Exploring the elements of effective public cycle parking: A literature review

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ABSTRACT

In the field of cycle policy and planning, alongside ambitions to expand segregated cycle networks, there is a push across many countries for increasing the quality and quantity of cycle parking as a critical component of cycling infrastructure. In order to support these measures, planning guides have been developed to guide the expansion and improvement of cycle parking facilities. A common feature of these policies and guides for cycle parking interventions is an absence of dialogue with, or reference to, peer-reviewed research investigating cycle parking and the potential effectiveness of different approaches to cycle parking planning. The use of such research could help to create cycle parking that may be more effective in attracting and providing for people cycling. On this basis, we engage in a literature review of a select body of cycling research whose findings could contribute to more effective cycle parking planning practice. Drawing on our review, we propose a number of tentative ‘elements’ for effective public cycle parking planning practice: visibility, protection, accessibility, proximity, integration, and diversification. These elements could be used in conjunction with local knowledge and context-specific assessment measures to maximise the potential effectiveness of cycle parking planning in different regions, and can be situated as part of a wider struggle to acquire public space for cycling within car-dominant contexts.

1. Introduction: cycle parking in policy and planning

Internationally, cycle parking is seen as a crucial component of facilitating and promoting cycling as a normal transport mode and as part of multi-modal journeys, as evidenced by the scale of its inclusion in international transport policies (e.g. Department for Transport, 2014; Director General for Passenger Transport, 1999; Federal Ministry of Transport & Digital Infrastructure, 2020; Le Gouvernement République Française, 2018; Tour de Force, 2017). According to Pucher, Dill and Handy (2010), both the quantity and quality of cycle parking is increasing sharply in various cities across Europe (see also, Buehler, Pucher, Gerike & Gotschi, 2017), North America and Australia, as well as some cities in Asia and South America. While much parking internationally is unsheltered, there is a movement toward sheltered parking and, in Northern Europe, toward guarded parking facilities, including substantial implementation of ‘bicycle stations’ in the Netherlands, Germany, and Japan in terms of both the quantity of stations and station capacity. Through the provision of cycle stations situated near public transit stations, Pucher et al. (2010) report that cycle parking is the single most important integration measure in both Europe and Japan for rail and metro.

As two distinctly low-cycling sites within Europe with considerable ambitions to promote cycling, the UK and Ireland provide two particularly fruitful contexts to closely examine the status and position of cycle parking policy and planning. Within the relatively low-cycling context of the UK, specific policy directives and planning guidelines promote cycle parking as a means to increase cycling journeys. In England, actioning aspects of the Walking and Cycling Investment Strategy (Department of Transport, 2017), the Department of Transport (2020b) reported the installation/upgrade of 3380 cycle parking spaces in numerous cities across the country in addition to installing 4000 cycle parking facilities near rail stations in order to facilitate multi-modal journeys. There are various high-quality planning guides for delivering cycle parking available, such as Transport for London’s (2016) ‘London Cycle Design Standards’. In Scotland, national policy aims to increase secure cycle parking and to engage in a concerted effort to use the provision of secure cycle parking facilities to increase public transport integrated journeys (Transport Scotland, 2017). For Wales, the national ‘Active Travel Action Plan’ (Welsh Government, 2017) posits an ambition to “consider and enhance provision for walkers and cyclists” (p. 32) when directly investing in any transport infrastructure projects along with making other funding mechanisms for active travel infrastructure and projects available. More recently, the Welsh Government (2021) have released a comprehensive ‘Active Travel Act Guidance’ document for constructing high quality active travel infrastructure. In this document, cycle parking planning is covered in detail in relation to selecting the quantity and cycle

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parking type for a given destination. Lastly, in Northern Ireland’s official cycling strategy (Department for Regional Development, 2015), cycle parking features as a fundamental component of the ‘Build’ pillar of a ‘three pillar’ approach to increasing rates of ridership, once again highlighting the importance of on-street public cycle parking, the availability of secure cycle parking options, and the need for cycle parking at public transport transfer locations to promote integrated journeys.

Examining the Republic of Ireland, the provision of secure parking constitutes one of the main objectives stated in the relatively dated National Cycle Policy Framework (Smarter Travel, 2009): Ireland’s first and only national cycle policy to date. In this policy paper, Smarter Travel (2009) argues that the supply of “well-located, plentiful, sheltered and secure parking facilities is as important to the cyclist as the provisions for moving cyclists” (p. 27). In this respect, as a form of cycle infrastructure, cycle parking should not be considered an optional add-on for cycle networks but instead as an essential cycling infrastructure for current and potential cyclists. Among other measures, this framework proposes the construction of high-capacity guarded bicycle parks and exploring paid cycle parking stations with associated cyclist services and amenities. In this way, aspects of the National Cycle Policy Framework are arguably more expressively ambitious than some recent policy and planning emerging from the UK (e.g., Department of Transport, 2014; Transport Scotland, 2017; Welsh Government, 2021).

Complementing the National Cycle Policy Framework (Smarter Travel, 2009), the ‘National Cycle Manual’ (National Transport Authority, 2011) provides a guide for planning cycling related infrastructure in Ireland, including cycle parking. Overall, the manual provides a good guide for planners unfamiliar with cycling parking interventions in terms of important factors to consider (e.g., proximity to destinations, likely durations of use; ‘convenience’, ‘cost’, and ‘quality’) and nuances to understand (e.g., cycle parking types beyond the unsheltered ‘Sheffield stand’); however, the manual is relatively inconsistent in terms of its guidance for cycle parking (e.g., where a stand should go versus a guarded compound) – prescriptive in some instances, relativist in others – and, alike other high-level planning guides (Transport for London, 2016; Welsh Government, 2021), no peer-reviewed evidence is cited to back up claims made regarding the likely effectiveness of cycle parking interventions.

More generally, cycle parking planning guidance appears to lack a coherent body of design principles that are widely and consistently used. This stands in stark contrast to cycle network infrastructure planning guidance, of which there is evidence that many design guides (e.g., Department of Transport, 2020a; Transport for London, 2016; Welsh Government, 2021), including the ‘National Cycle Manual’ (National Transport Authority (2011), adopt critical elements of the CROW Design Manual for Cycle Traffic (Groot, 2016); namely, that cycle network infrastructure ought to be designed in such a way that it is safe, direct, coherent, attractive, and comfortable for users. A gap in distinctive cycle parking design principles can be seen, for example, in the Welsh ‘Active Travel Act Guidance’ (Welsh Government, 2021), which appears to draw on CROW cycle network design principles for cycle parking despite the arguably very different functions of both infrastructures. Similarly, Van der Spek and Scheltema (2015) refer to CROW principles in considering how to plan optimal cycle parking in the Netherlands. The difficulty to decisively determine what elements or design principles should be incorporated in the planning of effective cycle parking is apparent in this article, as the authors refer a wide range of factors to consider but do not appear to offer a consolidated framework for good quality cycle parking planning. In this respect, there appears to be not only an lack of peer-reviewed research being used in cycle parking planning policy and guidance, but also a dearth of well-established and widely-endorsed cycle parking specific planning principles to consider.

Perhaps one explanation for this apparent policy and planning neglect for cycling parking relative to cycling mobility infrastructure is that, outside of high-cycling contexts, cycling is not considered to be a legitimate form of utilitarian transport relative to other modes, and thereby may not be considered a mode that requires robust parking facilities (Aldred, 2012; Bonham and Cox, 2010; Petzer, Wieczorek & Verborg, 2021; Van Der Meulen & Mukhtar-Landgren, 2021). This is evidenced by policy and planning representations of cycling with leisure journeys (which of course may not involve an end destination) and slowness (Aldred, 2012; Bonham and Cox, 2010; Van Der Meulen & Mukhtar-Landgren, 2021); reducing the externalities of the car and promoting health, rather than enabling transport accessibility (Aldred, 2012; Van Der Meulen & Mukhtar-Landgren, 2021); and local rather than nationally strategic transport objectives (Aldred, 2012; Van Der Meulen & Mukhtar-Landgren, 2021). Van Der Meulen and Mukhtar-Landgren (2021) have also alluded to the lack of quantification of accessibility provided by cycling relative to driving and rail transport as evidence for cycling’s marginalisation as a strategically important transport mode in Sweden, where both accessibility and its measurement are major components of national transport policy.

A prevailing conception of cycling as a transport mode of marginal strategic significance is also reflected in the weakness of official spatial allocation mechanisms for cycle parking within the EU relative to car parking. Examining the relatively lower-cycling contexts of Birmingham and Brussels, Petzer et al. (2021) has revealed how the regulatory mechanisms for cycle parking allocation have historically been weak, whereas car parking allocation has been supported by a multitude of legally binding ‘parking minimums’ for new developments; Amsterdam, on the other hand, demonstrates a reversed scenario, in which car ‘parking maximums’ have been nationally instituted, while cycle parking minimums have been enshrined in planning policy. Importantly, Petzer et al. (2021) observes that while car parking can generate significant revenue, cycle parking is often free. This may provide another partial explanation for the apparent reluctance to consider cycle parking as intensively as cycling mobility infrastructure; however, Petzer et al. (2021) points out that car parking provision is often heavily subsidized.

In light of national and international policy and planning directives to promote cycling, which explicitly highlight the importance of cycle parking but do not necessarily base their directives on peer-reviewed research evidence nor employ well-established design principles, the purpose of this review is to explore how existing peer-reviewed research relating to cycle parking can practically inform cycle parking planning efforts. In this respect, the review could complement and inform transport and cycling-specific policy in addition to cycle parking planning guidance at national (e.g., National Transport Authority, 2011) and local (e.g., Dún Laoghaire-Rathdown County Council Municipal Services Department, 2018) levels.

In relation to existing literature, this article provides a review of seminal studies examining cycle parking with a focus on guiding policy and planning practice. This complements the recent systematic review of cycle parking research by Heinen and Buehler (2019), which demonstrated empirical and methodological gaps within existing studies investigating cycle parking and the broad areas of consensus that appear across the literature (e.g., secure is generally favourable to unsheltered and unguarded; closer to destination is often preferred to more distant; free is often preferred to paid). Critically, this review is focused on extracting nuanced policy and planning insights from existing seminal studies rather than systematically reviewing the state of cycle parking research and how it can be advanced, which has already been comprehensively executed by Heinen and Buehler (2019).

First, we explain the approach taken for this literature review. Second, the review examines research that has been carried out investigating the role and impact of cycle parking in relation to cycle-public transport integration – an area that has been studied substantially. Third, the review outlines and discusses research focusing more generally on publicly available cycle parking. Fourth and last, the review presents a table of elements relating to effective public cycle parking that could inform cycle parking planning and that is based on the peer-reviewed evidence.
reviewed and situates these elements within a wider socio-technical consideration of the importance of cycle parking.

2. Method

The research question for this review was ‘How can cycle parking-related research guide cycle parking policy and planning?’ This question was used to help to identify key elements that policy-makers and planners might consider when planning cycle parking to either meet existing cycle parking demand, promote greater or more diverse cycle ridership, and/or increase public transport use by accommodating multi-modal journeys involving cycling. The databases of Science Direct, JSTOR, Taylor & Francis and SAGE were searched for peer-reviewed articles relevant to the research question due to their inclusion of various high-quality transport-related journals. Due to the scarcity of literature focusing on the area of cycle parking, the broad search terms of “cycle parking” OR “bicycle parking” OR “bike parking” were used. Article titles were initially examined in relation to their relevance to the research question and abstracts were next examined using various inclusion and exclusion criteria. Namely, articles selected were required to meet the following criteria: utility cycling as focus, cycle parking as significant variable or focus, public cycle parking, empirical focus. On the other hand, articles were excluded for consideration on the basis of the following criteria: station-based bike sharing, bike sharing focus, school parking, residential/private parking, methodological focus. Importantly, numerous methodologically focused articles were identified that were relevant to the research question broadly defined; these articles propose promising methods to aid the planning of cycle parking facilities based on various criteria (e.g., Fazio, Giuffrida, Le Pira, Inturri & Ignaccolo, 2020; Veillette, Grisé & El-Geneidy, 2018; Zhao & Ong, 2021). However, our aim was not to provide a sophisticated or innovative methodology for operationalizing various criteria for cycle parking planning but, instead, to derive in part how existing empirical research evidence can guide the development of numerous criteria for cycle parking planning policy and practice. With these grounds for inclusion and exclusion in mind, this search culminated in 24 articles which we review in this paper and use as a basis for our proposed ‘Elements of Effective Public Cycle Parking Planning’ section.

Overall, we examine two thematic study areas on the basis of their primary content: i) public transport integration, in which cycle parking is primarily examined as a measure to promote public transport integrated – and therefore multi-modal – journeys; and, ii) public cycle parking, in which cycle parking is explored more generally, such as in relation to cycling-only journeys. Our categories reflect a focus on publicly available cycle parking (versus private- or institutionally-specific parking) – hence the lack of inclusion of work, school, university and home parking (see Heinen & Buehler, 2019) – and are framed on the basis of the purpose of the studies (i.e., multi-modal integration, uni-modal journeys). In the following two sections, we review the selected studies in dialogue with our proposed ‘Elements of Effective Public Cycle Parking’ (Table 2), which originate from this review.

3. Public transport integration

There has been considerable research investigating cycle parking as measure for integrating cycling with public transport, particularly metro and rail (Appleyard & Ferrell, 2017; Arbis, Rashidi, Dixit & Vandebona, 2016; Bachand-Marleau, Larsen & El-Geneidy, 2011; Chen, Pel, Chen, Sparring & Hansen, 2012; Halldörsdóttir, Nielsen & Prato, 2017; Harvey, Brown, DiPetillo & Kay, 2016; Jonkeren & Kager, 2021; Krizek & Stonebraker, 2011; Martens, 2007; Mitra & Schofield, 2019; Molin & Maat, 2015; Paix, Cherchi & Geurs, 2021; Ravensbergen, Bulling, Mendonca & Garg, 2018; Weliwitiya, Rose & Johnson, 2019; Yang, Zhao, Wang, Liu & Li, 2015). Table 1 below details the diverse methodologies employed in these studies and the internationally varied contexts in which the studies were carried out. These different countries and regions have very different levels of cycling and cycle parking provision and, therefore, could each be seen to have specific cycle parking challenges and needs. It is notable that the vast majority of these studies are quantitative, which arguably demonstrates a lack of more exploratory and in-depth inquiries into the likely differentiated experiences and practices of cycle parking in relation to public transport integrated journeys, which could be extremely useful in informing future promotional efforts.

The need for protection (refer to Table 2) – primarily protection of one’s cycle from theft, but also protection from the natural elements – is one strong element that emerges as prevalent across numerous studies in the thematic area examining cycle parking as a public transport integration measure (Appleyard & Ferrell, 2017; Arbis et al., 2016; Bachand-Marleau et al., 2011; Chen et al., 2012; Halldörsdóttir et al., 2017; Harvey et al., 2016; Ravensbergen et al., 2018; Weliwitiya et al., 2019; Yang et al., 2015).

In a mixed-methods study based in New Jersey, U.S., Harvey et al. (2016) carried out a station infrastructure inventory of 214 stations, an intercept survey with 158 transit users, and a focus group with eight participants. Interestingly, Harvey et al. (2016) found major discrepancies in the supply and use of formal cycle parking across the sample of stations, in which only a small minority of stations had parking facilities that were being heavily used (i.e., only 13% of stations had cycle parking that was between 75% - 100% occupied). As Harvey et al. (2016) argue, this suggests that cycle parking installation does not equate to ‘build it and they will come’, as only about half of the bicycle parking spaces recorded in this study were occupied. However, ‘security’ was raised as a major built environment issue by participants in the intercept survey and focus group, particularly in relation to cycle theft; indeed, in the focus group, participants ‘recommended more and improved bicycle parking, as well as an increased presence of police or security’ (p. 58). In this respect, protection could be considered from the perspective of physically protective cycle parking facilities (such as cycle compounds or lockers) and protection through the professional guarding of cycles – both of which go beyond the protection provided by open cycle racks alone. This call for improved cycle protection – and evidence of a shared concern with insufficient protection from theft, but also shelter from weather conditions – is mirrored in the survey study of Ravensbergen et al. (2018), which explored the challenges of, and barriers to, cycle-transit use amongst people living in the Greater Toronto and Hamilton areas of Canada.

Similar to Harvey et al. (2016), Weliwitiya et al. (2019) implemented a quantitative study that included both observational (i.e. cyclist counts) and built environment data to investigate cycle-public transport integration – particularly cycling as an access mode – in the context of Melbourne, Australia. They found that, out of the 203 rail stations, 73 had ‘secure’ cycle parking (in the form of a locked cycle cage), numerous stations had unsheltered cycle hoop parking, and all stations had some form of parking (inclusive of street furniture). Unlike Harvey et al. (2016), who did not engage in a formal analysis of data, Weliwitiya et al. (2019) found that the availability of secure caged (i.e., physically protected) parking was associated with higher levels of cycling as an access mode to rail stations; more specifically, cycling as an access mode was reportedly 0.542 times lower at stations without protected parking facilities compared to stations with protected parking facilities. Thus, alike Harvey et al. (2016) and Ravensbergen et al. (2018), the study of Weliwitiya et al. (2019) reveals a preference amongst transit users for protected cycle parking facilities (i.e., in the form of a locked cycle cage/compound) in a different context.

By drawing on police data, Appleyard and Ferrell’s (2017) study on the influence of crime on access journeys to Bay Area Rapid Transit (BART) services in Northern California further supports the importance of protection as an effective cycle parking element which can be derived from Harvey et al. (2016), Ravensbergen et al. (2018), and Weliwitiya et al. (2019). On the basis of multinomial logit modelling analysis, they reported that cyclists to BART services were highly sensitive to property crime at BART stations and were not deterred by violent
crimes at the station: violent crime was in fact positively associated with cycle access journeys. Importantly, the authors note that most of the cycle access respondents were male (similar to Harvey et al., 2016), so the positive association with violent crime could indeed be different if cycle access respondents were primarily women, who may face greater risks of victimisation (Kearl, 2010; Vera-Gray, 2018). In light of their findings, the authors call for more protected cycle parking facilities to address cycle property crime that appears to deter cycle access journeys to rail services. Furthermore, the study usefully shows how the degree of protection that may be suitable for a given public transport integration focused cycle parking facility can be informed by location-specific data regarding theft.

While the previous studies provide evidence for the importance of protection as an element for effective cycle parking on the basis of stated preference (Harvey et al., 2016; Ravensbergen et al., 2018), observed preference (Weliwitiya et al., 2019), and in relation to cycle access behaviour in the context of crime (Appleyard & Ferrell, 2017), what is not investigated is how different durations of cycle parking might influence (amongst other things) individual preferences and requirements for cycle parking protection at public transport stations. This aspect of cycle parking practice can be usefully examined drawing on the work of Chen et al. (2012), Hallårdössdättir et al. (2017) and Yang et al. (2015). First, examining cycle parking in China, Chen et al. (2012) implemented a quantitative study in which they surveyed transit users from two metro stations (500 respondents) and from the surrounding neighbourhoods of these stations (1284 respondents) in Nanjing. As part of this survey, Chen et al. (2012) measured the cycle parking time and duration at bicycle-metro transfer facilities of respondents, offering five time categories. They discovered that for one station – that was situated in a residential area – respondents predominantly parked for 8 h + (32%); in contrast, for the other station – which was located in a shopping area – respondents predominantly parked for 4–6 h (37%). On this basis, they found that cycle-transit users may be more likely to park for longer durations if their access station is in a residential area compared to a shopping area, thereby indicating the importance of land use patterns for cycle parking durations. These findings may have implications for the appropriate level of protection (i.e., from the natural elements, theft and vandalism) of cycle parking depending on station location and the associated predominant parking durations for such locations.

However, while such questions of protection are not explicitly examined in the study of Chen et al. (2012), the studies of Hallårdössdättir et al. (2017) and Yang et al. (2015) – which explicitly consider the relationship between cycle parking duration and appropriate level of protection – lend credibility to such a hypothesis. Namely, in a Copenhagen-based study, Hallårdössdättir et al. (2017) showed that the availability of sheltered cycle parking significantly increased the probability of cycling to rail stations – excluding metro stations – at the activity end; the authors comment that this increase may be due to the use of second cycle by rail users in Copenhagen. That is, with covered facilities, more rail users might be motivated to make use of a second cycle at their activity-end station, due to the shelter covered facilities would provide for long-term, overnight parking, which may not be required for home-end journeys to the same extent. Similarly, in a Nanjing metro commuter satisfaction study, Yang et al. (2015) hypothesised – but also found evidence for – a relationship between a preference for more protected cycle parking and longer parking duration. Namely, the researchers reported that their respondent group that engaged in cycle access and walk egress (‘Cycle-Metro-Walk’) were most dissatisfied with cycle parking availability in relation to cycle parking facilities, while, for the cycle access and bus egress group (‘Cycle-Metro-Bus’), the authors reported that cycle parking security was the major cycle parking-related dissatisfier. Interrogating these findings, the authors reported that ‘Cycle-Metro-Bus’ users had similar duration access journeys but longer duration egress journeys compared ‘Cycle-Metro-Walk’ users. This difference in duration, the authors argue, likely results in longer cycle parking times at the home-end metro station for ‘Cycle-Metro-Bus’ users, thereby potentially increasing their concerns for the safety of their parked cycles. In this way, these results – unlike Hallårdössdättir et al. (2017) – suggest that longer parking durations may warrant greater protective measures for cycles in cycle parking planning interventions (both in these sense of protection from theft and protection from weather conditions).

In keeping with the above studies with which we have argued for multi-faceted considerations for cycle parking protection (see Table 2), the study of Arbis et al. (2016) likewise indicates the importance of ample and appropriate cycle parking protection for promoting cycle access journeys to public transport. However, in addition, Arbis et al. (2016) discovered a preference amongst cycle access train users for parking that is proximal to the station and highly visible to the public, and they speculate on the potential security implications of the public visibility of cycle parking. In this way, this work demonstrates how planning the degree of appropriate cycling parking protection for a given parking facility ought to be informed in part by other considerations that may negatively or positively impact the perceived and/or observed security of cycle parking; in particular, the public visibility of cycle parking and the proximity of cycle parking to public transport stations (see Table 2). Drawing on observed spatial data from 248 Australian train stations, the authors examined the use and characteristics of open-air (including use of street furniture) and protected cycle parking (cycle lockers). They found that cyclists revealed a preference to park as close as possible to public transport station entrance which, Arbis et al. (2016) argue, is a means of reducing walking distance to access the station; this is similar to the findings of Ravensbergen et al. (2018), in which survey participants raised the challenge posed by long distances between cycle parking facilities and rail

### Table 1

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<thead>
<tr>
<th>Author</th>
<th>Context</th>
<th>Methodology</th>
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<tbody>
<tr>
<td>Martens, 2007</td>
<td>Netherlands</td>
<td>Case Study / Policy Analysis</td>
</tr>
<tr>
<td>Bachand-Marleau et al., 2011</td>
<td>Montreal, Canada</td>
<td>Quantitative – Self-Reported Behaviour &amp; Preferences</td>
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<tr>
<td>Chen et al., 2012</td>
<td>Nanjing, China</td>
<td>Quantitative – Self-Report Data</td>
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<tr>
<td>Molin &amp; Maat, 2015</td>
<td>Delft, Netherlands</td>
<td>Quantitative – Stated Choice Experiment</td>
</tr>
<tr>
<td>Yang et al., 2015</td>
<td>Nanjing, China</td>
<td>Quantitative – Self-Report Data</td>
</tr>
<tr>
<td>Arbis et al., 2016</td>
<td>New South Wales &amp; Sydney, Australia</td>
<td>Quantitative – Observation &amp; Spatial Data</td>
</tr>
<tr>
<td>Harvey et al., 2016</td>
<td>New Jersey, U.S.A.</td>
<td>Mixed Methods – Self-Report &amp; Observational Data, Focus Groups</td>
</tr>
<tr>
<td>Hallårdössdättir et al., 2017</td>
<td>Copenhagen, Denmark</td>
<td>Quantitative – Self-Report &amp; Observational Data</td>
</tr>
<tr>
<td>Ravensbergen et al., 2018</td>
<td>Greater Toronto &amp; Hamilton, Ontario, Canada</td>
<td>Mixed Methods – MCQ &amp; Qualitative Self-Report Survey</td>
</tr>
<tr>
<td>Mitra &amp; Schofield, 2019</td>
<td>Toronto, Canada</td>
<td>Quantitative – Self-Report &amp; Spatial Data</td>
</tr>
<tr>
<td>Weliwitiya et al., 2019</td>
<td>Melbourne, Australia</td>
<td>Quantitative – Observation &amp; Spatial Data</td>
</tr>
<tr>
<td>Jonkeren &amp; Kager, 2021</td>
<td>Netherlands</td>
<td>Quantitative – Self-Report Data</td>
</tr>
<tr>
<td>Paix et al., 2021</td>
<td>The Hague &amp; Rotterdam, Netherlands</td>
<td>Quantitative – Stated &amp; Revealed Preference Survey</td>
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On the basis of both these interpretations, Arbis et al. (2016) recommend that open-air cycle parking facilities should be placed “conspicuously to the public eye” (p. 503), which they suggested was within 30 m of a transit station entrance: in other words, by increasing visibility (including by increasing proximity), less physical protection is required. They argue that protected cycle parking (in this case, cycle lockers), however, can be placed at a greater distance if space near the entrance is not available, since this form of parking does not require public surveillance like insecure parking: that is, with greater parking protection, there may be less need for visibility and proximity. Furthermore, Arbis et al. (2016) reported that more open-air cycle parking was associated with the presence of various streetscape features such as bus stops, shops, visibility from station platforms and CCTV cameras – all of which provide some form of passive surveillance (i.e. they enhance parking visibility). In this respect, open-air cycle parking interventions could be more effective if they are placed with these features present (Arbis et al., 2016). Lastly, Arbis et al. (2016) argue cycle parking interventions (e.g., installing protected vs open parking) can be informed by the level of use or “passenger patronage” (p. 503) of a given station. In this study, stations with less passengers displayed higher use of protected cycle parking versus open cycle parking, despite the cost of protected parking; this indicates that protected parking may be more useful and appropriate for smaller stations, potentially due to the decreased passive surveillance if one parks their cycle in an open parking facility – another potential element to consider along with crime data (Appleyard & Ferrell, 2017) to inform the protective aspect of a planned cycle parking facility.

The public transport integration studies discussed thus far lend support to the elements of protection, visibility and proximity for cycle parking as an effective public transport integration measure. Two studies in this thematic area suggest the importance of an additional element: accessibility, by which we mean the physical and financial accessibility of cycle parking for different potential users. Both the studies of Jonkeren and Kager (2021) and Paix et al. (2021) – which were both based in the uniquely high-cycling context of the Netherlands – suggest that particular cycle parking practices and users can be prioritised when there is an excess of cycle parking demand in relation to supply. In particular, Jonkeren and Kager (2021) found that the practice of parking second bicycles at activity-end rail stations in the Netherlands – a practice also examined by Hallårdödtör et al. (2017) – generated a great deal more ‘parking pressure’ than home-end rail station cycle parking. On the basis of their analysis, they argue for various ways to free up high-demand station parking space from second bicycles, such as through pricing measures to disincentivise longer term parking and providing free facilities further away from stations for second cycles. In this way, by varying the conditions for particular cycle parking practices (e.g., charging for long-term parking and/or making it less proximal), planners can prioritise particular practices over others. In this case, they can disincentivise the use of second bicycles through increasing parking cost and distance. The work of Paix et al. (2021), on the other hand, found that ‘frequent’ train users for the Rotterdam and Hague region were far more sensitive to changes in both the cost of parking and walking time required from parking to platform than ‘infrequent’ train users. On the basis of this finding, they interpret that discounting the cost of cycle parking and reducing the time it takes to walk to the train platform from parking facilities could increase demand for cycling as a feeder mode amongst frequent train users.

The study of Molin and Maat (2015), on the other hand, speaks to questions of accessibility in terms of cost and proximity (Jonkeren & Kager, 2021; Paix et al., 2021), but instead of manipulating cycle parking accessibility to prioritise particular practices, demonstrates how cycle parking may be planned to facilitate a diversity of preferences and priorities in relation to visibility, protection, proximity, and accessibility (see Table 2). On these grounds, this study informs the element of diversification (Table 2), which relates to the potential cycle-promoting effects of diversifying cycle parking measures to facilitate a diversity of cycle

<table>
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<th>Table 2</th>
<th>Elements of Effective Public Cycle Parking</th>
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<tr>
<td>Visibility</td>
<td>- Maximise the public visibility of open cycle parking (Aldred &amp; Jungnickel, 2013; Arbis et al., 2016; Chen et al., 2018; Harvey et al., 2016; Hull &amp; O’Holleran, 2014; Lierop et al., 2015).</td>
</tr>
<tr>
<td>Protection</td>
<td>- If public visibility is sub-optimal and/or existing open cycle parking is not well used, protected cycle parking may be appropriate (Arbis et al., 2016; Bachand-Marleau et al., 2011; Harvey et al., 2016; Ravensbergen et al., 2018; Welisiwty et al., 2019) – which can involve professional supervision and/or physically protected facilities.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>- The likely duration of cycling parking (Chen et al., 2012; Hallårdödtör et al., 2017; Pucher et al., 2016; Yang et al., 2015) may be considered in relation to appropriate protection from theft and weather conditions.</td>
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<tr>
<td>- The supply of ample formal cycle parking may reduce incidents of fly-parking, thereby improving cycle protection (Aldred &amp; Jungnickel, 2013; Lierop et al., 2015).</td>
<td></td>
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<tr>
<td>- Station property crime data (Appleyard &amp; Ferrell, 2017) and “passenger patronage” (Arbis et al., 2016, p. 500) may inform the appropriate level of protection needed for cycle parking at rail stations.</td>
<td></td>
</tr>
<tr>
<td>Integration</td>
<td>- In order to accommodate disabled cyclists and non-traditional cycles, provide parking for specialist and adapted cycles, enable wheeled access to the point of cycle parking itself, and make available alternatives to cycle parking that require lifting one’s cycle (Parkin et al., 2018).</td>
</tr>
<tr>
<td>- In the case of high demand for cycle parking, parking management measures in relation to cost and proximity to destinations can be implemented to prioritise particular cycle parking practices and users – such home-end cycle-rail parking (Jonkeren &amp; Kager, 2021) and frequent rail users (Paix et al., 2021).</td>
<td></td>
</tr>
<tr>
<td>Proximity</td>
<td>- Maximise the proximity of cycle parking to user destinations (Aldred &amp; Jungnickel, 2013; Arbis et al., 2016; Lierop et al., 2015; Paix et al., 2021; Ravensbergen et al., 2018).</td>
</tr>
<tr>
<td>Diversification</td>
<td>- Consider existing cycles (e.g., their value, type), locking and parking practices, and parking facilities – namely, the existing cycle parking system – when planning public cycle parking (Larsen, 2017; Martens, 2007).</td>
</tr>
<tr>
<td>- To maximise impact, cycle parking interventions should take place as one measure amongst a “coordinated implementation of the multi-faceted, mutually reinforcing set of policies” (Pucher &amp; Buehler, 2008, p. 525) to promote ridership, such as networked, segregated cycling facilities and restrictions to car use.</td>
<td></td>
</tr>
<tr>
<td>- To promote public-transport integrated journeys, target cycling as an access mode for rail users through the provision of cycle parking (Bachand-Marleau et al., 2011; Martens, 2007; Mitra &amp; Schofield, 2015; Pucher &amp; Buehler, 2008; Pucher et al., 2010).</td>
<td></td>
</tr>
<tr>
<td>- Diverse public cycle parking types (e.g., ‘Locked’, ‘Guarded’, ‘Open’) could be provided to maximise aggregate cycle journeys, improve the inclusivity of ridership, and/or facilitate diverse cycle-activities, such as cycle-shopping (Egan, Dowling, &amp; Caulfield, 2022).</td>
<td></td>
</tr>
</tbody>
</table>

platforms in integrating their cycle-rail journeys. However, in addition, Arbis et al. (2016) hypothesise that parking as close as possible to the station entrance may also be a way of making openly parked cycles more visible to nearby pedestrians in order to prevent theft and vandalism, thereby presenting potential crossovers between visibility, protection and proximity as potential elements for effective public cycle parking from a cycle security perspective.
parking practices and users. Analysing data from a stated choice experiment with 886 train travellers who parked their bicycle at Delft station in the Netherlands, Molin and Maat (2015) modelled the preference tendencies of four different types of user: ‘free facility lovers’ (26.5%), ‘price sensitive cyclists’ (34.1%), ‘walking time sensitive cyclists – mode switchers’ (20.3%), and ‘paid facility lovers’ (19.1%). Specifically, there were unique patterns of preferences amongst the four groups relating to cost of parking, security of parking, walking distance from station, and supervision of parking (i.e., in relation to Table 2, accessibility, protection, proximity, and visibility), and the younger respondents were, the more likely they were to belong to the first three types of cycle-transit user. This research suggests that stations would benefit from a mix of cycle parking – particularly in terms of protection, which could involve trade-offs with accessibility and proximity – to accommodate a mix of user preferences with differentiated parking priorities. Importantly, the protection discussed in relation to this study primarily relates to the professional supervision of cycle parking as opposed to the use of an independently physically protective enclosure in which one can park their cycle, such as a cycle compound or locker.

Lastly, various studies suggest that prioritising cycle parking for access journeys to rail is one of the most fruitful means of promoting integrated cycle-public transport journeys (Bachand-Marleau et al., 2011; Jonkeren & Kager, 2021; Krizek & Stonebraker, 2011; Martens, 2007; Pucher et al., 2010). In this respect, we derive the element of integration (see Table 2) as it relates to cycle-public transport integrated journeys, by emphasising the provision of cycle parking for cycle access journeys to rail as the most supported multi-modal integration measure across the literature reviewed. Martens (2007) documents the major initiatives to promote cycle-rail integration in the Netherlands, detailing the major policy initiative of the Netherlands – the ‘Bicycle Master Plan’ – and how it involved various experimental and research measures to promote cycle-public transport integration, such as cycle stations, cycle lockers and improved cycle parking at public transport hubs, and the subsequent policy initiative to upgrade cycle parking facilities at all train stations in the country known as ‘Space for the Bicycle’. As part of this policy, guidelines were delineated to promote greater use of cycle and ride and to enhance the quality of the cycle and ride experience. In evaluating these efforts, Martens (2007) reports that the promotion measures for access trips by bike for train journeys have generally been successful in the Netherlands due to upgrades in cycle parking, with evidence of increased user satisfaction, more cycles being parked at stations, and increased access trips to rail by cycling; this contrasts with the limited success of interventions to promote cycle-service integration and shared cycle egress services.

Similarly, the study of Bachand-Marleau et al. (2011) supports cycle parking as a primary measure for cycle-public transport integration. Investigating patterns of cycle-transit use preferences amongst a public survey sample from Montreal, Canada (N: 1432), the authors reported that “good-quality bicycle parking facilities will be most useful to regular commuters, whereas racks on vehicles will appeal more to those irregularly using C-T” (Bachand-Marleau et al., 2011, p. 114). However, since data on the quality and quantity of cycle parking was not collected, Bachand-Marleau et al. (2011) remark that the strong preference amongst the sample for cycle-bridge-cycle as a cycle-transit mode may be due to cycle parking that is not of sufficient protection or supply at present to be considered a genuine or attractive option due to a risk of cycle theft, for example – thereby bringing in the importance of protection (Table 2). This argument is further supported by the study of Krizek and Stonebraker (2011), who reported that their U.S.A. focus group participants generally favoured ‘bike on transit’ over other public transit integration strategies including ‘bike to transit’ – which the authors found was far more cost effective – while repeatedly raising the issue of insecure cycle parking facilities. Furthermore, using a similar methodology for the user typology to Bachand-Marleau et al. (2011), Mitra and Schofield (2019) found the ‘secure’ cycle parking was the most important end-of-trip facility by a substantial margin for rail user groups who were either the most frequent cycle-access rail users (‘All-Purpose Cyclists’), or were the most interested in engaging in cycle access journeys (‘Recreational Cyclists’). In this way, the provision of cycle parking that is perceived and/or observed as ‘secure’ (which may depend on the degree of physical protection and/or public visibility provided) may favour the greatest promotion of cycle-public transport integrated journeys (Krizek & Stonebraker, 2011), but there is a possibility that less frequent users may be more orientated to bringing their cycle on board public transit services (Bachand-Marleau et al., 2011) in particular contexts.

4. Public cycle parking

In the previous section, we examined research explicitly related to cycle parking as a public transport integration measure, deriving and introducing five elements for effective public cycle parking: protection, visibility, proximity, accessibility, integration and diversification (Table 2). However, research exploring cycle parking as either a variable or as a focus has been carried out not only (although predominantly) on station parking for public transport integration but also for publicly available cycle parking, in which cycling is not necessarily part of a multi-modal journey (Aldred & Jungnickel, 2013; Hull & O’Holleran, 2014; Larsen, 2017; Lusk, Wen & Zhou, 2014). Studies in this area have included qualitative work looking at the status of bicycles in low cycling contexts (Aldred & Jungnickel, 2013) and cycle parking practices and how they relate to cycle parking materials (Larsen, 2017); auditing cycle infrastructure (Hull & O’Holleran, 2014); measuring public cycle parking preferences (Lusk et al., 2014); and investigating cycle theft (Chen, Liu & Sun, 2018; Lierop, Grimsrud & El-Geneidy, 2015). In this section, we will review this public parking specific work in order to further develop our proposed elements for effective public cycle parking, that may inform public cycle parking planning that is not necessarily only orientated toward multi-modal journeys (i.e., not only for the purposes of ‘public transport integration’).

Alike the work reviewed in the previous section, protection once again emerges as a clear element that can be derived to inform more effective cycle parking planning across various public cycle parking studies (Aldred & Jungnickel, 2013; Hull & O’Holleran, 2014; Lierop et al., 2015; Lusk et al., 2014). Much like the body of work examining stated and revealed preferences with cycle parking as a form of public transport integration (e.g., Arbis et al., 2016; Molin & Maat, 2015), and filling a gap examining public cycle parking in particular, Lusk et al. (2014) carried out a particularly insightful study on both forms of preference but in relation to general cycle parking using self-report and objective spatial data, in Hangzhou, China. This study is distinctive amongst the cycle parking literature in that is measures both revealed and stated preference specific to a range of cycle parking types: cycle parking sheds (this denotes a ‘cycle station’ like those discussed in Pucher & Buehler, (2008)), storage rooms (also described as a ‘garage’ in the study), rooms at home/office, areas beside office or apartment buildings (does not clarify if this is a cycle parking area), and roadside cycle parking. Drawing on data from 1150 respondents, they found that parking sheds were the both most used (used by 42.1% of women and 39.7% of men) and most preferred (preferred by 62.2% of women and 60% of men) form of cycle parking amongst respondents. However, importantly, it is not ascertained in this study what scenario specific preferences respondents may have – for example in terms of cycle parking duration (Chen et al., 2012; Yang et al., 2015). Nevertheless, the study does show in general that protected cycle parking in the form of cycle stations is highly preferred both in practice and in stated preference in this context, in keeping with public transport integration studies that support a preference for physically protected cycle parking (Appleyard & Ferrell, 2017; Halldórssóttir et al., 2017; Harvey et al., 2016; Ravensbergen et al., 2018 Welliwitya et al., 2019; Yang et al., 2015).
While we have derived the element of protection from a considerable body of studies reviewed in this article primarily on the basis of considering comparatively superior physically protective parking (such as cycle stations, lockers and compounds) to open style cycle racks (e.g., the “Sheffield stand”) in particular planning scenarios, the study of Lierop et al. (2015) provides a more rudimentary consideration in relation to protection: the basic supply of formal cycle parking facilities, irrespective of type. Drawing on self-report data from 1992 respondents to research patterns of bicycle theft in Montreal, Canada, Lierop et al. (2015) discovered that 50% of reported stolen bicycles were ‘fly-parked,’ thereby raising the importance of formal cycle parking supply itself. This finding supports the poorer ratings for cycle parking security provided in the auditing study of (Hull and O’Holleran, 2014) for the UK contexts of Cambridge and Edinburgh, where insufficient formal cycle parking supply and considerable fly-parking practices (i.e., parking one’s cycle on street furniture and/or undesignated locations) were observed, compared to Den Haag in the Netherlands, where supply was considered ample and security excellent. Lierop et al. (2015) suggest that public authorities can reduce incidents of cycle theft by increasing cycle parking supply (and therefore reducing fly-parking) and installing parking that is materially robust, well-anchored, and easy to lock one’s cycle to. Furthermore, in keeping with Arbis et al. (2016), they advocate for cycle parking that is both visible to other public space users and located near key destinations (i.e., for visibility and proximity): these are both elements of cycle parking that, as mentioned earlier, may cross over with overall security. Indeed, if cycle parking is proximal to one’s destination, there is arguably less chance of fly-parking (Aldred & Jungnickel, 2013); likewise, for one to use a formal cycle parking facility, one must know that it is available – something which greater public visibility surely helps.

The qualitative work of Aldred and Jungnickel (2013) theoretically goes beyond the almost entirely quantitative work that has been reviewed thus far, richly adding to a consideration of the various elements of effective public cycle parking planning that we propose. This work contributes particularly to planning considerations – like the above studies – of protection, while problematising visibility and socially situating the importance of proximity in relation to the broader social status of cycling and cyclists in the UK. Drawing on a interviews with regular cyclists and cycling stakeholders across four relatively high-cycling contexts in the UK, Aldred and Jungnickel (2013) provide a convincing interpretation that the static (versus moving) bicycle/cycle is something which may be considered by much of the UK public as ‘matter out of place’ (p. 605), or, in other words, ‘a transport object of dubious legitimacy’ (p. 605); a claim which fits the wider policy marginalisation of cycling in the UK (Aldred, 2012). This object is threatened by the risk of vandalism, theft, removal by officials, and disapproval, and is otherwise considered, much like the cyclist in low-cycling contexts, as something ‘in the way’ and not in the right place, or, indeed, lacking a ‘right’ place. This diagnosis of the static cycle as an object ‘in the way’ and lacking a place usefully relates to work historically documenting the progressive displacement of cycling and cyclists from public space in the wake of growing automobile and the expansion of driver rights (Bonham and Cox, 2010; Cox, 2012). One could argue that much like cyclists in an Irish context using public space with other mobile subjects, the conditions for cycle parking in Ireland and, on the basis of Aldred and Jungnickel (2013), the UK, may be considered conditions of precarious entitlement to public space, where one may have a (limited) formal right to park one’s cycle in theory that is precarious to exercise in practice (Egan & Philbin, 2021).

Aldred and Jungnickel (2013) show how cyclists deal with this precariousness in practice through parking-related practices. First, one means of dealing with the risks of cycle parking amongst participants was by using a second cheap bicycle so that theft would not cause a great deal of concern; in this way, insufficient physical protection from theft appears to be prevalent. By using lower value bikes, then, cycle parking protection was less important and theft was less consequential – something also found by Larsen (2017) in Copenhagen, which has high levels of cycle theft. Second, participants could deliberately neglect or even vandalise their bikes in order to reduce the risk of theft. This finding shows how visibility is complex: in this case, efforts to make one’s cycle appear less valuable to potential thieves are undertaken to reduce the risk of theft; thus, the public visibility of cycles in this context appears to lead to strategies to reduce the visibility of one’s cycle to a potential thief. Third, street furniture afforded many parking locations for cyclists, often in a sub-optimal fashion, at least in terms of official parking recommendations. Parking on street furniture, however, can come with a fear of removal by officials: “The lack of legitimacy enjoyed by bicycles in public spaces deters cyclists from using ‘unofficial’ locking places, yet—as participants commented—there is often a lack of ‘official’ bicycle parking near popular destinations” (p. 617). In this instance, a lack of formal parking supply – unlike Lierop et al. (2015) – is a threat to the protection of one’s cycle and theft, unlike other studies in this review, is not the only scenario in which one can lose possession of their cycle. However, relatedly, the lack of supply of formal cycle locations near major destinations is apparent: cycle parking in this context appears to lack proximity, thereby resulting in increased fly-parking – something also observed in the UK contexts of Cambridge and Edinburgh by (Hull and O’Holleran, 2014). In the context of parked cycles understood as ‘matter out of place’ (Aldred & Jungnickel, 2013) in particular contexts where cycling may be marginalised, this finding supports cycle parking planning that aspires towards maximising the proximity of formal parking to major user destinations. Importantly, this may inherently involve challenging the potentially privileged spatial positioning of driving and car parking and undoing the positioning of cycling infrastructure primarily within “redundant” and “left-over” mobility spaces (Cox, 2019, p. 182).

However, proximity to high-demand locations can be associated with higher levels of cycle theft. In a Seattle-based cycle theft study, Chen et al. (2018) found that areas “with a higher density and a greater concentration of human activity.” (p. 176) were associated with higher rates of cycle theft. Although, there was an important exception to this pattern: cycle theft was less likely to occur at intersections than mid-block locations. Chen et al. (2018) surmises that this is may be due to the enhanced public visibility – described as “natural guardianship” (p. 176) – for cycle parking that intersections in this context likely provide. On this basis, both proximity and visibility of formal cycle parking may enhance security, which arguably both involve positioning cycle parking in prime public locations that may be in demand for other purposes, including car parking. With this in mind, “the conversion of car parking spaces into cycle parking” observed by Hull and O’Holleran (2014, p. 382) may provide an important strategy for effective public cycle parking planning.

Similar to the theoretically-informed qualitative work of Aldred and Jungnickel (2013), the comparative study of Larsen (2017) provides a consolidated perspective that can inform effective public cycle parking planning, particularly in relation to the importance of designing cycle parking that attends to the appropriate integration of a given cycle parking development within an extant cycle parking system. In a comparative ethnographic study of the primarily public cycle parking practices of cyclists in the cities of Amsterdam, Copenhagen and New York City, Larsen (2017) describes how particular designs can ‘script’ particular actions of users while they can also be interpreted and engaged with in creative ways, such as through the practice of fly-parking. In Copenhagen, formal cycle parking facilities generally involves ‘grid racks’ and one third of parking is fly-parking. Importantly, the cycles generally used in Copenhagen enable certain types of parking; namely, O-locks are the primary means of locking one’s cycle in a fashion that does not require the ‘mooring’ of any formal cycle parking facility. Amsterdam has many more bike racks available compared to Copenhagen and these racks are generally positioned in convenient locations and provide the capacity to stabilise the user’s bike. Compared to Copenhagen, Larsen (2017) remarks that cyclists in Amsterdam appear to “travel and park heavy” (p. 67), often involving large, cumbersome chain locks which can be car-
ried in baskets or wrapped around a bike; compared to Copenhagen, ‘unmoored’ bikes are rare and could be viewed as risky due to the conspicuousness of an unmoored bike – thereby problematising certain kinds of visibility like Aldred and Jungnickel (2013). Lastly, in New York City, inverted U-racks are the main form of cycle parking, with U-locks being the main form of cycle lock. However, racks have only recently become widely available in NYC; street furniture was formerly a major style of parking when such racks were in lower supply. In this context, bikes never seem to be unmoored and there is widespread evidence of bike ‘stripping’ for parts as a result of theft and ‘novice’ locking practices.

Accordingly, Larsen (2017), shows how cycle parking practices are very context specific and how cycle parking facilities are only one component of a wider cycle parking system, that includes existing cycle parking practices, cycle theft practices, police and official practices, street infrastructure, cyclist locking competences, and – perhaps crucially – the types of bikes widely used (and the extent to which they integrate locking and stabilisation systems). On the basis of this work, Larson argues for planners to adopt a relational/systemic approach to cycle parking design, in which the various related materials, competences and meanings that make up existing cycle practices should be considered before cycle parking interventions are made. This claim regarding a sensitivity to the systemic integration of cycle parking is more broadly supported by the seminal comparative work on cycle promotion measures by Pucher and Buehler (2008), Pucher et al. (2010), and Buehler et al. (2017). These researchers each emphasise cycle parking as one promotional intervention that ought to be integrated with a complementary and coordinated package of measures, such as the development of dedicated cycling mobility networks, regulation of car use, implementation of compact mixed-use development, and – alike the public transport integration studies reviewed – integration with public transport systems as a primary measure for more sustainable multi-modal travel. As Pucher and Buehler (2008, p. 525) argue that “The key to the success of cycling policies in the Netherlands, Denmark and Germany is the coordinated implementation of the multi-faceted, mutually reinforcing set of policies”, one of which is cycle parking.

Finally, our recent study on cycle parking type preferences explicitly considers the value of public cycle parking diversification (Egan, Dowling, & Caulfield, 2022). A typology development study drawing on survey data from Dublin, Ireland, we identified five clusters of cycle parking type preferences (i.e., comprised of differential preferences for ‘locked’, ‘guarded’ and ‘open’ cycle parking facilities) amongst the 574 respondents: Informal (low preference for any formal cycle parking), Open (high preference for ‘open’, low preference for ‘locked’ and ‘guarded’), Any (favourable to any type of formal cycle parking), Accessible (preference for ‘open’ and ‘guarded’ cycle parking), and Secure (preference for ‘locked’ and especially ‘guarded’ cycle parking). Having discovered different patterns of parking type preferences, we suggested three potential strategies for cycle parking planning: i) maximising cycle parking that promotes the greatest aggregate increase in ridership, ii) prioritising cycle parking for currently underrepresented groups (i.e., cycle equity), iii) planning cycle parking to promote particular ‘mode-activities’ (Cass & Faulconbridge, 2016). Depending on the approach selected by planners, use of the typology could support the implementation of cycle parking provision for i) the Secure group, since they have the greatest stated interest in increasing ridership and cycle access journeys to public transport; ii) open cycle parking, since the clusters with the highest proportion of women (i.e., Open, Any, Accessible) all rated open forms of cycle parking relatively highly; and iii) using the mode-activity of ‘cycle-shopping’ as an example, the Accessible group, since they demonstrate the highest rates of shopping-related cycle journeys. The final mode-activity approach could be important from a cycle equity perspective, since, across many contexts, women disproportionately engage in ‘velo-mobilities of care’ (Ravensbergen, Buliung & Sersli, 2020) that may involve household-serving trips – such as grocery shopping – compared to men.

5. Elements of effective public cycle parking

On the basis of the above review of cycle parking literature relating to public transport integration and public cycle parking, the table below (Table 2) proposes several fundamental elements derived from this review of peer-reviewed evidence that could inform effective public cycle parking planning measures. These elements could also be framed as tentative ‘principles’ that could contribute to efforts to promote cycle parking planning practice that is informed by peer-reviewed research along with local knowledge and context-specific assessment practices, such as surveys of cycle parking supply and demand (National Transport Authority, 2011; Parkin, 2018). These elements could be used as rules of thumb in local planning efforts but could also be operationalised in more strategic, regional-level approaches to cycle parking planning that might involve the development of indicators for protection, visibility, accessibility, and so on. Nevertheless, we do not propose these elements as either comprehensive or indisputable; instead, we merely propose them as useful research-derived factors that could help to improve the effectiveness of public cycle parking planning practice in light of the current lack of both well-established cycle parking design principles and use of cycle parking research evidence in planning practice. The effectiveness of any measure, of course, depends on what is the strategically desired ‘effect’. In our recent research discussed above (Egan, Dowling, & Caulfield, 2022), we outlined various strategies that could be taken for cycle parking planning, which could prioritise the promotion of aggregate ridership, greater cycle equity, and/or particular cycle-activities. With these divergent approaches in mind, we propose these elements as potentially useful for both considerations to maximise general ridership and/or more targeted promotional efforts (e.g., diversification). Equally, Anaya-Boig (2021, p. 13) argues for a cycling policy approach which emphasises the facilitation of universal accessibility rather than cycle promotion, thereby removing a hierarchical promoter-recipient dynamic that can be inherent to policy-making oriented toward influencing individual and group behaviour; the proposed elements could also be plausibly considered ‘effective’ from this perspective.

Importantly, despite the apparent lack of use of peer-reviewed evidence in many planning guides – at least within the UK and Ireland (e.g. National Transport Authority, 2011; Transport for London, 2016; Welsh Government, 2021) – this does not mean these resources are not based on evidence from planning practice itself and that a flexible approach is not warranted. Indeed, as Parkin (2018) comments, “There is good latitude for creative design of the spaces to accommodate cycle parking” (p. 155). Furthermore, the inclusivity of any given parking intervention for different groups should be considered – something which does not appear to be robustly empirically investigated in existing cycle parking research, but, by comparison, has been explored in considerable depth in relation to mobility infrastructure for cycling itself, particularly in terms of age and gender (e.g. Aldred & Dales, 2017; Aldred, Elliott, Woodcock & Goodman, 2017; Carroll et al., 2020; Garrard, Rose & Lo, 2008). As Aldred, Woodcock and Goodman (2016) have shown, increasing cycling levels does not equate with increasing the diversity of people cycling in terms of age and gender, at least for commuter cycling. Looking at disability in particular, Andrews, Clement and Aldred (2018) have pointed out how the needs of cyclists who are disabled in different ways are often marginalised in cycling strategies and policies in the UK and that there is a lack of research in this area to understand the unique challenges of disabled cyclists. In this respect, the ‘Accessibility’ element below could be developed much further and in more nuanced ways with future cycle parking research that explores the unique experiences and practices of cycle parking for different individuals/social groups and the particular cycles they may use. We have added the partial recommendations of Parkin et al. (2018) to acknowledge the relative absence of work in this area and the need to consider accessibility broadly in spite of this lack. This is also important from a consideration of the growth in the use of alternative cycles – most notably cargo cycles, which also
overlaps with the element of diversifying cycle parking provision, which could help enable a broader diversification of cycling practices.

6. Conclusion

In this review, a variety of peer reviewed literature on the topic of cycle parking was examined in order to extract significant insights that can inform efforts to plan cycle parking facilities to promote/enable cycling and cycle-public transport integration. Emerging from our review, we have proposed several ‘Elements of Effective Public Cycle Parking’. Aspects of these elements broadly correspond with the systematic review of Heinen and Buehler (2019), in which they point out various cycle parking characteristics that can potentially promote and facilitate greater ridership, such as adequate formal cycle parking supply, higher quality facilities that protect from weather conditions and theft, and proximally located cycle parking. Unlike the more empirically and methodologically focused work of Heinen and Buehler (2019), this review uniquely synthesises a smaller, more targeted body of cycle parking research on the basis of a well-identified gap in cycle planning guidance to conceptually propose a body of effective public cycle parking elements that can be easily adapted by planning practitioners, while situating these elements within a wider socio-technical consideration of cycle parking as part of a system of velomobility.

Namely, viewed as a critical component for the development of a wider socio-technical system of velomobility, implementing cycle parking with the above elements in mind will likely involve similar struggles over public space that have been documented much more saliently for cycling mobility infrastructure (e.g., Aldred, 2019; Wild, Woodward, Field & Macmillan, 2018). Achieving cycle parking that is, for example, highly visible, proximal to central destinations, and well-integrated with rail transport hubs and wider pro-cycling measures that underpin a system of automobility (Urry, 2004) will involve the acquisition of highly coveted, centrally located public spaces and spaces that are not “left-over” and “redundant” (Cox, 2019, p.182), where cycles are hidden and positioned on the peripheries of in-demand destinations. Instead, expanding high-quality cycle parking spaces – much like expanding cycling mobility spaces – will, in many cases, involve a reclamation of the spaces of automobility for velomobility (Cox, 2019) in the context of scarcity (Petzer et al., 2021), where cycles are constituted as legitimate public objects rather than ‘matter out of place’ (Aldred & Junngickel, 2013), while the users of these spaces are reconstituted as legitimate public space users (Bonham, 2006; Egan, 2021). In this way, cycle parking planning may implicitly require a process of expanding the rights of cyclists relative to drivers – not just in relation to spaces for mobility but also spaces for mooring (Adey, 2006; (Spurling, 2020)); indeed, the (illegal) moorings of drivers can greatly impinge on the mobilites of cyclists (e.g., Egan & Philbin, 2021).

Cycling has been historically marginalised in transport planning theory and practice (Koglin and Rye, 2014). As planning regulations are a major component of cycling policy (Anaya-Boig, 2021), and existing regulations can ‘reify’ particular claims to public space for car parking in particular (Spurling, 2020; Petzer et al., 2021), the cycle parking elements we propose in this article can potentially help planners to legitimise bolder, more ambitious efforts to embed cycle parking as part of a wider cycling system that is more favourable to the promotion and enablement of diverse cycling practices, particularly in lower-cycling contexts. Amidst the multitude of existing cycle parking design guidance (e.g. National Transport Authority, 2011; Transport for London, 2016; Welsh Government, 2021) – much of which does not draw on peer-reviewed cycling research – these elements can be used to inform specific cycle parking developments along with local knowledge, context-specific assessments (Parkin, 2018), and public deliberation (Anaya-Boig, 2021). Furthermore, our review could promote greater use and consideration of existing research evidence in the cycle parking planning process and can contribute to future dialogue regarding cycle parking design principles in research, policy and practice.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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