Graz, the contract is agreed between the city and developer making construction plans. As a result, the occupancy of the streets and parking spots in the city does not increase in a fast and uncontrolled manner. This allows to avoid the decrease in speed of commuting in the city. There

is a change in mobility patterns of the residents. and an increased use of public transport and bicycles is observed. Less parking spaces in upcoming investments allow developers to build more living quarters and save money. In years 2011 - 2020 there were 33 of such contracts signed [11].

Correlated measures

Push measures
Parking standards for new investments;

Pull measures
Improving bikeability and walkability; Public transport improvement; Subsidizing alternative means of transport;

Parking enforcement

Parking enforcement is a set of measures set up to ensure that introduced regulations are being executed. It contains a workforce supervising parking area (PE officers), and tools supporting them in this task. Another component, is the level of enforcement–defined as the density of the enforcement units in the area. The last element of parking enforcement, is a citation fee, which is imposed as a penalty for illegal parking. The choice of detection technology is a long term decision, but the level of enforcement and citation fees may be easier to adjust depending on the current situation [12].

Reasons for introduction

Illegal parking leads to reduced traffic speeds, more accidents, and loss of income by municipalities from legal parking [12]. Hence, it is essential to detect vehicles parked incorrectly and react accordingly.

The introduction of parking fees will have little effect on the society and environment, if not backed by proper enforcement. It is important to discipline the citizens, so that they are aware of the inevitability of the punishment.

Implementation problems

Unless appropriate methods, that are ready for easy up-scaling, are put in place, extension of paid parking zones could generate a lot of costs and may turn out troublesome for the municipality.

Increasing the efficiency of enforcement in both on-street and off-street parking lots can be, for example, achieved by introducing sensors on parking spaces (fig. 5) and providing PE officers with the real-time information on occupancy of parking space with information on lack of payment for the place in question. Unfortunately, this solution is relatively expensive and generates additional high costs each time the range of parking zones is increased. Alternatively, to support parking enforcement, a system based on video detection of the free parking spots (fig. 6) can be successfully used. Although, usually cheaper, it is a solution not applicable to all areas, due to limited view of cameras.

Figure 5: Example of ground sensor for detecting parking spot occupancy. (source: https://www.asmag.com)

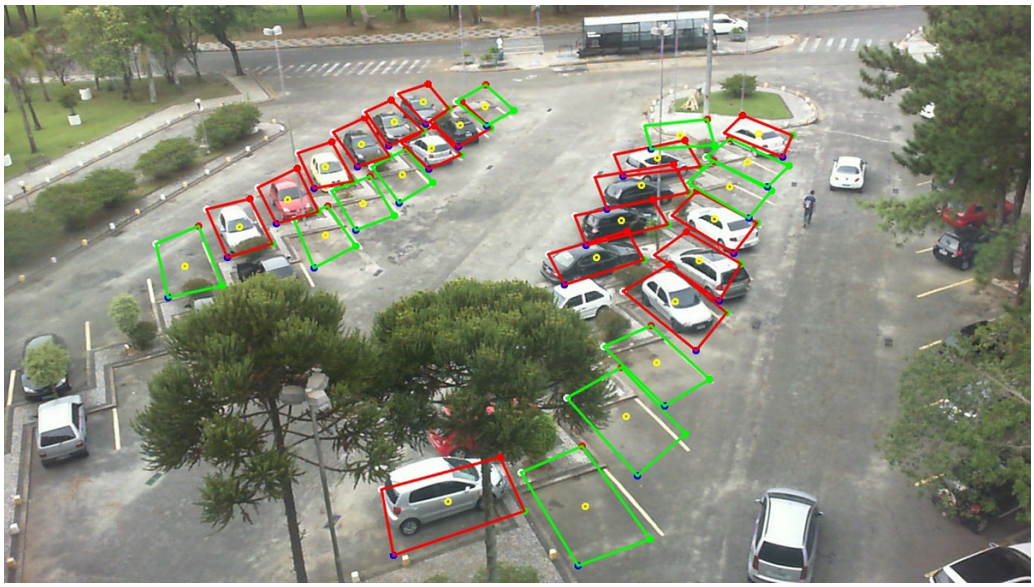

Figure 6: An example of parking spot occupancy detection using a camera where tree blocks detecting a few places. (source: https://www.behance.net/)

For off-street parking, the easiest solution is the installation of barriers or cameras at the entrance to the car-park. However, for on-street parking, a very effective solution that could improve the efficiency of enforcement could be ”scan-cars”. Scan-cars are vehicles equipped with cameras and plate recognition system linked to database of valid parking permits. Such system is already successfully being used in many cities all over Europe, e.g. Amsterdam, Hague or Utrecht [8].

Creating an effective parking enforcement system is strongly correlated with setting appropriate citation fees. They have to be high enough to work as a deterrent of illegal and prolonged parking, but should also include payment options, that would be inclusive for all (high and low-income) drivers [12].

Examples

Extension of controlled on-street parking in Edinburgh – impacts in one sub-area (Edinburgh, UK)
After expanding on-street parking controls, the proportion of cars parked for more than 4 hours fell from 22% to 10% (with most of the cars belonging to the residents). Occupancy on 3 out of 4 surveyed streets fell by 40-50% after the introduction of parking controls, and the occupancy on uncontrolled streets, just outside the aforementioned area, doubled [8].

On-street parking enforcement with digital parking permits (Utrecht, Netherlands)
The enforcement use scan-cars, which are cars with cameras that record plate numbers of the cars parked on-street and automatically check in the system if the car has a valid parking ticket. Adopting this solution resulted in the increase of payment rate by 10% in the years 2010-2012. It also allowed to reduce the number of enforcement officers from 63 to 45, and decrease the number of visitors to the parking desk by 35% in the period from 2008 to 2012. Data collected through these scan-cars is also used during the decision making process. [8].

On-street parking enforcement and management through a sensor system
Each parking space has a sensor and a number. Driver has to enter the number of a parking bay where he parked. Wardens could easily identify whether the parking space is occupied and if it was paid for. [8]

Correlated measures

Push measures
Paid parking zones; Assigned parking spaces.

Pull measures
Information and promotion campaigns; Shared mobility; Digital parking.

Assigned parking spaces

In order to limit the traffic in some places, a parking ban for people living close to a given place can be considered. For those people, changing the means of transport should be the least an-

noying, and it will make parking easier for those, who have no choice but to come by car. This measure is usually applied by companies and institutes, and targets employees of those.

Reasons for introduction

Typical reason for assigning parking spaces is shortage of parking spots. When company's car-park is not big enough to fit all the cars, assigning parking places to particular employees solves the problem. Big congestion in the parking lot can cause safety issues and accidents. This also reduces the search time for spot and solves the problem of "wild" parking.

Institutes with big campuses can use this measure to establish an ecology friendly environments. Giving up on cars reduces the energy consumption during work-home trips. By forbidding particular people to come to the campus by car, less parking spaces are needed. Free space can be used for new buildings, or what is usually more appreciated by the community, green leisure areas.

Implementation Problems

The first challenge is to come up with an assigning system that is fair and takes into account all commute participants. There should be an effort put on identifying current users of the parking spaces, their needs and expectations. Users that are about to be banned from parking their cars near facilities, should be able to travel to it and back fast and in comfort.

Similarly to other push measures, this one makes people to change their general habits. Opposition to the idea may be high, and the idea can meet resistance. It is important to educate car drivers on reasons for such a change being applied.

Examples

Mobility concept of the Technical University of Graz following the Push&Pull principles (Graz, Austria)

Technical University of Graz implemented this measure. The criteria for getting a permission to park was the distance to the living place. Initially, those who live closer than 1,5 kilometers form campus were not allowed to park their cars in University's car-parks. Later, this radius was expanded to 2.5 kilometers. There were many pull measures introduced. Among them, expanding cycling paths and free bike service for employees in nearby bicycle shop. For those who switched to public transport tickets were reimbursed. The number of people with parking permit has been reduced from 1340 to 740 [8]

INFICON AG – parking management at the work place (Balzers, Lichtenstein)

The company based in Balzers, implemented a management system that has following main characteristics. Firstly, parking fees were introduced. Secondly, most of parking spots were assigned to particular employees. A few places were left unassigned for carpoolers, and unpredicted circumstances. Third the most important characteristic are a clear criteria of assigning parking spots, applicable to all staff members. Criteria was based on distance to work, accessibility of public transport and length of the trip using public transport compared to using car.

As a result 13% of employees switched to public communication from cars in years from 1999 to 2007. Each year the company saves €80,000 net annually [9].

Correlated measures

Push measures
Parking enforcement.

Pull measures
Improving bikeability and walkability; Information and promotion campaigns; Shared mobility; Public transport improvement; Subsidizing alternative means of transport.

Pull measures

Improving bikeability and walkability

Bikeability is defined as the environment status of convenience and safety for cycling [13]. Similarly, walkability could be defined for walking. In this section, we shortly summarize the benefits and most important aspects for bikers and pedestrians. For more detailed information about methods of increasing the number of cyclists, it is worthwhile to check European Commission guidance related to cycling projects [14].

Reasons for introduction

Cycling is beneficial to the public health, the environment, and the economy. Cycling improves the physical and mental health of travellers, reduces vehicular emissions and travel times, and generates cost-savings [15]. So it is crucial to encourage people to use this mean of transport. There are several important factors for bikers: comfort, directness, coherence, attractiveness and safety. The most effective method to ensure the safety of cyclists, is investing in proper infrastructure, especially at intersections. It may reduce the severity of injuries, crashes, collisions and falls [16]. Cyclist prefer to ride on the designated cycling infrastructure [17].

Implementation problems

It is reasonable to focus on the mentioned most essential aspects of bikers. The following section lists the most important problems to deal with in them.

Comfort for cyclists consists of two factors – proper road infrastructure and bike storage/parking possibilities. Relevant infrastructure change should contain: detour reduction, slopes, proper pavement quality, and reduction of obstacles [15]. Cyclists are sensitive to the frequency of turns [18] and stops at the traffic lights along their route. A great convenience for cyclists is installing foot rests (fig. 7) by the traffic lights for them to wait for the change of lights comfortably, as well as creating bike boxes (fig. 11) and refuge islands on crossings. While slopes could be difficult to change, due to environmental constraints, in general, pavement smoothness is significantly affecting bicycle's controllability [18]. Improving cyclists' comfort with regard to the storage/parking of bikes, includes the creation of proper bicycle racks and changing rooms for cyclists (fig. 8). Nowadays most of the modern business centers are designed with great number of racks marked for bicycles 9. The advantage of placing bicycle racks, is that they take up much less space in relation to cars' parking spaces. It is also worth to ensure, that there are changing rooms in the workplace where cyclists can change clothes comfortably, and take a shower. Various types of incentives could be introduced for employers or developers to create such places, such as reducing the required minimum number of car-parking spaces, significantly reducing costs.

Directness and coherence are related to time and travel distance. An adequate bicycle network should provide direct routes and avoid cyclists having to make detours [15]. It is also crucial that bicycle paths do not end suddenly, just to come up again after some distance not to force the cyclist to use the road with cars.

Figure 7: Foot rests for cyclists in Copenhagen (source: https://cyclingsolutions.info)

Figure 8: Lockers and storage units for cyclists (https://www.re-publicspace.com)

Figure 9: Map of available parking spots for bicycles in a modern office buildings campus (source: https://www.oliviacentre.com)

Attractiveness is related to aesthetic aspects of the environment around the biking path. Cyclists prefer to ride quieter environment, especially connected to nature. Noisier places are generally more stressful for bikers [18].

Improving safety factor leads to the increase in the number of cyclists, or higher usage of active transport [17]. The creation of separated bike lanes (fig. 10) leads to more cyclists [19], the reason for that, is that the probability of stressful events is significantly lower on physically segregated cycle paths than on cycle paths on streets [18]. When there is only possibility to create bicycle paths on the road, lowering the speed of motorized vehicles, using traffic-calming devices could be a good solution [19]. Another stress factor for cyclists are intersections, so it is essential to reduce the possibilities of conflicts there. For this reason, there are recommended features like bike boxes (fig. 11), intersection crossing markings, two-stage bicycle turn boxes (fig. 12), and refuge islands [14]. Reducing the possibilities of stressful situations is very important because the repeated occurrence of intensely stressful events may make actual cyclists more likely to abandon cycling [18].

Examples

Mobility Management at campuses – the case of Camosun College (Victoria, Canada)
Camosun College increased the number of people coming by bike by implementing proper bicycle infrastructure. They provide bike-fix stations, free of charge showers and changing rooms. There is also a possibility of renting a locker, or having a towel service for a small fee. Bicycles could be parked on free of charge outdoor racks or in the paid secured parking. By implementing other measures as well, they obtained a decrease in vehicle use from 63% in 2018 to 49% in 2013 [9].

Zurich parking supply cap (Zurich, Switzerland)
For each of the new created off-street parking place, one on-street space have to be removed and usage of these spaces for green spaces, pedestrianisation and bicycle traffic. [8]

Figure 10: Separated bicycle lane in Gdańsk (source: https://commons.wikimedia.org)

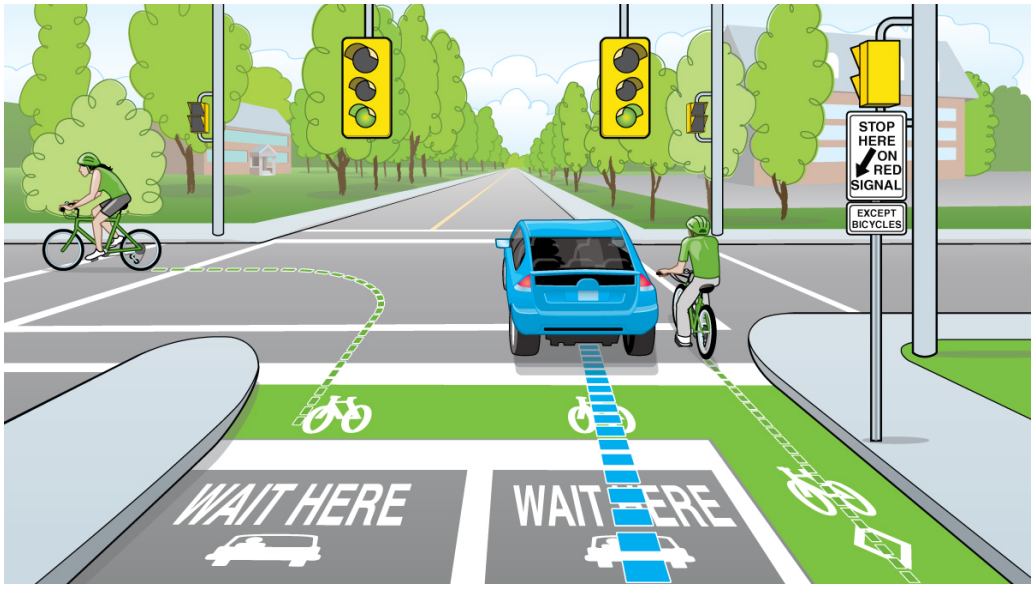

Figure 11: Bike box (source: https://guelph.ca/)

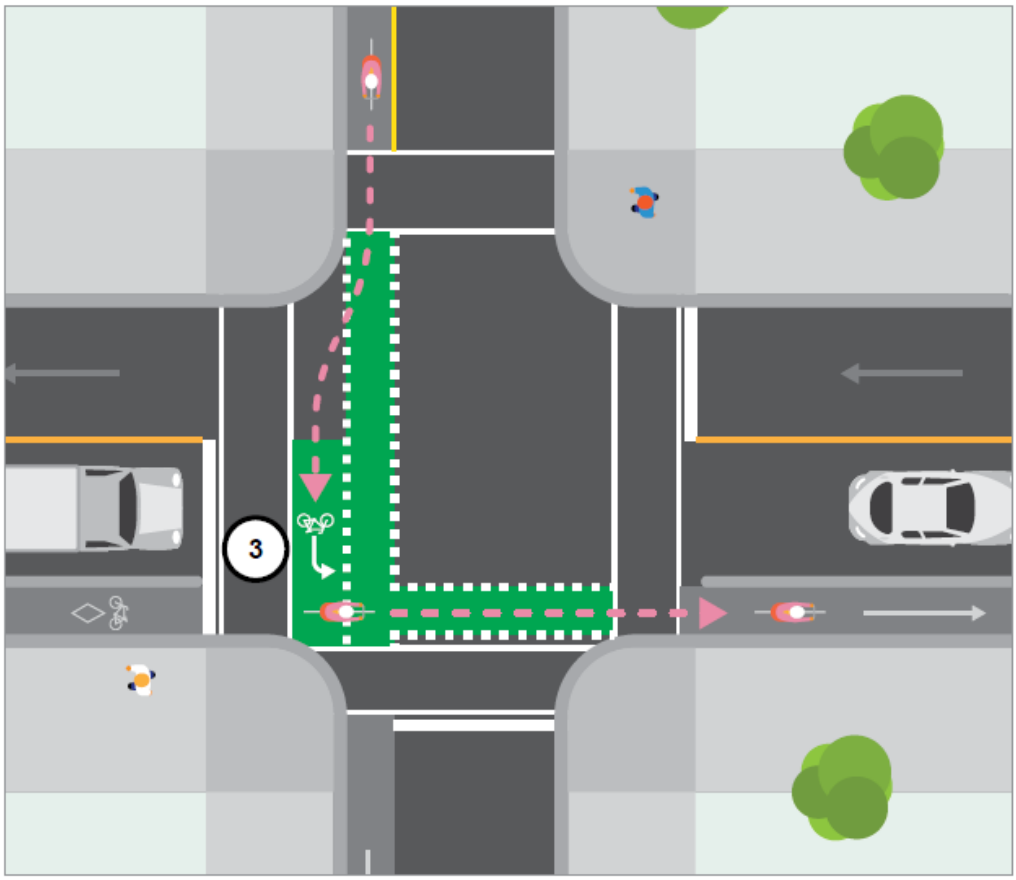

Figure 12: Two stage bicycle turn box (source: https://winnipeg.ca/)

Correlated measures

Push measures
Restricted zones; More space for pedestrians; Parking standards for new investments; Assigned parking spaces.

Pull measures
Information and promotion campaigns; Park & Ride; Subsidizing alternative means of transport.

Information and promotion campaigns

Even the best plan can be a failure, if not adequately communicated to residents. Another aspect is reaching out to people visiting the city. But only informing about current or planned possibilities may not be enough, there is also a need for promotion campaigns to encourage people to use more sustainable means of transport.

Reasons for introduction

First, there is a need to communicate the planned changes, with an explanation why are they being established, to the target groups. If people understand the reasons for certain decisions, it will be easier for them to agree to some inconveniences. Citizens may be unaware of alternative modes of commutation, which can be more convenient for them.

Another aspect, is informing visitors and tourists visiting the city about sustainable ways of transportation. It is good to have easily accessible materials in several languages on the most popular ways of getting around the city prepared. It is especially worth to describe in detail how to use public transport. Thanks to accessible information the number of visitors using cars may decrease.

It is also worth trying to trigger the social change in the way people commute. Biking, walking, and using public transport should be perceived as primary modes of transportation. It could be achieved for example through introduction of various pull measures.

Implementation problems

The main problem is that people are reluctant to change. When they are doing a routine for a long time, they could not even consider other approaches. People may lack the knowledge about other means of transportation and perceive them as a worse type of transport.

Examples

European Mobility Week
EUROPEANMOBILITYWEEK is one of the flagship projects of European Commission. Its goal is to promote behavioral change in citizens' way of commuting. Part of the program is a contest for best promotion actions of mobility with mobility awards. Organisers of the project created a huge base of promotion materials for local governments, NGOs, schools to use [20]. There is a mascot, branding the undertaking in all European countries, with many variations to use by local graphics shown on figure 13

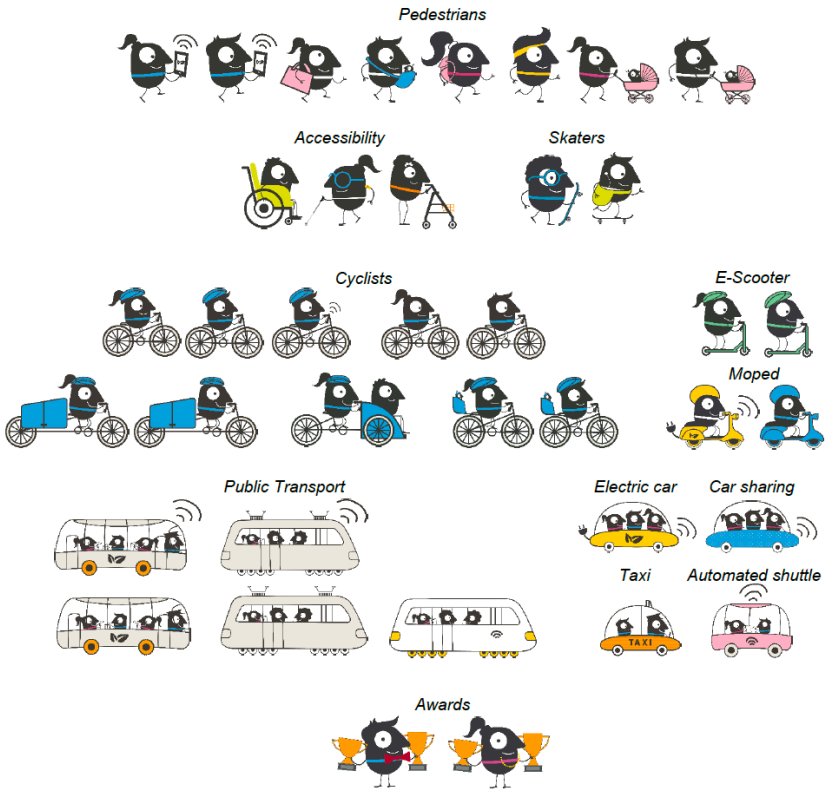

Figure 13: The EUROPEANMOBILITYWEEK mascot personifies urban mobility (source: https://mobilityweek.eu/)

Gscheid Mobil (Munich, Germany)

Gsheid Mobil is a programme that informs and promotes the use of environmentally friendly modes of transport. It focuses on the families, children, senior citizens, companies, new residents and migrants and for each group offers targeted information, for example for new families, information is provided through maternity hospitals and midwife practices. According to a study evaluating the impact of welcome folders on new citizens, the number of new citizens who used public transport was 7.6% higher among the group who received the information folder and the telephone consultation, than the group who did not. This is equivalent to almost 6,500 cars less in the streets of Munich per year [9].

Mobility Jackpot (or Lottery) at Seewer AG (Burgdorf, Switzerland)

Seewer AG company implemented mobility jackpot in the early 2000's. Once a week, on a random day, one of the employees is selected and asked about mode of transport they used for reaching workplace that day. If they used sustainable mode of transport, they were offered a cash prize, but if they did not use sustainable mode of transport, money remains in jackpot and is added to sum of the following weeks. In 2007, 4% modal shift from car to cycling was noticed. This type of lottery was adopted later by various other companies [9].

Correlated measures

Push measures
Paid parking zones; Restricted zones; More space for pedestrians; Parking standards for new investments; Mobility Contracts; Parking enforcement; Assigned parking spaces.

Pull measures
Improving bikeability and walkability; Shared mobility; Park & Ride; Public transport improvement; Cooperation with private companies; Subsidizing alternative means of transport; Digital parking.

Shared mobility

An excellent way to increase the percentage of people using bikes, is to introduce bike-sharing systems (fig. 14). Many people living in the city either have no place to store their bikes, or it would be a hassle for them to store them. In addition, the cost of buying a bike is a considerable expense, and not everyone can afford it. The introduction of bike-sharing systems addresses both of these problems, and people can use a bike for a small fee. In addition to the bikes themselves and their servicing, a one-off cost may be the construction of stations, where it is possible to rent and leave a bike. Of course, there is also a need for an appropriate network of bicycle paths in this case.

It is also worth taking other shared mobility measures, such as electric scooters, as they also make it easier to move around the city. In this case, it is also worth appropriately regulating their movement. It is useful designating appropriate parking spaces, because a common problem is that these means of transport are left in inappropriate places, that make it difficult for other road users or pedestrians to move, and may even cause a risk of accidents. Additionally, it is worth introducing speed limits on sidewalks and promenades, so that pedestrians can feel safe there.

A concept of car sharing is becoming more and more popular mode of commute. Car sharing is a great way to travel around cities, avoiding costs of purchase and maintenance of a vehicle. Such a car can be rented by anyone with a dedicated application. One car serves a larger group of people, so it reduces the need for parking spaces (fig. 15). Shared cars stay parked for much shorter time than private cars, making parking spots in popular areas less occupied. Higher usage of shared cars should reduce occupancy of car-parks as well. With more parking spots available, time needed to find a spot reduces. In some restricted zones shared cars are allowed, even though private cars are forbidden, making them much convenient mean of transport.

All shared means are an alternative to using classic means of transport, like public communication and even more private cars. Within a realistic price, passengers can travel in an on demand manner in great comfort. It should be taken into account to be used as main mode of transport for home-to-work and home-to-school routes.

Reasons for introduction

Shared mobility allows private users to save money by avoiding costs of purchase, repairs, and maintenance of vehicles. In the big picture, car sharing can be introduced as an answer to

Figure 14: A bike-sharing platform in a Brazilian city (source: Tembici)

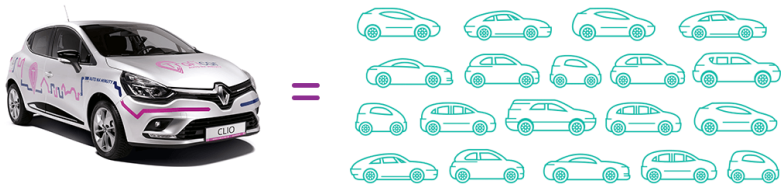

Figure 15: One shared car can be substituted for many private cars. (source: https://www.traficar.pl)

crowded car-parks and busy city centers. This measure reduces the number of private cars in use, especially for single occupancy trips. Unused parking spaces can be turned into pedestrian-use areas. As car sharing market is mostly privatised, costs of implementation fall on the car sharing companies.

With alternative means of transport available, many people would choose the opportunity to use a bike, an electric scooter, or a car. Reducing the number of single occupancy trips. Usage of green energy to propel the vehicle, makes this solution environmentally friendly and sustainable. Scooters and new cars used by car sharing companies are often electricity-powered. This is a counterweight to old diesel powered cars driven by some citizens. A shift from motorized individual transport to more sustainable modes of transport is needed, and an introduction of such possibilities is the first step, which has to be taken.

Creating space and infrastructure for shared mobility means can be used to pedestrianize some areas, and increase overall satisfaction of its' citizens. It also diversifies the number of transportation modes. If increase of alternative transportation modes is needed, shared mobility should be implemented in at least minimal form.

Implementation problems

Car sharing solutions require roads and parking places, that in many cases already are built. This makes implementation of car sharing one of the cheapest measure from the city's perspective. To make usage of bike and scooter sharing practical, safe, and fast, new infrastructure may be required. This may require both financial and logistic effort.

Despite growing popularity of shared means of transport, there must be an effort put to promote that behaviour. For some of the citizens, renting a car may be considered hard, and effort on education in online payments, and usage of such shared cars must be made. Local car sharing and bike rental companies may find such opportunity rewarding, and may be willing to join forces in citizens education.

Examples

Mobility Management at campuses – the case of Camosun College (Victoria, Canada)

In one of the Canada's Colleges, there was a "Transportation and Parking Management Plan" created, which originated from parking challenges. The transportation plans are prepared regularly every three years. They include objectives and measures to indicate success or failure of a plan. The university has established partnership with local car sharing operator, and dedicated special parking spaces for carpoolers. As a result, there was a decrease of single occupancy vehicles observed from 5.4% to 3.8% in years 2010 to 2012. From year 2008 to year 2013 vehicle use dropped from 63% to 49% [9].

Mobility management at a Science and Innovation Park - Skolkovo Foundation (Moscow, Russia)

As a big research center, many employees and clients travel to and from Skolkovo - Science and Innovation Park. All development work must be executed according to Green Code - a set of rules and urban development standards guaranteeing environmentally friendly expansion. There was

Figure 16: Park and ride in Gdańsk (source: https://gzdiz.gda.pl)

a collaboration established with local operators such as: Belkacar, Delimobile, YouDrive. All of these companies offer electric cars. Moreover, bike sharing service at relatively small price is available. Monthly cost of a rental is 566 Russian Rubles [9].

Correlated measures

Park & Ride

Park & Ride (P&R) parking area (fig. 16) is an inter-modal connection point between private vehicles and public transport [21]. It could be viewed as an inclusive means of transportation, because it allows people from places with a lack of public transport system, or without a convenient connection to their final destination, to have an opportunity to use mass transit.

There are three types of P&R parking areas distinguished based on their location [22]:

- remote, which the drivers use at the beginning of the journey, usually in the suburban area;
- peripheral, which is intended for use by drivers when nearing end of their commute, usually at the edge of the municipality;
- local, which is situated near main transport corridors, mostly in the non-residential areas.

Reasons for introduction

City centres and other popular daily destinations like business centres cause much traffic, especially in the rush hours. These places usually do not have space for increasing traffic and parking capacity. With P&R system, there is the possibility of shifting traffic to the outskirts of the cities. Already existing P&R parking areas are primarily used in the working days for job-related journeys [21] [22], so P&R system could be a reasonable choice to reduce traffic near working areas.

The second reason, is to make public transport possible for people from suburban or rural areas, where there is no public transport, or it has low frequency. It could provide them with a more convenient way of commuting and lower their daily expenses.

The third reason, could be lowering car traffic and increasing use of sustainable means of transport, while reducing the negative impact on the environment. Without doubts, it will lower the pollution level in the city centres, but this could be tricky because it increases traffic in the outskirts and there are examples that creation of P&R parking areas increased the overall number of car trips, when people who used only public transport before, now also used cars [23]. This effect is related primarily to peripheral P&R parking areas, but doesn't affect the remote type [23].

Implementation problems

The main problem to overcome, is finding a good location for P&R parking areas. Many studies on methodologies address this topic, and they include a wide range of variables. Studies range from using planner experience to mathematical models. One of the essential aspects, is identifying the catchment area to get a better view of potential users [24]. However, one thing is sure, it should be located in close proximity to the public transport system and major roads.

The demand of the P&R parking areas becomes part of the demand for public transport [24] and the most crucial factor for P&R users is the quality of public transport, which includes comfort, frequency and speed [21] [23]. This means that there is a need to thoroughly look at the public transport, as it has a massive impact on the success. More about it is in chapter Public transport improvement

When P&R parking area is located near public places, such as shops, business parks, and universities, it could be treated as regular parking by people visiting these places. On the other hand, when the same amount of parking spaces are kept in the city centre, there is a lower likelihood that drivers will use P&R parking area. It is recommended, that P&R should substitute for city-centre parking, and with the creation of it, a similar amount of the parking spaces should be removed from the city centre [6].

The last thing that should be kept in mind, is that creating a P&R parking area could fix one problem of heavy traffic by making the second one in the outskirts. It is necessary to consider the capacity of the nearby roads upfront, and set the proper size of the parking lot. The second factor to consider during the determining size of parking, is the occupancy of public transport and how more people can be taken over. It is reasonable to install bike racks as well, to provide an opportunity to use this type of transportation.

Examples

A modern tram network as the key element of an urban development and mobility strategy (Strasbourg, France)

In Strasbourg, there were 4000 parking spaces developed overall on the P&R system. They are most commonly located near tram stops and cost of a parking fee includes a tram ticket to be used on the same day. In 2015 5% of the tram users were using P&R parking areas on the weekdays, and on the Saturdays, this number increased to 15% [8].

Correlated measures

Push measures
Paid parking zones; Restricted zones; More space for pedestrians; Assigned parking spaces.

Pull measures
Improving bikeability and walkability; Information and promotion campaigns; Shared mobility; Public transport improvement; Cooperation with private companies.

Public transport improvement

Having efficient public transport, that meets the needs of residents, is undoubtedly an essential aspect of mobility management. A key aspect of public transport is a schedule tailored to the needs of residents.

Enlarging the network of connections may help to persuade some people to use public transport. With more innovation, more people are reluctant to use public transport, so when adequate direct connections are provided, citizens are more encouraged to use public transport.

During rush hour, if the bus is in the same traffic jam as cars, people are more likely to use private cars because they provide more comfort in comparable travel time. A method to speed up the public transport, is to create dedicated bus lanes (fig. 17), thanks to which buses do not stand in traffic jams with other vehicles.

The mean of communication that is usually resistant to traffic jams, is trams. Usually, it travels on a separate traffic lane, separated from cars. However, the advantage of the trams may be offset by inadequately synchronized traffic lights. A method to increase travel efficiency by public transport, is the appropriate management of traffic lights, which prioritizes the means of public transport, or is synchronized with the timetables of buses and trams.

An essential part of the collective transport experience is the ease of payment. Nowadays, more and more people are moving away from paper tickets, favouring digital payments. It is a greener and more convenient solution. In addition, an important aspect is that in one application, there should be a possibility of paying for various means of transport, so that the user does not have to switch between multiple applications when changing mode of transport. An interesting solution are combined season tickets for the services of many carriers, which makes it easier for the user to manage their payments.

Reasons for introduction

Main reason for improving public transport is to offer various valid alternatives to private cars, and creating a sustainable mobility scheme. Convincing drivers to travel by massive transit systems reduces the traffic and takes off leverage from car-parks, reducing the time needed to find a parking spot.

Modern busses and trams are powered by electricity. This impacts the pollution of given areas by reducing greenhouse gas emissions. Reduction of the environmental impact of home-to-work mobility can be achieved by this measure.

Implementation problems

There are a few problems that shall be taken into account when the implementation of this measure is planned.

It is challenging to create communication time schedule for zones with many small and medium-sized businesses which suits all of them. Research may be conducted to make sure newly implemented changes fit to employees needs, as those people are the target group of the undertaking. The employers may not find upgrading the communication system rewarding for them, from the marketing and economic point of view. An effort must be made to educate stakeholders and change their mobility culture. Furthermore, there may be a need for a lobby, to convince local public transport organisation for expanding the number of connections in the area.

Examples

Ropka tööstusrajoon - a Public – Private Partnership for Mobility Management (Tartu, Estonia)

Due to lack of entities responsible for public transport management, local mobility group was created. It consisted of multiple members from different groups: NGOs, transport experts, local administration and representatives of local businesses. Main aim of the group was to analyses mobility situation and create a plan for making the improvements. The plan focused on various aspects, not only planning physical connections, but also giving attention to educating and informing potential clients. [9]

Correlated measures

Push measures
Restricted zones; More space for pedestrians; Parking standards for new investments; Assigned parking spaces.

Pull measures
Information and promotion campaigns; Park & Ride; Cooperation with private companies; Subsidizing alternative means of transport.

Cooperation with private companies

Another good practice is to contact private companies to cooperate to create a positive shift in mobility behaviour.

Reasons for introduction

In places with a high number of small and medium-sized enterprises with diverse work schedules, it is challenging to know the needs of their employees. Without this knowledge, it could be hard to choose relevant measures. Finding out the demands of their employees for the means of transport and destinations of their everyday commutation could be beneficial.

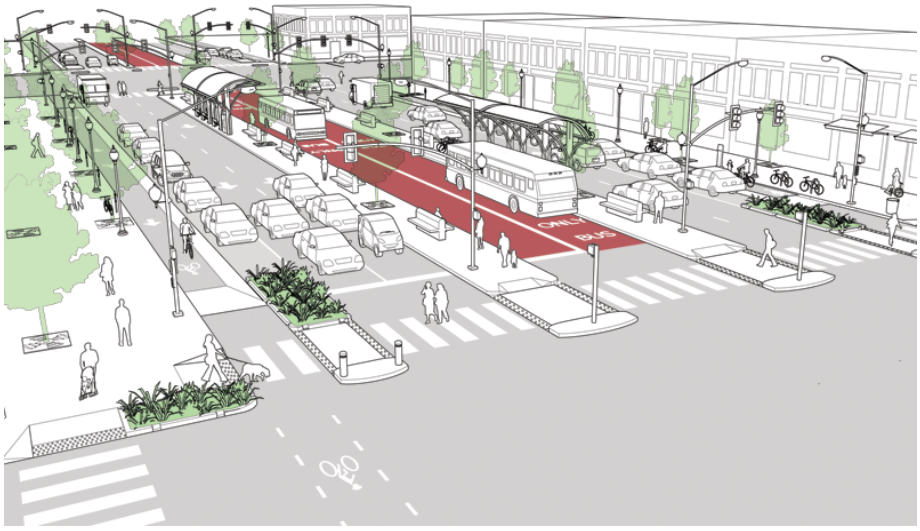

Figure 17: Dedicated median bus lanes (source: https://nacto.org/)

When an established body is responsible for communication with companies, it is easier to inform about the possible use of alternative means of transportation. There is also a possibility of encouraging employers to introduce incentivising measures for sustainable modes of transport.

Implementation problems

It could be challenging to communicate with many small- and medium-sized enterprises. Companies may consider contact attempts as another unnecessary obligation. The initial problem may also be a lack of sustainable mobility culture among local stakeholders.

Examples

Ropka tööstusrajoon - a Public – Private Partnership for Mobility Management (Tartu, Estonia)

Ropka tööstusrajoon is an industrial zone of Tartu, with a high number of small and medium-sized enterprises. A local mobility group formed there, in cooperation with private companies, created and implemented a mobility plan for this district. It resulted in better accessibility with sustainable transport modes, raised awareness of different transport options, provided modal shift through them, and created sustainable mobility culture among the local stakeholders [9].

Correlated measures

Push measures
Paid parking zones; Restricted zones; More space for pedestrians; Assigned parking spaces.

Pull measures
Improving bikeability and walkability; Information and promotion campaigns; Shared mobility; Public transport improvement; Subsidizing alternative means of transport.

Subsidizing alternative means of transport

One of the most direct measures of encouraging the use of sustainable modes of transport, is subsidizing their costs. It ranges from providing free or discounted tickets for public transport, through providing bike repairs for free, to subsidizing the purchase of bicycles.

Reasons for introduction

When the cost of coming by car is less or equal to riding by public transport, people could prefer to come by their vehicle because it is probably more convenient. Reducing the cost of public transport could positively affect this situation.

Using a bicycle is less expensive than cars, but it also involves costs, and inadequate maintenance of a bicycle can be dangerous for its user. It may be a good idea to create yearly, or more frequent, campaigns where there is a possibility to inspect the bike for free or for a small fee. Such actions are usually carried out in workplaces.

Some people could not afford to purchase bikes. When there are no bike-sharing possibilities, then purchasing or subsidizing the purchase of a bike could change the mobility behaviour of these people to a more active means of transport.

Implementation problems

For all of the methods of subsidizing alternative means of transport, the main problem is defining groups of people who will benefit from this policy. These will usually be the groups of the less wealthy people. For smaller entities, it is also reasonable to finance a sustainable mode of transportation for all of their employees.

Examples

Mobility concept of the Technical University of Graz following the Push&Pull principles (Graz, Austria)
– All of the measures described in this section were introduced at the Technical University of Graz. First of all, they established financial support for public transport tickets for people who would fulfill specified criteria. Additionally, university subsidizes buying bicycles for their employees, and each year offers free of charge bike repairs at the start of the biking season in the spring [8].

Free Metroshuttle financed by a ring-fenced parking reserve (Manchester, UK)
The city of Manchester provides free of charge bus. The service links all the city centre railway stations, main car-parks and many bus and tram stops (fig. 18). Large part of cost of this project is financed from parking fees [8].

Correlated measures

Pull measures
Improving bikeability and walkability; Information and promotion campaigns; Public transport improvement; Cooperation with private companies.

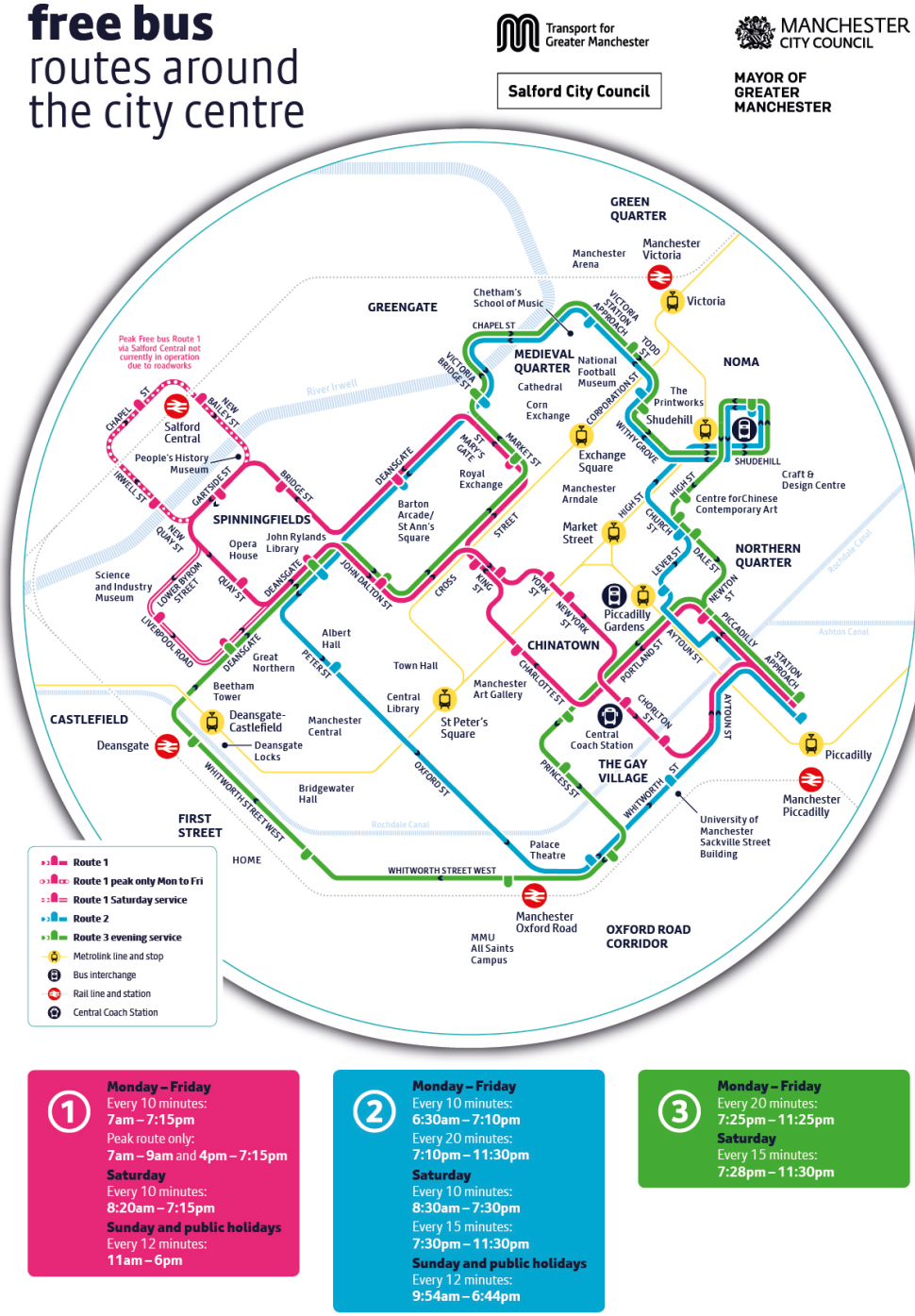

Figure 18: Map of the free bus routes around the city centre of Manchester. (source: https://tfgm.com)

Digital parking

Digital parking includes measures that improve the situation both for management of the parking and the drivers' situation. For the first group, they provide tools which give more insights into the current and historical situation. For the drivers, they help to find a free spot and reduce the time of cruising during the search for a place to park or allow an easier payment for the parking.

Reasons for introduction

Moving away from paper tickets for parking can reduce the costs of running parking lots and makes life easier for drivers, since they do not have to search for the parking machine to get a ticket and walk back to the car to leave the ticket behind the windscreen. When a user has to provide his car's license plate number, this opens up, e.g. the possibility of using more advanced forms of enforcement such as scan-cars.

Parking managers would probably benefit from using tools which give more insights into the current situation and historical statistics. This would allow them to notice unusual situations and adequately react in real-time. Historical data would also allow to see some patterns and have better knowledge about how parking is used.

Creating the desired changes in driver behaviour, such as using certain parking lots and not driving into an already crowded place, can be provided by informing about the number of free spaces in real-time. Then the driver, seeing that he will not find a free spot in a given place, will go immediately to another location and not increase the congestion unnecessarily.

Implementation problems

Providing real-time parking occupancy for drivers and management requires a method of counting cars. Technology for this could differ from cameras, with or without plate recognition, through LIDAR to sensors on the ground. There is also a possibility to set a car location in the mobile app during payment for the parking.

When creating a parking management system, it is also worth considering opening the data contained therein. It is then necessary to ensure their anonymity and security, so that they are not used in a dangerous way.

Examples

On-street parking Enforcement with digital parking permits (Utrecht, Netherlands)
The city of Utrecht creates a parking system where there is no need for paper tickets. Drivers only have to type their number plate on the ticketing machine, there is no need to go back to the car. Residents with long-term parking permission also have to register their number plates. Enforcement checks if the car's number plates are registered in the system and have a valid parking pass [8]. It also allows for better enforcement with "scan-cars" shown on figure 19. The payment rate increased 10% in 2010-2012 (from 68% to 78%). The number of enforcement officers decreased from 63 in 2008 to 45 in 2012. The number of visitors to the parking desk decreased 35% in 2008 (before the new system) and 2011, from 28,409 to 18,260 visitors per year. Data is now used during the decision making process for new policies [8].

Figure 19: Example of scan-car in Amsterdam (source: https://algoritmeregister.amsterdam.nl)

On-street parking enforcement and management through a sensor system (Treviso, Italy)
In Treviso, there is a system where each parking spot has its parking sensor. It is able to detect the presence of a vehicle. Driver needs to provide the number of parking bay where he parked. There is no need for paper tickets. If the user wants to extend the parking time, he can do it from any other parking meter in the central area (there are 54 parking meters in the whole area) or via mobile phone app by indicating the number of the parking bay where they parked the car [8].

Correlated measures

Push measures
Paid parking zones; Restricted zones; Parking enforcement; Assigned parking spaces.

Pull measures
Information and promotion campaigns; Shared mobility; Park & Ride; Public transport improvement; Cooperation with private companies;

Conclusions

There is a variety of push&pull measures that can be implemented. To ensure the best outcome and impact of implemented measures, a good practice is to establish a ”mobility group”. Such a group would be responsible for the implementation of the changes, from the beginning to its end. This group should perform a wide range of tasks, with the main goal of creating a sustainable and reliable communication system, with respect to all stakeholders' interests.

There should be a wide research analysis performed on current state of the mobility situation. Needs of the citizens must be assessed. The developed action plan must be feasible. It should be able to accommodate all requirements depending on problems to solve, current situation, and people's needs. Development of a system, that in the long run does not bring profit to the citizens, tourists and passersby, can be considered a failure.

In many cases, introduction of one particular measure may be not enough to reach established goals. Fortunately, there is a handful of them, and what is more important, they complement each other. Many of them are able to solve similar problems, while serving completely different functions for the society. When choosing measures for an implementation, it is wise to keep balance between push and pull measures used. Push measures, in their nature, are directly interfering with people's mobility habits. Applying only push measures may raise frustration among citizens, as they may find the changes too obstructive. On the other hand, usage of pull measures may be too soft, leaving the mobility situation untouched. A good practice is to consider implementation of at least one pull measure per each push measure implemented.

For mobility specialists, the need for changes may seem obvious. It is important to keep in mind, who is the target group of the changes. These people may not find changes attractive or, at the very least, profitable. Hence, there should be a huge effort made on education and information propagation. Change of the mindset and mobility behaviours is the real measure of success. When the citizens understand why there is a need for change, and know how to enjoy the fruits of the changes, they will be more willing to accept those, and adapt.

References

[1] Department of Economic United Nations and Population Division (2019) Social Affairs. World population prospects 2019: Volume i: Comprehensive tables.

[2] Department of Economic United Nations and Population Division (2019) Social Affairs. *World Urbanization Prospects 2018: Highlights*.

[3] Car occupancy, england: since 2002. https://www.gov.uk/government/statistical-data-sets/nts09-vehicle-mileage-and-occupancy, September 2021. ONLINE, accessed: 27.04.2022.

[4] Emily Nagler. Standing still, July 2021. RAC Foundation.

[5] Eren Inci. A review of the economics of parking. *Economics of Transportation*, 4(1):50–63, 2015. Special Issue on Collective Contributions in the Honor of Richard Arnott.

[6] Robert Pressl and Tom Rye. Good reasons and principles for parking management. park4sump.eu, January 2020.

[7] Tomasz Zwoliński. Parking policies enabling new mobility solutions – results and acceptance. EPA-POLIS Webinar, October 2021.

[8] Tom Rye, Giuliano Mingardo, Martina Hertel, Jörg Thiemann-Linden, Aljaz Plevnik, Tomasz Zwolinski, Simon Dale, Robert Pressl, Laurence Bannerman, Peter Vansevenant, Jan Gheldof, Juan Carlos Escudero, Gerhard Ablasser, and Marta Carvalho. Catalogue on case studies for parking management solutions. push-pull-parking.eu, May 2015.

[9] United Nations Economic Commission for Europe. *Mobility Management. A guide of international good practices*. Geneva, 2020.

[10] Silviya Barrett, Joe Wills, and Mario Washington-Ihieme. Reclaim the kerb: The future of parking and kerbside management, March 2020.

[11] Jürgen Gies, Martina Hertel, and Susan Tully. Parking standards as a steering instrument in urban and mobility planning. how to make parking standards more sustainable, February 2021.

[12] Mehdi Nourinejad and Matthew J. Roorda. Parking enforcement policies for commercial vehicles. *Transportation Research Part A: Policy and Practice*, 102:33–50, 2017. SI: Freight Behavior Research.

[13] Giulia Reggiani, Tim van Oijen, Homayoun Hamedmoghadam, Winnie Daamen, Hai Vu, and Serge Hoogendoorn. Understanding bikeability: a methodology to assess urban networks. *Transportation*, 06 2021.

[14] Guidance for cycling projects in the eu. https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/cycling/guidance-cycling-projects-eu_en. ONLINE, accessed: 27.04.2022.

[15] Julián Arellana, María Saltarín, Ana Margarita Larrañaga, Virginia I. González, and César Augusto Henao. Developing an urban bikeability index for different types of cyclists as a tool to prioritise bicycle infrastructure investments. *Transportation Research Part A: Policy and Practice*, 139:310–334, 2020.

[16] Conor Reynolds, M. Anne Harris, Kay Teschke, Peter Cripton, and Meghan Winters. The impact of transportation infrastructure on bicycling injuries and crashes: A review of the literature. *Environmental health : a global access science source*, 8:47, 10 2009.

[17] Rebecca Mayers and Troy Glover. Safe cycling space: How it is produced and experienced by cyclists. *Journal of Leisure Research*, 52:1–22, 02 2021.

[18] Inaian Pignatti Teixeira, Antônio Nélson Rodrigues da Silva, Tim Schwanen, Gustavo Garcia Manzato, Linda Dörrzapf, Peter Zeile, Luc Dekoninck, and Dick Botteldooren. Does cycling infrastructure reduce stress biomarkers in commuting cyclists? a comparison of five european cities. *Journal of Transport Geography*, 88:102830, 2020.

[19] Lieze Mertens, Sofie Compernolle, Benedicte Deforche, Joreintje D. Mackenbach, Jeroen Lakerveld, Johannes Brug, Célina Roda, Thierry Feuillet, Jean-Michel Oppert, Ketevan Glonti, Harry Rutter, Helga Bardos, Ilse De Bourdeaudhuij, and Delfien Van Dyck. Built environmental correlates of cycling for transport across europe. *Health Place*, 44:35–42, 2017.

[20] Europeanmobilityweek. `https://mobilityweek.eu/the-campaign/`. ONLINE, accessed: 27.04.2022.

[21] Elżbieta Macioszek and Agata Kurek. The use of a park and ride system—a case study based on the city of cracow (poland). *Energies*, 13(13), 2020.

[22] Giuliano Mingardo. Transport and environmental effects of rail-based park and ride: evidence from the netherlands. *Journal of Transport Geography*, 30:7–16, 2013.

[23] Vladimir Karamychev and Peran van Reeven. Park-and-ride: Good for the city, good for the region? *Regional Science and Urban Economics*, 41(5):455–464, 2011.

[24] Jairo Ortega, János Tóth, and Tamás Péter. Planning a park and ride system: A literature review. *Future Transportation*, 1(1):82–98, 2021.