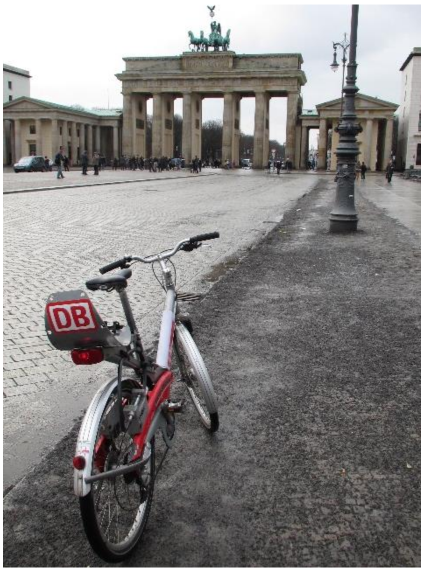
RICARDO-AEA

# Public Bike Sharing

## Final Guidance Note



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# 1 Introduction

The purpose of this note is to provide short and simple guidance on public bike sharing (PBS) for ECF's networks who are interested in the concept, with a focus on the relationship between PBS, the role of emerging technologies and EU policies. More specifically, it aims to provide some user-friendly information on:

- What are the policy implications and advantages of the latest PBS technologies currently being developed or implemented in terms of EU new technology policies and investments?
- Can a stronger case be made for PBS as a new technology in order to better benefit from the EU policy framework and funding streams that support new technology research and deployment?

To do this we examine:

- What new technologies a policy-maker / funder / operator should be aware of in the context of PBS;
- What their respective merits and challenges are in order to inform the design of the scheme.

The note is structured into four sections: the first briefly presents the concept; the second summarises the main practical considerations to bear in mind when considering the implementation of PBS, including costs, business models and key enablers and barriers; the third investigates the latest technological developments and their relative strengths and weaknesses; and the fourth summarises the key implications and advantages of PBS in terms of EU policy.

The briefing can be used to encourage greater investments in PBS by making EU policy makers and transport funders aware of the possible relationship of PBS to areas such as Intelligent Transport Systems and electric mobility; and to support the work of researchers, developers and businesses in the sector by signposting possible EU-level policy support and even funding for their work. It should also give city managers a brief overview of how PBS can be integrated into proposals for funding as part of developments such as SMART Cities and Intelligent Transport Systems.

It is complementary to ECF's much wider portfolio of advocacy for cycling in general.

ECF's vision for the whole of cycling (not just public bike sharing) is that levels of cycling could double in the EU with the right policies and investments. This briefing was commissioned as a resource to help achieve that vision.

# 2 Background – a brief overview of PBS

## 2.1 Key features

Public bike sharing schemes are short-term urban bicycle rental schemes that enable bicycles to be picked up at any self-serve bicycle station and returned to a similar point, either at the point or origin or elsewhere in a network. PBS offers a low cost, flexible transport option particularly adapted to cities given the short distances usually travelled.

In most systems, after paying a daily, weekly, monthly, or annual membership fee, riders can pick up a bicycle locked to a well-marked bike rack or electronic docking station for a short ride (typically an hour or less) and return it to any station within the system. Most schemes offer the first 30 minutes for free and operate 7 days a week, 24 hours a day, all year round (although some do close at night and in the winter months).

It is worth noting that there can be variants to the conventional PBS: the schemes can be limited to one site (e.g. university campus), one target group (e.g. commuters), or one use e.g. cargo-bike sharing. Finally, aside the 'paying' model, there are marginal schemes which rely on exchange such as peer-to-peer bike sharing but this is not common.

## 2.2 Implementing PBS

There are a number of elements to take into account when assessing the possibility of implementing PBS. These elements are presented in this section.

### 2.2.1 Delivery model

There are a range of business models in place for the implementation and operation of PBS depending on the involvement of the public and private sector. They are broadly summarised in the table below.

| Lead organisation | Business model | Examples |
|---|---|---|
| **Public-private partnership** | Provide & operates system in exchange of advertising rights | Cemusa, JC Decaux, Clear Channel |
| **Local authority** | Contracts with a provider or designs, owns and operate the system | Aarhus, Tehran |
| **Public transport operator** | Provides & operates system to enhance public transport services | BIXI (Montreal), OV Fiets (Netherlands), Velos Jaunes La Rochelle |
| **For profit enterprise** | Private sector company operating with minimal government involvement | Hamburg (NextBike) |
| **Not-for-profit organisations** | Associations / charities operating with the support of local authorities | Copenhagen |

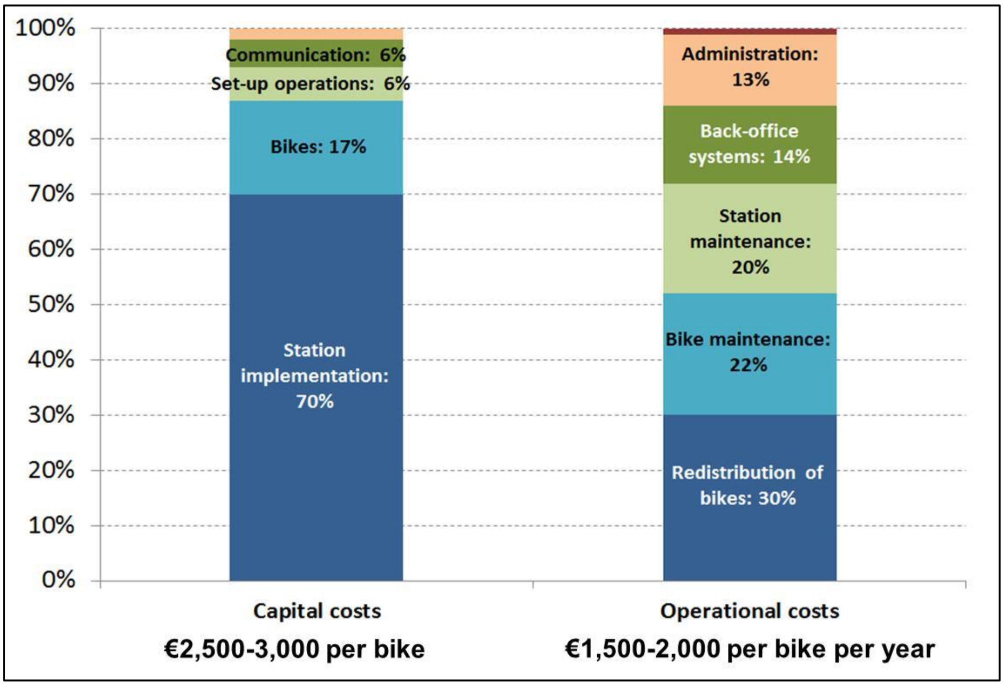
Among these, the first two are more pertinent to large-scale systems, while the latter two are characteristic of small-scale systems.

The most common approach overall relies on leadership from local / city authorities. In most cases, a contract between the municipality and the operator of the scheme is agreed. In 2010, 27% of the world's public bike sharing schemes were operated by local Governments, followed by JC Decaux (23%) and Clear Channel (16%). Having approved of the concept, local authorities then tend to be involved throughout all stages of the project: consulting with stakeholders and individuals; commissioning feasibility studies from consultants to evaluate costs and technical requirements; contracting an operator or procuring the bikes and stations themselves, depending on the business model chosen. Operators should be involved as early as possible in the process in order to make use of their technical and operational know-how.

### 2.2.2 Costs and funding

The implementation costs vary depending on the scheme size and design. OBIS produced some broad estimates of total costs and of the structural breakdown of investment and operating costs based on the Barcelona scheme. Data on capital costs for Paris and Lyon supported these estimates. There are presented below for illustrating purposes.

***Figure 1 PBS cost structure***




Source: OBIS

As mentioned earlier, there can be significant variations depending on the technical features of the model (technologies, network size, logistics, city-specific characteristics). For instance, a scheme without stations or a scheme with stations which do not need any groundwork (e.g. solar or battery powered stations) can be implemented at a fraction of the costs of conventional station-based schemes. The Velib experience in Paris also showed that there can be unexpectedly high costs linked to theft and vandalism.

In order to cover the costs of implementing PBS, there is a range of financing models. The main financing sources from an operational point of view are registration charges and usage charges paid by the customer. As many systems offer a 30-minute-period free of charge for each ride, registration charges are most likely to be the most important income source rather than the usage charges. As a result, subsidies are needed for most PBS schemes because revenues from the scheme hardly ever cover the operational and investment costs. Depending on the type of contract with the operators, scheme can be co-financed by direct subsidies, various advertising contracts, sponsorships (whole scheme, single components, stations or bikes), parking enforcement incomes or congestion charges. Capital investment to set up the scheme may require grants from local authorities, be funded by the operating partners or by a public private partnership of some description. Generally, local authorities should explore the possibility of blending different sources of income to help support the long-term viability of the scheme.

### 2.2.3 Key enablers for and risks to the success of a scheme

There are a number of aspects to take into account when designing a PBS scheme in order to maximise ridership and long-term viability. The table below summarises the key enablers and barriers to the success of PBS. This does not include broader risks and enablers for cycling such as road safety.

| Enablers |
|---|
| Scheme size and density as a successful scheme requires a well-developed network of stations. The location and density of the stations needs to be carefully considered in order to ensure that they are easily accessible; integrated with other transport modes; available at all strategic locations with high footfall such as commercial areas, cultural venues et hospitals as well as stations. |
| Availability of a safe cycling infrastructure incl. cycle lanes or paths, direction signs for longer cycle routes, different safety measures at places of interaction with cars (such as junctions) and pedestrians (such as zebra crossings and where cyclists pass bus stops), safe and secure cycle parking places. |
| User accessibility. This covers all measures taken to make the system easy to access, both in space and time. It covers the ease of the registration process; the density of stations and bikes; the rapid repair of malfunctioning stations and bikes; and the hourly and yearly opening times. |
| Bike and station design. Resilient and visible bikes are needed to weather wear and tear and deter theft. |
| Redistribution traffic in order to ensure a constant supply of bikes. |
| Wider transport policy. PBS should always be combined with other transport measures in order to be part of an efficient and sustainable transport system. This includes in particular the need for integration to the public transport, in terms of information (e.g. multimodal Info-traffic App in Lyon); physical infrastructure (i.e. stations); access and charges (with one card and integrated tariffs). |
| **Risks and barriers** |
| Financial viability. PBS relies on a mix of funding sources, all of which are vulnerable. In addition, costs can be under-estimated, especially those related to bike replacement as a result of theft and vandalism. |
| Topography and climate can limit the uptake of cycling. |
| Existing high levels of bike ownership and use tend to result in a low participation in PBS. |
| Compulsory helmet use can significantly hinder the success of the scheme. |
| Planning process and space limitations can create delays and constraints on the size and location of stations. |

# 3 Technology developments

There is a wide range of technology options for PBS depending on the level of investment available to the scheme operator and the utility to be delivered to the user. The emerging group of technologies is sometimes referred to as "4th Generation Public Bike Sharing", however because of the divergent nature of the different options we believe it is unlikely that one single development will be recognised as the future standard. Therefore the report avoids the use of one overarching term and instead provides an overview of the broad trends that are emerging.

## 3.1 Technology options – now and in the future

The table below summarises the key components of a PBS schemes and the different levels of technological sophistication which may be considered. The last column presents the most recent and emerging innovations.

***Table 1 – Levels of technology input for PBS***

| | Basic | Intermediate | Advanced | Emerging technologies |
|---|---|---|---|---|
| **Bikes** | Bikes with a conventional locks for securing at fixed stations | Unique, high-visibility design to deter theft<br>Robust parts to minimise vandalism or accidental damage, and decrease maintenance costs<br>Advertising space on bikes to offset scheme costs | Electric bikes and cargo-bikes included in the scheme to add to user choice<br>Child-size bikes and bikes with stabilisers to encourage use by children<br>Puncture-proof tires to reduce maintenance requirements and improve bike availability<br>Easy ergonomic adjustment – seat height adjusted via gas pressure cylinder (like office chairs) and handlebars that automatically adjust to ensure most ergonomic fit<br>Buttons on bikes to report faults instantly<br>Audible alarms to deter theft | Real-time **on-bike** information on navigation, train schedules, local activities, the status of the bike (including battery status) and the availability of nearby docks<br>GPS tracking to aid positioning and navigation systems, mitigate risk of bike being lost/stolen, or facilitate station-less scheme<br>Solar panels fitted to bikes to power electronic components<br>New e-bike technology with pedal generator<br>Pedal generator bikes which remove the need for a battery and charging infrastructure<br>Accelerometers to detect the bike being moved or interfered with without authorisation<br>Sensors to detect attempts to tamper with locks<br>Robust-yet-lightweight design through better engineering and use of more advanced materials |

| | Basic | Intermediate | Advanced | Emerging technologies |
|---|---|---|---|---|
| | | | | "Smart" bike locks that fit to standard bikes and connect with smartphone apps, allowing small-scale "social" bike sharing schemes where individual bike owners can offer their own bikes for hire |
| **Stations** | Fixed docking stations with coin operated locking system | Fixed docking stations with static information about the network, the rental system and the surrounding stations<br>The bike is locked electronically to a docking point<br>Stations offer space for additional advertising and information measures | Electronic advertising provided at rental points<br>'Wireless' stations that do not require groundwork – using solar power for electricity and 3G for networking<br>Simple concrete blocks for docking stations (coupled with 'smart' bikes that detect whether they are docked with RFID) that require no power – reducing installation and operating costs and facilitating quick expansion<br>Electric bike recharging<br>Real-time information provided at stations on parking spaces and bike availability across the whole network | Automatic bike diagnostics at the station<br>Mobile stations – that can be relocated by the operator to match demand at short notice<br>Stations that collect energy generated by users on their bikes and feed it back into the grid<br>Complete abolition of stations in systems based on free-reigning, GPS-tracked bikes, as a means of improving convenience and reducing installation costs |
| **User payment and access systems** | Person to person, on-site transactions | The rental process takes place at the rental unit (kiosk near the docking point, or at the docking point itself) using electronic payment methods such as smart cards, codes and keys | The rental process takes place at the rental unit and can include touch screen display, card reader, RFID-reader, printer, and keyboard<br>Bike booking via mobile phone call or text message<br>Payment via contactless bank card transfer and mobile phones<br>On-demand helpdesk support | Ticketing system integrated with wider transport network so that users with smartcards for other modes do not need to acquire a separate key or smartcard to access bike system<br>On-bike payment systems – for payment without kiosks or docks<br>Payment through use of account details held for other online purchases, such as amazon.com accounts |
| **Intelligent Transport System technology** | No use of ITS: coin operation and paper records | Software used to monitor bike and docking station status, inform redistribution and maintenance operations and strategy, and provide users with an electronic payment and billing system | Software used to automatically optimize redistribution efforts<br>Software used to support pricing that incentivizes redistribution by users<br>High quality real-time data on scheme use made available for third parties through an application programming interface (API) so that applications can be developed and improved independently from the operator<br>Real time information across modes for optimal journey planning | Integration of PBS data into online journey planners so that by default, details of bike hire options appear alongside alternative options for travel<br>Integration of cycle hire with wider fares system so that multimodal tickets can be purchased which cover PBS<br>Use of smartphone applications for journey planning and real-time information on the availability of bikes and stations<br>Use of smartphone applications to connect individual bike owners and users in a peer-to-peer bike sharing system – negating the need for a single public provider and allowing individuals to hire out their bikes for profit |

| | Basic | Intermediate | Advanced | Emerging technologies |
|---|---|---|---|---|
| **Bicycle distribution system** | Ad-hoc redistribution by conventionally-fuelled vans | Use of low emissions vehicles to improve the environmental impact of redistributing bicycles | User journey pricing differentiated by origin and destination to incentivize better redistribution by users<br>Operator's redistribution efforts based on optimization algorithms to reduce vehicle-km and improve the availability of bicycles and unoccupied docks | Dynamic pricing used to affect distribution by users<br>Abolition of docking stations (with "smart" locking technology fitted to bikes instead) as a means of solving the problem of docking stations filling up<br>Designation of "virtual docks" – areas where users are encouraged to return their bikes in schemes without fixed stations – as a means of tackling the unpredictable distribution of bikes |
| **Peer-to-peer** | Person to person rental at a local community level | Shared specialist vehicles such as a cargo bike shared by a user group | International peer-to- peer systems with a large client base, significant investment in technologies, insurance for users and lenders. | Integration with existing PBS or bike rental<br>Integration with car share or other peer-to-peer services. |

## 3.2 Benefits and shortcomings of PBS emerging technologies

This section explores the latest thinking on the emerging technologies listed above, and more specifically on their respective benefits and shortcomings which policy-makers should be aware of when finalising the design of a PBS schemes.

### 3.2.1 Bikes

Most PBS schemes currently in operation make use of bikes that cost considerably more than a basic roadworthy consumer model. This is because experience has shown that without upfront investment in making the bikes more durable and easier to maintain, they tend to break too quickly for the scheme operators to be able to keep a good number in circulation at a reasonable operating cost. Although it is essential to ensure that working bikes are sufficiently durable to keep them in circulation, increasing durability also tends to detract from user-friendliness to some extent: strong frames and encased parts make bikes heavier, and 'puncture-proof' solid rubber tires make the ride bumpier. A balance ought to be struck between making the bikes durable and making them pleasant to use.

New features such as electrification and on-bike information screens are being developed as a means of adding to the convenience and fun of the user's experience. These technologies have the potential to significantly boost ridership both by attracting new users and increasing the frequency of use amongst existing customers. For instance, battery assist may prove an important draw in hilly areas. However, these undeniable advantages must be assessed in the context of the additional costs they involve and, in the case of e-bikes, possible concerns about safety and speed.

Other emerging bike technology has been put forward as a means of saving costs. Security technology such as alarms may reduce the rate of theft and vandalism and therefore might partner well with bikes with expensive added features such as battery power (although the security features themselves also add to the up-front costs).

A more radical bike technology change with potentially very significant – but as yet unproven – implications for costs is "*smart locking*" bikes without docks. These bikes are fitted with locks and Global NavigationSatellite Systems (GNSS – such as GPS or the European Galileo), and users can "return" them into the system by locking them almost anywhere they like because their location is tracked and can be shared with other users. These systems remove or reduce the need for docking stations, which form a significant part of the upfront costs of a scheme. For instance, one bike share company estimated that their smart-locking bikes would cost approximately €1,900 each and prevent the need for €5,000 of heavy infrastructure per bike[1]. However, removing docking stations potentially generates other scheme costs and disbenefits – these are discussed in more detail in the next section.

| |
|---|
| There are therefore exciting developments ahead for bikes which can extend the appeal of PBS for users (e.g. e-bikes, smart locking, on-bike information). A scheme operator will make a final choice of bike technology depending on the net balance between the technology's marginal positive impacts on the bikes' durability and maintenance requirements, improved safety and security, and increased ridership against the potential increases in investment costs. If the additional investment costs involved do not significantly improve the uptake of PBS or reduce total scheme costs, investing in the latest bike technology will not be justified. |

[1] http://www.bikebiz.com/news/read/newcastle-s-scratch-bikes-releases-bike-sharing-technology-to-all/

### 3.2.2 Stations

Bicycle stations are a costly aspect of current PBS schemes (around 70% of capital costs and 20% of operational costs). They also take up space in areas (i.e. city centres) where it is typically a scarce resource. Some of the emerging technologies for PBS stations offer the potential to address these constraints.

One of the reasons docking stations are costly is that they usually require groundwork to install – the docks and payment kiosks need connecting to the electricity supply, and they are also often connected to a fixed line telecommunications system for relaying data to a central location. One solution to this is to provide docks without groundwork through use of solar panels for power and GSM[2] or wireless connection to a fixed line for networking. This allows the stations to be redistributed across the city in order to better respond to travel patterns and provide greater flexibility in the management of the network. However, not all areas will have enough coverage by the sun or the GSM network for those solutions to work, nor are the operating costs associated with those solutions negligible.

A more sophisticated option is to use new "smart-locking" technology and GNSS tracking on bikes and dispense with docking stations altogether. This system has been pioneered by Deutsche Bahn in several German cities as "Call a Bike" – the bikes are locked and unlocked with a system of authentication codes which the user obtains by calling a hotline. Parked bikes' locations are shared online so that users can find them on their smartphones. Such schemes require less investment in 'heavy' infrastructure and provide great flexibility for users. However, the overall cost and operational implications of the technology are not fully understood at this stage. Allowing users to leave bikes anywhere is likely to add to the burden of redistributing them. In addition, although abolishing docking stations may make things more convenient for some users some of the time, it also has the potential to make the scheme more *unpredictable* for users. Knowing that there are particular points at which you will usually be able to find a bike is arguably an important positive feature of PBS. Finally, getting rid of docking stations also requires the scheme owner to think about the likely consequences for tourist users – how will these people be made aware of the existence of the scheme and how to use it? How will they know where to find bikes – considering that many tourists may not be willing to pay data roaming charges on their smartphones when travelling abroad?

A third option for the future development of PBS schemes is a hybrid one, which involves providing some docking stations as well as the option of returning bikes into the system outside of docks – possibly at a higher price, to incentivise better distribution. Indeed, Call a Bike now provides basic concrete blocks as docks. The smart locking technology negates the need for power or networking in the docks so they are inexpensive to install and easily relocated or expanded.

The potential game-changer with regards to docking stations in PBS is their disappearance and replacement by on-bike locking systems allowing bikes to be left anywhere. While this is appealing in terms of flexibility, the net impacts of this approach in terms of costs and convenience of use is still unclear and further analysis would be needed before making a final decision to adopt this technology.

### 3.2.3 User payment systems

The user payment system for PBS needs to fulfil two functions: to provide some insurance against bike theft and damage through a deposit; and to collect payment for the use of the bike. In order to maximise use, from locals and tourists alike, this needs to be done as quickly and easily as possible. This is a now well-established area of technology although further developments can still occur in order to enable users to use mobile phone and contactless technologies.

[2] Global System for Mobile Communications, i.e. the system which includes 2G, 3G and 4G

The key area for development in user payment systems relates to their integration with other existing ticketing systems across the wider urban transport network. Doing this would increase the propensity of users of public transport to try out PBS and help to implement a seamless travel offer across non-motorized transport. This is a core tool to support a shift away from cars in urban areas. Efforts are being made in this direction but there are still significant barriers, mostly related to data handling, technology standards and costs. Integrated payment systems require: investment in appropriate software and hardware; designing interoperable standards and specifications across different systems; and cooperation between different operators to allocate revenues across modes.

The key area for innovation in user payment systems relate to integrated ticketing where significant progress is still needed but the potential benefits for PBS in particular and urban transport networks in general are great. It is an essential component of a city-wide, low carbon transport offer. At the moment, the most advanced system is the Taipei Card which combines all public transport ticketing, PBS and some low value purchasing power in a single travel card.

### 3.2.4 Intelligent Transport System technology

The current generation of PBS schemes increasingly rely on ITS as a means of improving their effectiveness and efficiency. This trend will only accelerate in the future as the Internet of Things (a technology and a market development based on the inter-connection of everyday objects among themselves and applications) continues to develop and be used to deliver smarter cities.

ITS technologies offer considerable benefits for both users and operators. For operators, ITS technologies help to better understand the use of the scheme and adapt it to customer needs by collecting and monitoring data on travel patterns and bike use. For users, ITS – and in particular, information on the availability of bikes and docks - makes the experience with the scheme more convenient and predictable. Users would now expect any mature scheme to have a website and application for mobile devices which provides real-time information on the availability of bikes and docks. However, it may be possible to forgo some investment in developing advanced features for apps if the data owners released the data publically along with an application programming interface so that entrepreneurial (or hobbyist) developers are free to create and release their own applications. Two considerations that should be borne in mind when doing this: (1) data will need to be anonymised before being released to the public, to comply with EU data protection law, and (2) serving very high volumes of requests for data can create significant bandwidth costs for data providers, so public access to the data may need to be throttled.

The increased use of ITS in cycling is both inevitable and desirable in order to maximise synergies with the wider transport system and benefits to users. The form which ITS technologies will take can be split into two broad types: on-bike technologies and applications for mobile devices. This needs to be carefully considered when designing the scheme as on-bike technologies can increase the risk of theft. In addition it is important to monitor the wider context of applications relevant to journey planning and cycling in order to avoid duplication as there is an increasing number of free and ‘grass root’ apps which already provide valuable information.

### 3.2.5 Bicycle redistribution system

The redistribution of bicycles constitutes one of the larger operating cost components of PBS, and can also offsets some of the environmental benefits of the scheme if bikes are transported by trucks with combustion engines. The use of natural gas or alternative fuel vehicles to provide redistribution services instead of petrol or diesel vehicles is therefore worth considering in order to reduce greenhouse gas and particulate matter emissions. The operator will need to consider the respective costs, operational challenges and long-term benefits of each type of power train according to local circumstances and policy priorities. There are small scale emerging examples of cargo-bikes being used to service and re-distribute bikes which is a positive integration with overall cycling promotional aims.

Optimising bicycle redistribution operations is a complex problem and at least some investment should be made in addressing the problem computationally (using software), although there is no ‘perfect’ algorithm for optimising redistribution and some amount of trial and error will still occur.

Another area of technology for redistribution relates to the use of differentiated pricing by origin and destination in order to reduce the costs of redistribution (by incentivising users to return their bicycles to more useful locations) without otherwise affecting the scheme’s operating costs. However, it could also affect the perceived benefits of the scheme – users may feel unfairly penalised if they find they are being charged significantly more than the average journey price in order to return their bike to a station more convenient to them. Dynamic differentiated pricing (i.e. that varies in real-time) might in theory provide even better redistribution, but it also detracts from the predictability of the scheme in the mind of users.

The main potential game-changer for redistribution systems would be the abolition of fixed docking stations. Such schemes would probably be wise to use some form of incentive structure that encourages returning bikes to common locations (such as low-tech bike racks, or even broadly defined street corner areas) to cut down on redistribution costs and improve the predictability of scheme.

# 4 Policy benefits of PBS

Public bike sharing has a key role to play as part of city-wide sustainable and smart transport networks. It provides a complementary transport offer to buses, trains and tramways and generate multiple benefits:

- It enables a mode shift away from cars which in turn helps to reduce congestion and transport-related air pollution and $CO_2$ emissions. By contributing to lower car use, PBS benefits the remaining car users as well as the wider city population at large through road congestion avoided, making the city more attractive to tourists and improving accessibility across all social groups.
- Finally PBS supports wider goals such as improving residents' quality of life and health, making town centres more attractive and liveable and creating local jobs for the installation and operation of the schemes.

In order to maximise its benefits PBS should be fully integrated in a city's public transport system and available to the widest number of people by being as user-friendly as possible. This can best be achieved through the use of ITS and by the inclusion of e-bikes in the scheme.

This is directly supported by our analysis of new cycling technologies within the EU policy context which concludes that ITS for cycling and electric bikes are the main areas which can support exponential uptake of cycling in the future.

ITS are a very strong, cross-cutting theme across EU policy as it can contribute to a large number of key objectives and strategic priorities including: sustainable and resource-efficient transport, smart cities, digital Europe, road safety and industrial leadership amongst others. The integration of PBS in ITS is critical for policy-makers to consider in order to maximise the value of their investment and the benefits of the scheme to users.

E-bikes will increasingly be included in PBS as a way to attract new users and extend the reach of the scheme by allowing riders to cover longer distances. They offer a larger potential for use as car substitutes in more sustainable and smarter cities.

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