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Planning for Diverse Cycling Practices: A Cycle-Parking Type Preference Typology

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ABSTRACT

The purpose of this study is to develop a typology of cycle parking type preferences among a sample who have access to a cycle and travel within or to the electoral county of Dún Laoghaire-Rathdown, Ireland. Valid online survey questionnaire data were gathered from 574 respondents. First, using Principal Components Analysis, we reduced 11 cycle parking type preference variables into three cycle parking type components: *Open, Locked* and *Guarded*. Second, analysing cycle parking type preference data for each component, we implemented both a hierarchical and k-means cluster analysis to generate a five cluster solution comprising of *Informal, Open, Any, Accessible* and *Secure* cycle parking preference clusters. Third and last, we profiled our five cluster solution, examining the demographic composition, current and hypothetical mobility/cycling practices, and perceptions of cycle parking in Dún Laoghaire-Rathdown at present for each of the clusters. We conclude that our cycle parking type preference typology could be used to inform local and national cycle parking policy and planning efforts in several ways: i) targeting clusters that may yield the greatest increase in aggregate cycle ridership, ii) catering for clusters on the basis of enhancing cycle equity for those demographically underrepresented in cycle ridership and/or potentially marginalised in cycle infrastructure planning efforts, and iii) providing for clusters on the basis of strategically promoting particular cycle-activities (Cass and Faulconbridge, 2016), such as cycle-shopping, and end use practices (Spurling, 2020) that may require unique forms of cycle parking.

1. Introduction

Cycle parking facilities are a central constituent of well-developed cycling systems; systems that embed cycling as a normal transport mode in its own right and facilitate cycling as an access mode for multi-modal journeys. Although relatively marginalised in media discourses regarding cycling promotion compared to segregated cycling infrastructure, the primacy of cycle parking in the promotion of mass cycling is demonstrated by its widespread inclusion across international transport policies (e.g. Department for Transport, 2014; Director General for Passenger Transport, 1999; Federal Ministry of Transport and Digital Infrastructure, 2020; Ministre de la Transition écologique et solidaire, 2018; Tour de Force, 2017).

In Irish cycling policy in particular, the provision of secure parking facilities is stated as one of the major objectives for promoting cycling across the nation (Smarter Travel, 2009). Indeed, high-quality parking is described in this policy as equal in importance to high-quality cycling mobility infrastructure. By this logic, the policymakers propose the development of not only plentiful unsheltered cycle parking stands but, more robustly, the implementation of dedicated, guarded and high-volume cycle parks as well as potential cycle parking stations – a common feature of high-cycling contexts within Europe. With these goals in mind, elements of Smarter Travel (2009) arguably demonstrate greater ambition than some recent policy and planning emerging from the UK (e.g. Department of Transport, 2014; Transport Scotland, 2017; Welsh Government, 2021).

However, across many international cycle policies and planning guides relating to cycle parking, there is a lack of incorporated peer-reviewed evidence (see Author, Date) – including the 'National Cycle Manual' (National Transport Authority, 2011), the official guide for planning cycling-related infrastructure in Ireland. While we have proposed more evidence-based planning elements for effective cycle parking planning and policy (Author, Date), a good deal of official cycle parking planning and policy literature equally demonstrates arguments relating to the provision of different types of cycle parking; however, this work does not appear to effectively justify the evidence-base for

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implementing one type of cycle parking facility over another, thereby leaving cycle parking type selection to the discretion of the planner (Department for Transport, 2020; National Transport Authority, 2011; Transport for London, 2016; Welsh Government, 2021). From a policy and planning perspective, this more nuanced evidence gap provides a basis for the aim of our study: to explore and develop a context-specific cycle parking type preference typology that can inform cycle parking policy and planning in Ireland.

In a synthetic review of how cycle parking research can inform more effective cycle parking planning (Author, Date), we argue for *variation* – the provision of varied cycle parking facility types, particularly in terms of security – as one provisional principle or 'element' for effective cycle parking planning. In particular, we claim that *variation* could lead to greater use of cycle parking than homogenous forms (e.g. unsheltered cycle racks) that are widely provided across Ireland, for example. We base this claim in part on the work of Molin and Maat (2015), who develop a typology of cycle parking users with distinct patterns of cycle parking preferences in the context of the Netherlands. Effectively, for this context, Molin and Maat (2015) show that unique patterns of cycle parking preferences, particularly in terms of cost and walking distance from destination, can be derived for cycle parking users rather than a 'one-type-fits-all' solution.

The need for variation in cycle parking planning can be fruitfully considered from a social practice theory perspective, particularly from the perspective of 'practice bundles' (Shove et al., 2012). Cass and Falconbridge (2016), for example, argue for transport researchers to move away from considering forms of mode-specific mobility practices in isolation – such as 'cycling' – and, instead, to consider the 'mode-activity' as a unique form of mobility that requires a combination of distinctive elements to be achieved – such as 'cycle-commuting'. In this way, one can consider different kinds of combined practices that might involve cycling, such as 'cycle-shopping', 'cycle-delivering', 'cycle-racing' or, perhaps when considering school runs, 'cycle-collecting'. These different cycle-activities likely have implications for cycle parking planning and policy. Similarly, in considering varied patterns of vehicle 'dormancy' such as parking, Spurling (2020) argues for a consideration of not only mobility practices but also the 'end use practices' from which mobility practices may be derived, such as working, shopping and socialising. Incorporating these social practice perspectives, variation in cycle parking may facilitate a wider range of potential current and future variations in cycle-activities/end use practices in policy and planning efforts to induce modal shift away from the private car.

With these considerations in mind, the purpose of this study is to develop a typology of cycle parking user preferences among a sample of respondents who have access to a cycle and travel within or to Dún Laoghaire-Rathdown County (henceforth "the county") for various purposes. Building on our existing cycle parking research (Author, Date), this study can help to further inform more nuanced cycle parking policy and planning interventions, particularly in terms of providing an appropriate cycle parking type for a given potential user group and their potentially distinct cycle-activities (Cass and Faulconbridge, 2016) and end use practices (Spurling, 2020). Therefore, this research could provide a novel contribution to existing 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. More broadly, our study provides a novel addition to existing cycle parking literature (Heinen and Buehler, 2019) but also broader cycling research that has employed or drawn on cyclist typologies to advance knowledge in this field (e.g., Bachand-Marleau et al., 2011; Damant-Sirois et al., 2014; Félix et al., 2017; Fraboni et al., 2021; Geller, 2006; Mitra and Schofield, 2019; Molin and Maat, 2015).

The paper proceeds as follows. To begin, we provide a background to the study, exploring research literature relating to cycle parking, cycle parking user typologies and cyclist typologies. Next, we impart the methodology for this study, which involved i) the design and dissemination of online survey questionnaire for a respondent sample who cycle in the county for various purposes, and ii) the analysis of this data using, first, principal components analysis and, second, two-step cluster analysis. Following the methodology section, we present our findings; namely, cycle parking users were clustered in five groups on the basis of their cycle parking type preferences: *Informal, Open, Any, Accessible, Secure*. The unique clusters are then profiled on the basis of various survey item responses to provide a better picture of their composition in terms of socio-demographics, practices and perceptions. To conclude, we discuss the findings and make a number of policy and planning suggestions on the basis of the findings.

2. Literature review

To date, there has been considerable research examining cycle parking. At an international level, there have been investigations into the effects and style of cycle parking interventions in relation to the promotion of cycling, particularly in high-cycling contexts (Pucher and Buehler, 2008; Pucher et al., 2010; Buehler et al., 2017). These works examine cycle parking as one intervention among many that can be implemented to promote cycling and public transport use. Overall, the authors collectively report an increase in the quality and quantity of cycle parking across multiple countries, particularly European nations, through the increased provision of sheltered and, in some cases, guarded cycling facilities. Furthermore, they stress the importance of considering cycle parking as a component of cycling promotion that should be implemented alongside complementary measures, such as car access restrictions and segregated cycle spaces.

Focusing on more specific national and urban contexts, a good deal of research literature investigating public cycle parking can be separated on the basis of its primary area of inquiry. Namely, there is a body of literature that examines public cycle parking (e.g., Aldred and Jungnickel, 2013; Chen et al., 2018; Hull and O'Holleran, 2014; Larsen, 2017; Lierop et al., 2015; Lusk et al., 2014) and another strand of research that relates more broadly to cycle parking as a public transport integration measure and therefore as a component of multi-modal journeys (e.g., Arbis et al., 2016; Bachand-Marleau et al., 2011; Chen et al., 2012; Harvey et al., 2016; Martens, 2007; Mitra and Schofield, 2019; Molin and Maat, 2015; Weliwitiya et al., 2019).

In the public cycle parking strand, diverse areas have been explored, including the status of bicycles as objects in low-cycling contexts (Aldred and Jungnickel, 2013); practices of cycle parking and how such practices relate to the materials of cycle parking – such as parking facilities, cycle locks and cycles themselves (Larsen, 2017); cycle parking as a component of cycle infrastructure auditing (Hull and O'Holleran, 2014); context-specific preferences for public cycle parking (Lusk et al., 2014); and the relationship between patterns of cycle theft and cycle parking related variables (Chen et al., 2018; Lierop et al., 2015). Across these studies, varied findings relevant to cycle parking policy and planning have included: how the low status of bicycles in particular contexts can leave bicycles threatened by vandalism, theft and removal (Aldred and Jungnickel, 2013); the importance of considering the contextual specificity of cycle parking practices and how they interact with cycle theft practices, police/official practices and the kinds of cycles that are widely in circulation (Larsen, 2017); the relationship between built environment factors (e.g. household density, mixed land use, parking location) and cycle theft prevalence (Chen et al., 2018); the importance of ample formal cycle parking supply to reduce incidents of cycle theft (Lierop et al., 2015) and to improve the attractiveness of cycling (Hull and O'Holleran, 2014); and, lastly, the popularity of secure cycle parking as an alternative to less protected forms in stated and revealed preferences (Lierop et al., 2015).

On the public transport integration side, studies have examined, among other things, cycle parking practices for cycle-transit users in relation to parking facility characteristics (Arbis et al., 2016; Weliwitiya et al., 2019), dominant land use type (e.g. residential, commercial) (Chen et al., 2012), and parking supply (Harvey et al., 2016); cycle-

transit use preferences, with cycle parking as one option among others such as carrying one's cycle on public transit (Bachand-Marleau et al., 2011); the impact of cycle-transit integration policies, including cycle parking provision, on cycle-transit integration practices (Martens, 2007); and, lastly, group-specific cycle-transit integration practices and preferences (Bachand-Marleau et al., 2011; Mitra and Schofield, 2019; Molin and Maat, 2015). From this unique strand of cycle parking research, important findings have included: the provision of cycle parking supply for public transport integrated journeys is not always successful and investment on the basis of observable demand can be a more prudent approach (Harvey et al., 2016); the provision of secure cycle parking can promote increased cycle access journeys to rail services (Weliwitiya et al., 2019); proximally located and publicly visible open cycle parking can promote cycle access journeys to public transport (Arbis et al., 2016); dominant land use patterns (e.g. residential/commercial) can inform likely cycle parking duration for public transport cycle access journeys and, arguably, the appropriate level of protection for a given cycle parking development (Chen et al., 2012); cycle parking may be more attractive for regular cycle-public transport users whereas vehicular racks may be more attractive for less regular users (Bachand-Marleau et al., 2011); and, finally, cycle-public transport integration policies have been successful in the Netherlands, particularly due to upgrades in cycle parking to enable access journeys (Martens, 2007).

While facilitating "more and better" (Pucher and Buehler, 2008, p.509) cycle parking in general for higher aggregate levels of cycling is an important objective, examining changes in ridership in the UK in terms of age and gender, Aldred et al. (2016) have demonstrated that increasing cycle ridership in general does not necessarily mean that the diversity of people cycling is likewise expanded. In this respect, more cycling does not equal more inclusive or accessible cycling. With this phenomenon in mind, the work of Bachand-Marleau et al. (2011), Mitra and Schofield (2019), and Molin and Maat (2015) may be considered particularly useful in relation to their common aim to identify unique groups of individuals with distinct patterns of practice and preference in relation to cycle parking and/or cycle-transit integration.

Indeed, there have been numerous attempts to develop group typologies or 'market segments' in the transport field in order to inform more tailored approaches to sustainable transport promotion that take into account heterogenous practices and preferences among different potential transport user groups (Félix et al., 2017; Krizek and El-Geneidy, 2007; Molin et al., 2016; Oostendorp et al., 2019; Alonso-González et al., 2020). In relation to cycling in particular, Félix et al. (2017) review methods for developing cycling typologies across the peer-reviewed and grey literature in this area. They report the use of 'top-down' (e.g. 'expert judgement') and 'bottom-up' (i.e., cluster/factor analysis) methodologies for developing cyclist typologies across numerous studies. Félix et al. (2017) also detail how typologies have been developed based on specific differentiating variables, such as cycle use frequency, trip purpose, cycling confidence, weather conditions, and motivations for cycling. In this way, typologies are developed on the basis of various preconceived variables; these variables can be selected, for example, on the grounds of expert judgment (e.g., Geller, 2006) and/or empirical support (e.g., Damant-Sirois et al., 2014).

Fundamentally, bottom-up approaches may be considered superior on the grounds of being developed through the systematic analysis of data gathered from a particular sample through the use of cluster or factor analysis. Top-down approaches, on the other hand, may be developed more arbitrarily on the basis of rules and/or professional intuitions that may lack empirical support if rigorously evaluated; however, these approaches may also lend themselves to easier application by national and local transport officials in transport-related decision-making due their potential simplicity and pragmatic orientation (Félix et al., 2017). While the selection of differentiating variables for any cycling typology requires judgement, in this study, we aim to contribute to the empirical discovery rather than the arbitrary or professionally-derived development of a cycle parking type preference typology for our study context. On these grounds, we opted for a bottom-up approach.

Re-examining the segmentation work of Bachand-Marleau et al. (2011), Mitra and Schofield (2019), and Molin and Maat (2015), these researchers develop three different kinds of typologies: i) a typology of current and potential cycle-public transit integrators, with 'parking bike-and-riders' as one segment who currently integrate cycling and public transit (Bachand-Marleau et al., 2011); ii) a typology of cycle access transit users, with 'secure cycle parking importance' included as a variable (Mitra and Schofield, 2019); and iii) a typology of cycle-train user cycle parking preferences (Molin and Maat, 2015). The study Molin and Maat (2015) provides, to our knowledge, the only focused cycle parking preference-based user typology to date. Gathering data through 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 among the four groups relating to cost of parking, security of parking, walking distance from station, and surveillance of parking, and the younger respondents were, the more likely they were to belong to the first three types of cycle-transit user.

Having considered existing cycle parking and cyclist typology literature, in our study, we look to focus – most similarly to Molin and Maat (2015) – on developing a 'bottom-up' (Félix et al., 2017) cycle parking user preference typology for a sample of relatively active cyclists who frequent the county. This typology, unlike Molin and Maat (2015), will not specifically focus on cycle parking as a public transit integration measure but will more broadly relate to any kind of public cycle parking use on the basis of cycle parking type in particular. We undertake this study for two reasons. First, we aim to contribute to the extant cycle parking and cyclist typology literature, particularly through our incorporation of sample preferences for well-defined and distinct cycle parking types. To our knowledge, this has not been undertaken to date. Second, we endeavour to create a preference typology that can help local and national authorities to design more tailored and precise cycle parking interventions in the county/country that may be replicated elsewhere and that, importantly, can be implemented with not only cycling promotion but also cycling equity in mind through the profiling of particular group preferences using sample data on gender, age, and educational attainment.

3. Context

Dún Laoghaire-Rathdown – the context of this study – is an electoral county of County Dublin situated in the province of Leinster, Ireland. Looking at ridership in County Dublin at large, recent statistics suggest that cycling journeys as a percentage of total journeys have decreased from 4.1 % in 2016 to 3.4 % in 2019 (Central Statistics Office, 2019). In terms of gender, cycling at a national level is primarily used as a mode by men (2.6 % of male journeys), with only 0.7 % of women's journeys by cycling for 2019, decreasing from 0.9 % in 2016. In addition to the low rates and exclusive demographics of cycling in Ireland, considering Dublin in particular, there is scarce high quality cycling infrastructure available for cycle users (Conway et al., 2019). However, considerable Covid-19 mobility-related interventions were implemented during the pandemic, including numerous temporary segregated cycle infrastructures (Dublin City Council National Transport Authority, 2020), leading to an expansion of higher quality cycling facilities in Dublin. In a study of pandemic commuting preferences for staff and students of Trinity College Dublin – a university located in Dublin city centre – Caulfield et al. (2021) reported a much greater stated preference for cycling to university during the pandemic compared to pre-pandemic cycle commuting practices, thereby suggesting a potentially greater demand for cycling during the pandemic. Drawing on counter data

gathered during the pandemic, Buehler and Pucher (2021) reported an increase in cycling in 11 European countries between 2019 and 2020 of 8 – 23 % on weekends and 3 % on weekdays. This increase, they argue, is largely attributable to a major increase in leisure cycling rather than utilitarian cycling. In spite of this, Buehler and Pucher (2021) argue that higher levels of cycling may persist following the pandemic due to increased cycle ownership, reallocation of driving space for cycling and the expansion of cycle facilities.

In the county, there have been considerable efforts to improve the cyclability of the local context during the pandemic. Most notably, the "Coastal Mobility Route" – a 3.6 km segregated two-way cycling facility – was rapidly constructed during the pandemic (Dún Laoghaire-Rathdown County Council, 2020). In addition to some provision of segregated cycling facilities, there is considerable cycle parking provision distributed across the county; in nearly all instances, this parking is free to access. The distribution of cycle parking in the county is particularly concentrated to the North, where there is a considerable density of destinations and residences, such as Dún Laoghaire town and Blackrock (the North-East coast). The mountainous areas of the South-West, on the other hand, are particularly sparse in terms of provision, likely due to the lack of settlement and roads in this region. In the most recently publicly available data (Dún Laoghaire-Rathdown County Council, 2021a), there are 2,511 public cycle parking spaces in total recorded in the county, with 2,028 of these spaces provided by the county council. In Fig. 1. (below), one can see the distribution of this cycle parking within the contours of the county. However, nearly all of this cycle parking comprises of unsheltered Sheffield Stand cycle racks. In this respect, there is a lack of diversified cycle facilities in the county; in particular, there is a dearth of more secure cycle parking types that may be more attractive to current and potential cycle parking users, such as rail users who might access the rail station by cycle.

4. Methodology

4.1. Data collection

4.1.1. a. Overview

This survey research was carried out as part of a wider cycle parking innovation trial project in Dún Laoghaire-Rathdown County, Ireland. The target sample group was selected on the basis that due to their access to a cycle and their residence within and/or travel to the county, they may be considered likely current or potential cycle parking users for the county who could, through innovation in cycle parking, be supported to cycle (more and in new ways) to or within the county as a means of travel. From a social practice theory perspective (Shove et al., 2012), this target population – those with access to a cycle who travel to or within the county – could be seen to have the most basic 'material' for the practice of cycling that may be unused and "dormant" (p.59): a cycle. Furthermore, for those with cycle ownership, likewise dormant competencies of being able to cycle in a generic sense may be available. Through providing bespoke cycle parking for particular clusters of such a population, the linking of critical elemental gaps to produce 'practice bundles' (Shove et al., 2012) may be achieved, thereby recruiting a potentially defected and/or aspirational cycle population from less sustainable modes of travel, such as the private car. This online survey was disseminated via the Dún Laoghaire-Rathdown County Council official twitter account and web page and was circulated via email to relevant groups and authorities (e.g. Dublin Cycling Campaign, Smart Dublin, etc.). Nearly 80 % of people in Ireland use the internet everyday (Central Statistics Office, 2020) while the Department of Health (2020)

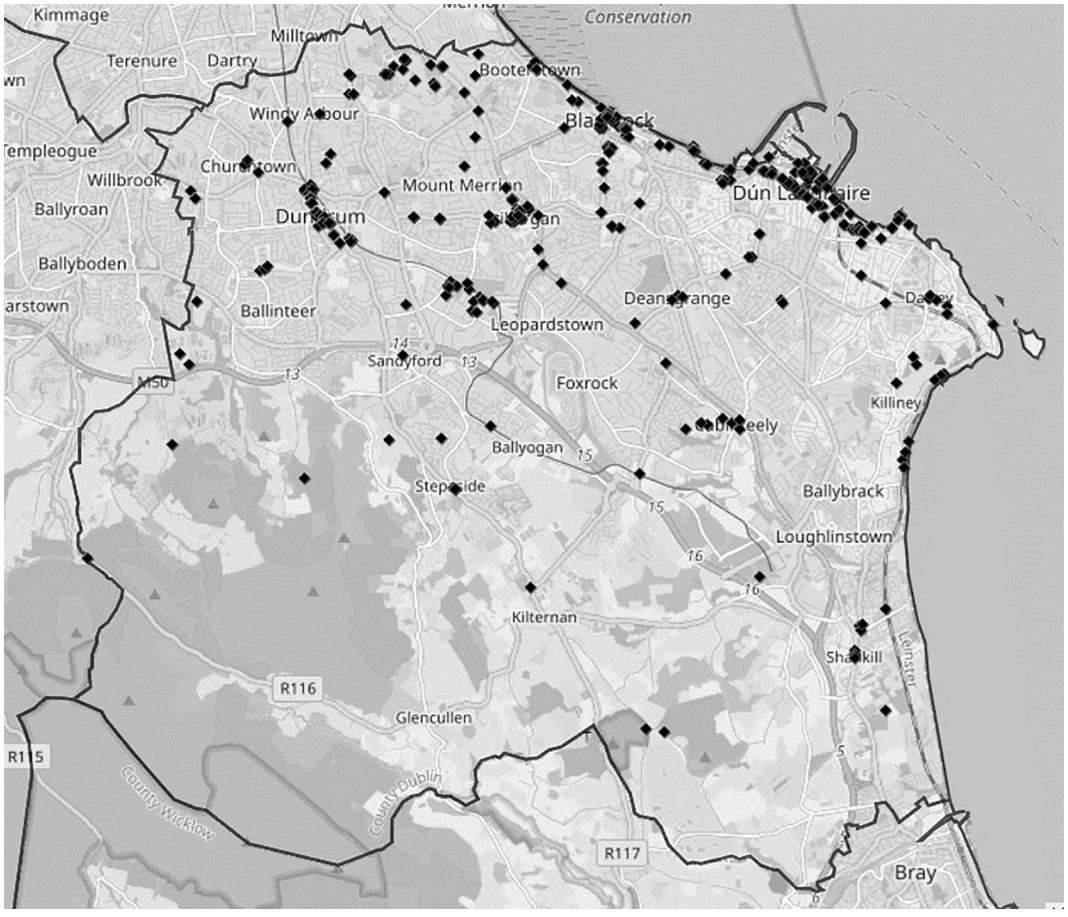


Fig. 1. Final cluster centres.

report very high levels of smart phone access and use among the Irish population. Consequently, our online approach to recruitment and data collection has considerable reach but is also limited to those in Ireland with the ability to access the internet, which appears considerably higher among those under 60 years of age (Central Statistics Office, 2020).

In some respects, the target sample may be considered in relation to Geller's (2006) 'Four Types of Cyclists' that has been widely used to inform cycling policies in North America (Dill and McNeil, 2013). Namely, Geller developed a basic scheme of categories different types of cyclist in Portland based on his professional experience: "The Strong and the Fearless," "The Enthused and the Confident," "The Interested but Concerned," and the "No Way No How". These conjectured cyclist types were categorised based on the premise that different groups of people in Portland possess categorically different patterns of perceived comfort with, and preferences for, certain forms of cycle infrastructural and traffic arrangements. For example, the 'Strong and Fearless' group are considered to be comfortable with no dedicated cycle infrastructure, while the 'Interested but Concerned' are stated to favour segregated cycling facilities and minimal, slow-moving vehicular traffic. While this has been more robustly developed in recent work (Dill and McNeil, 2013), the goal of its development – to inform tailored cycle infrastructural interventions that cater for group-specific preferences – is relevant to the relatively neglected area of cycle parking as a form of cycle infrastructure.

4.1.2. b. Measure

The survey questionnaire was created using the ArcGIS Survey123 platform in order to enable the collection of survey and geodata and was designed for online dissemination and completion. In the survey, we gathered respondent self-reported mobility and cycling practices; demographic information; stated preferences for different kinds of cycle parking facilities in the county; perceptions of cycle parking facilities in the county at present; willingness to pay for more secure cycle parking facilities in the county; and willingness to access public transport in the county by cycling with the provision of more secure cycle parking facilities. Importantly, prior to questions regarding respondent use and preference for different cycle parking types, cycle parking types were visually displayed and concisely described in the survey in order to enable informed responses. In the paragraphs below, we describe each of the survey items in more detail in order of appearance.

Usual Travel Mode was measured as a categorical variable through the question "How do you usually travel to work, school or college?" Options ranged between active travel modes, private cars, public transit modes, "Not at work, school or college", in addition to "Mainly work at or from home". This was adapted from the Central Statistics Office (2016).

Cycle Ownership/Access: one item measured cycle ownership (binary response: Yes/No) and if the respondent answered "No" to cycle ownership, a dropdown option measured cycle access (3 responses: a rental cycle, a friend/family member's cycle or "other"). Lastly, a final item measured the type of cycle owned/accessible to the respondent – "What kind of cycle?" – which involved options such as "Urban Bike", "Road Bike", "Standard E-Bike", "Adapted Cycle", and "Other".

Cycle Use was measured broadly using three items. First, respondents were asked "How often do you use this cycle", which involved a dropdown 5-point scale between "Less than once per month" (point 1) and "About four or five days per week (or more)" (point 5).

Cycle Destinations: one item measured respondents' "most frequent" cycle destination in the county. The same possible responses were available for both items included responses such as "shops (retail)", "workplace", "childcare", "café", "there is no destination (e.g. I do a cycling loop)" and an open-text box option of "other". For the purposes of this research, along with the 'cycle type' survey item, data on the cycle destinations of respondents can be seen as critical for profiling different clusters on the basis of their respective cycle-activities (Cass and Faulconbridge, 2016) and end use practices (Spurling, 2020).

Cycle Parking Practices were measured specifically for the respondents' cited "most frequent" cycle destination in the county in terms of type of cycle parking used and the general duration of cycle parking for this destination. In relation to cycle parking type, respondents were asked "Where do you park your cycle at this destination?" Several cycle parking options were provided including formal facility options (e.g. "open cycle rack", "cycle locker"), informal facility options (e.g. office space) and an open-text response option of "other". For general duration of parking at this destination (i.e. "How long do you generally leave your cycle parked having reached your destination?"), a drop-down 6-point scale option was provided ranging from "30 min or less" (point 1) to "6 + hours" (point 6). These survey items all provide important information to understand existing patterns of cycle dormancy (Spurling, 2020) that is used later in the profiling of clusters; duration has been measured in other cycle parking focused studies, such as Chen et al. (2012) and Yang et al. (2015).

Cycle Parking Type Preferences were measured using a 5-point scale (1 = Highly Unlikely to 5 = Highly Likely) in response to the question "Please rate the following types of public cycle parking in terms of your likelihood to use them if cycling in the county." Preferences for 11 types of cycle parking were measured in total. The parking types included – in the greatest generality – open cycle racks, cycle lockers, cycle bunkers, and cycle compounds. However, to make up the 11 types, varied subtypes of these more general types were listed to allow for more refined measurement of stated preferences (e.g. "open cycle rack – sheltered", "cycle compound – guarded by parking attendant", "cycle locker – digital access"). To our knowledge, this is the first study in the field to include such detailed cycle parking type survey content. Importantly, since our aim is develop a typology of cycle parking type preferences rather than cycle parking preferences based on several factors (e.g. distance from destination, cost of use), we only measured preferences for cycle parking type with this set of variables; however, later in the paper, we profile the various identified cycle parking type clusters incorporating variables relating to other factors that may influence cycle parking preference, such as willingness to walk and pay.

In terms of phrasing, the question for this segment of the survey queried respondents' "likelihood to use" various cycle parking types if cycling in the county. The question was phrased as such in order to elicit the stated preferences of respondents for particular public cycle parking types if they were made available in the county, not to discover their existing cycle parking type usage, which was already surveyed in the 'Cycle Parking Practices' segment of the survey. Importantly, high scores on the scales for "Cycle Compound" options and "Cycle Locker - Digital Access", for example, indicate that respondents correctly interpreted this question as a stated preference rather than self-reported use question, since there are no council-provided cycle facilities of these types available in the county at present and only 4.5 % of respondents reported using such cycle parking types at their main destination.

Lastly, the inclusion of a detailed collection of items on cycle parking type preferences rather than focusing more deeply on cycle parking type usage itself was decided on the basis of the currently available public cycle parking in the county, the vast majority of which is comprised of unsheltered open cycle parking in the form of Sheffield stands. (Please refer to the Context section for more detail on current cycling provision in the county.).

Cycle Parking Perceptions were measured using nine scale items with five points each (1 = Strongly Disagree to 5 = Strongly Agree). With the first four items in this section, we measured various perceived qualities of public cycle parking for the county at present among respondents. These items related to parking sufficiency in terms of supply, parking accessibility, parking security, and parking safety for users. Following this, with the provision of "secure" cycle parking in the county, we measured respondent perceptions of willingness i) to cycle more, ii) to access public transit by cycle, iii) to use public transport more, iv) to pay a defined fee, and v) to walk greater distances in light of this

hypothetical "secure" cycle parking provision in the county.

Sociodemographic Information were measured for respondents through the following items: Gender (i.e., Woman, Man, Non-Binary, Other, Prefer Not to Say), Age (eight options, from "18 to 24 years old" to "85 years old +"), Education (11 options, adapted from Central Statistics Office [2016]), "Do you live in Dún Laoghaire-Rathdown?" (binary Yes/No response), and, lastly, "Do you work in Dún Laoghaire-Rathdown?" (binary Yes/No response).

4.2. Data analysis

In keeping with the aim of this research – to develop a group typology for cycle parking user preferences for Dún Laoghaire-Rathdown county – cluster analysis was used. Cluster analysis is a method for grouping a set of objects into different 'clusters' based on particular, researcher-selected attributes. It is frequently used as a method for breaking down a given sample or population of into more refined groupings, sometimes called 'segments', on the grounds of patterns of similarities and differences for a number of variables. When implemented correctly, for a given collection of objects, cluster analysis generates two or more clusters that display a high degree of within-cluster homogeneity and between-cluster heterogeneity (Hair et al., 2014); in this way, the cluster solution clearly classifies objects based on robust similarities and differences.

A critical decision for any cluster analysis is the selection of cluster variables (Hair et al., 2014). In line with the aims of this study, the continuous variables relating to the aforementioned *Cycle Parking Type Preferences* were selected as the cluster variables. Principal component analysis (PCA) was implemented in order to reduce the 11 variables relating to cycle parking type preference into a more manageable number of fundamental components. As a form of factor analysis, PCA can be used to reduce data from multiple variables by i) identifying representative variables from a wider selection of variables, or ii) generating a new, more parsimonious and greatly reduced set of variables to replace an originally larger set. The PCA approach was taken in particular in order to combat multicollinearity amongst these variables by creating more consolidated principal components, as multicollinearity between variables can distort cluster analysis (Hair et al., 2014). Importantly, we judged that it was plausible that an underlying structure of preferences existing among the variables in relation to the qualities of different cycle parking types (e.g. key access, guarded or unguarded, sheltered or unsheltered, open or enclosed); this assumption was supported in the ensuing analysis.

Following the identification of three principal components relating to cycle parking type preferences, surrogate variables with the highest factor loadings for each factor (Hair et al., 2014) were selected for hierarchical cluster analysis in order to determine the optimal number of clusters. Based on an analysis of cluster solution agglomeration coefficients, percentage changes in heterogeneity were used as the stopping rule for deriving number of clusters from the hierarchical cluster analysis (Hair et al., 2014). This led to the selection of a five-cluster solution for nonhierarchical K-means cluster analysis in which the final five-cluster solution was identified. Each of the five clusters were labelled in terms of their unique characteristics relative to other clusters and were subsequently profiled in relation to cluster member survey item responses relating to socio-demographics, practices and perceptions.

5. Findings

5.1. Sample

In total, there were 574 valid respondents to the online survey. In Table 1, we detail the characteristics of the sample in relation to socio-demographic and mobility-related variables. The sample was primarily comprised of men (59.2 %) followed by women (37.6 %), with four respondents identifying as non-binary, one as "Other", and 13 not providing data on gender. This gender breakdown contrasts with the most recent demographic data available for the county, which indicate that the county is currently comprised of 53.3 % women and 47.7 % men (Houses of the Oireachtas, 2020); however, these sample characteristics fit with evidence of a cycling gender gap for both Ireland (Central Statistics Office, 2019) and Dublin (Sustrans, 2020). Respondent ages were primarily between 35 and 54 years old (65.5 %) and the vast majority of respondents were educated up to university level (86.9 %) – this greatly contrasts with recent statistics for the county population, which indicates that 48.8 % of the population in this region have attained third-

Table 1
Sample Characteristics.

Variable	*Frequency*	*Percent*
Gender		
"Woman"	216	37.6
"Man"	340	59.2
"Non-Binary"	4	0.7
"Other"	1	0.2
"Prefer Not to Say"	13	2.3
Age		
"18 to 24 years old"	20	3.5
"25 to 34 years old"	79	13.8
"35 to 44 years old"	191	33.3
"45 to 54 years old"	185	32.2
"55 to 64 years old"	75	13.1
"65 to 74 years old"	24	4.2
Education		
Primary	1	0.2
Secondary	32	5.6
Other	42	7.3
University	499	86.9
Live in Dún Laoghaire-Rathdown		
Yes	496	76.5
No	78	13.5
Work in Dún Laoghaire-Rathdown		
Yes	263	45.8
No	311	54.2
Usual Commute Mode		
"Not at work, school or college"	30	5.2
"On foot"	17	3.0
"Cycle"	282	49.1
"Bus, minibus or coach"	15	2.6
"Train, DART or LUAS"	46	8.0
"Motorcycle or scooter"	4	0.7
"Driving a car"	106	18.5
"Passenger in a car"	3	0.5
"Van"	2	0.3
"Other - including lorry"	1	0.2
"Work mainly at or from home"	68	11.8
Cycle Ownership		
Yes	564	98.3
No	10	1.7
Cycle Type		
Utility Bike	293	51.0
Sport Bike	199	34.7
Folding Bike	3	0.5
E-Bike	55	9.6
Alternative Cycle	24	4.2
Cycle Frequency		
"Less than once per month"	42	7.3
"About once or twice per month"	45	7.8
"About once per week"	75	13.1
"About two or three days per week"	151	26.3
"About four or five days per week"	261	45.5
Main Cycle Destination		
Social/Care	58	10.1
Work/Education	132	23.0
Indoor Recreation	38	6.6
Outdoor Recreation	79	13.8
Sport/Fitness	30	5.2
Shopping	109	19.0
Public Transit	12	2.1
Cycling	116	20.2

level qualifications or higher (Houses of the Oireachtas, 2020). In this way, the sample is comprised of respondents that have considerably higher levels of education than the county population at large. Overall, the sample for this study is a convenience sample rather than a representative sample for the population who have access to a cycle and travel to or within the county; this limitation that should be considered in the interpretation of the results.

The majority of respondents (76.5 %) lived in the county and 45.8 % of respondents worked in the county. While 16 % of respondents did not engage in a usual commute, cycling was by far the most frequent means of commute among the sample (49.1 %), followed by driving (18.5 %). Public transport only accounted for 10.6 % as primary commute mode among the sample. Data could not be found for adult-only commute patterns for the county. However, the sample's use of cycling as their main mode of commuting (49.1 %) appears far greater than estimates for the Dublin Metropolitan Area, where Sustrans (2020) report that up to 24 % of residents cycle up at least once per week compared to the Irish adult population's use of cycling as a mode of travel, with the Central Statistics Office (2019) indicating a national rate of only 1.5 %. 98.3 % of the sample owned a cycle and the majority of these were "utility" cycles (51 %), followed by "sport" cycles (34.7 %). In general, the sample appear to be very active cycle users, with 45.5 % of respondents cycling "About four or five days per week". Lastly, "Work/Education" destinations were reported as the main cycle destination for 23 % of the sample. This the most selected category, followed by "Cycling" (20.2 %) – which indicates journeys for the engagement of cycling itself – and "Shopping" (19 %). In this way, there was a considerable mix of commuter, leisure and utilitarian cycling amongst the sample.

5.2. Principal component analysis

Responses to the Likert scale items measuring preferences for 11 different types of cycle parking were subject to Principal Component Analysis (PCA) using SPSS. The variables selected for analysis demonstrated a lowest variable communality value of 0.704. In this respect, variable communalities were all well within the acceptable range for PCA. In addition, both the KMO Measure of Sampling Adequacy (value of 0.857) and Bartlett's Test of Sphericity ($p = 0.000$) were well within inclusion criteria for PCA (Hair et al., 2014). Through a PCA of these 11 variables, three components were extracted. We labelled these components i) 'Locked Parking', ii) 'Guarded Parking' and iii) 'Open Parking' on the basis of their unique qualities as cycle parking types (see Table 2). These components were extracted on several bases. First, they accounted for 83.347 % of cumulative variance. Second, each component demonstrated an Eigenvalue above 1 and therefore warranted inclusion. The analysis displayed in Table 2 is the result of a Varimax rotation method, which is one of the most widely used methods for PCA rotation, particularly when the aim of the analysis is data reduction as it is in this study. However, using the oblique rotation method of Direct Oblimin on SPSS, the same three components were suitable for extraction based on rotated factor loadings. Loadings greater than or equal to 0.50 were considered practically significant, in keeping with Hair et al. (2014). As displayed in Table 2, one variable demonstrates cross-loading: "Cycle Compound Key Access Indoor". Since the aim of this analysis was strictly data reduction (Hair et al., 2014) and the loading of this variable was considerably higher for component 1 (0.704) than component 2 (0.547), this sole variable was not removed and cross-loading was ignored.

Table 2
Principal Component Analysis of Cycle Parking Preference Variables.

Component	Variable	*1*	*2*	*3*
Locked Parking	Cycle Compound Key Access Unsheltered	**0.660**	0.488	0.174
	Cycle Compound Key Access Sheltered	**0.694**	0.499	0.085
	Cycle Compound Key Access Indoor	**0.704**	0.547	0.022
	Cycle Locker Padlocked	**0.880**	0.219	−0.151
	Cycle Locker Digital Access	**0.837**	0.250	−0.090
	Cycle Bunker Key Access	**0.884**	0.254	−0.071
Guarded Parking	Cycle Compound Guarded Unsheltered	0.312	**0.897**	0.069
	Cycle Compound Guarded Sheltered	0.332	**0.899**	−0.009
	Cycle Compound Guarded Indoor	0.332	**0.891**	−0.028
Open Parking	Open Cycle Rack Sheltered	0.000	0.106	**0.921**
	Open Cycle Rack Unsheltered	−0.092	−0.056	**0.930**

5.3. Cluster analysis

Following the extraction of factors, surrogate variables were selected for hierarchical cluster analysis for each factor. The variables selected were, as suggested by Hair et al. (2014), those with the highest factor loadings for each factor: namely, "Cycle Bunker Key Access" (Locked Parking), "Open Rack Unsheltered" (Open Parking) and "Cycle Compound Guard Sheltered" (Guarded Parking). Squared Euclidean distance was selected as the similarity measure and Ward's method was chosen as the clustering algorithm. Based on an analysis of cluster solution agglomeration coefficients, percentage changes in heterogeneity were used as the stopping rule for deriving number of clusters from the hierarchical cluster analysis (Hair et al., 2014). Specifically, a major relative change in heterogeneity was identified from Stage 569 to Stage 570 of 33.13 % compared to the previous change of 17.25 % from Stage 568 to Stage 569. On this basis, a five-cluster solution was chosen for nonhierarchical cluster analysis by stopping at stage 569. Next, K-means analysis was employed to further analyse a five-cluster solution. For this analysis, random software-generated seed points were used along with the SPSS 'Iterate and classify' method. Following six iterations, convergence was achieved for each of the five clusters, resulting in the final cluster centres presented in Table 3 and Fig. 1 below. For this cluster solution, each of the three variables displayed statistically significant F values (sig = 0.000). Cluster stability was tested by rearranging the order of cases used in the original K-means analysis for the surrogate variables. In this rerun of the K-means analysis, Three of five clusters generated displayed the exact same patterns of means for each surrogate variable as the original analysis, while two clusters demonstrated very similar patterns of mean values that could be plausibly matched with original analysis clusters. Using cross-classification of the two cluster solutions, it was found that nearly 78 % of cases (i.e., 446 of 574 cases) remained with the same cluster groups in terms of patterns of mean values. In this way, the final cluster solution was successfully validated through a test of stability.

Having identified the final cluster solution, each cluster was labelled in terms of its unique characteristics relative to other clusters – namely, on the basis of cluster members' patterns of preference for open, guarded and locked cycle parking facilities. The final cluster centres can be viewed in Table 3 and Fig. 1. We display the overall approach to data analysis in Fig. 2. In the section below, we delineate the characteristics of each cluster specifically in terms of the clustering variables used.

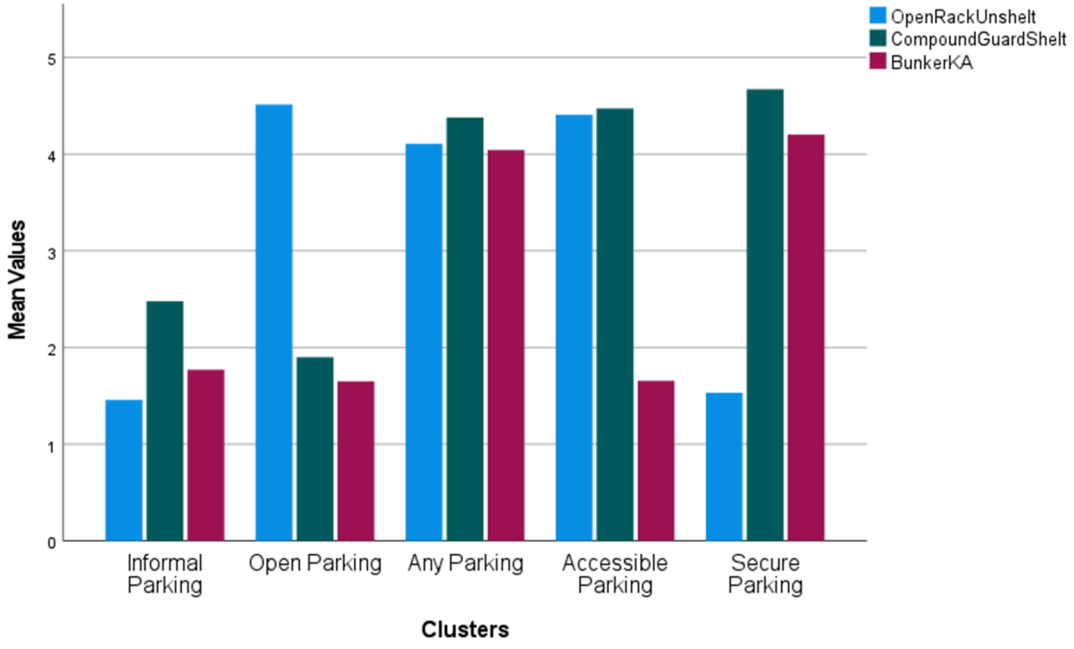
5.3.1. Cluster 1: Informal parking group (8.4 %)

The smallest of the five clusters, the 'Informal Parking Group' cluster is characterised by low scores for each of the three forms of parking identified in the PCA – open, guarded and locked – which can all be conceived as formal types of cycle parking. This suggests that this cohort does not prefer formal kinds of cycle parking, potentially favouring instead informal means of parking such as, perhaps, office or house spaces. Importantly, this cluster is characterised by a particular aversion to 'Open' styles of parking (i.e. cluster value of "Highly Unlikely" to use in the county) as opposed to guarded or locked variations (cluster value of "Unlikely" for each).

Table 3
Final Cluster Centres.

Clusters	*1 - Informal*	*2 - Open*	*3 - Any*	*4 - Accessible*	*5 - Secure*
Open Parking	1 = Highly Unlikely	5 = Highly Likely	4 = Likely	4 = Likely	2 = Unlikely
Guarded Parking	2 = Unlikely	2 = Unlikely	4 = Likely	4 = Likely	5 = Highly Likely
Locked Parking	2 = Unlikely	2 = Unlikely	4 = Likely	2 = Unlikely	4 = Likely
Cases	48 (8.4 %)	140 (24.4 %)	229 (39.9 %)	93 (16.2 %)	64 (11.1 %)

Figure 1. Final Cluster Centres.



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5.3.2. Cluster 2: Open parking group (24.4 %)

The second-largest cluster, the 'Open Parking Group' are characterised by a very strong preference for 'Open' styles of cycle parking and a low preference for both 'Guarded' and 'Locked' varieties. Consequently, this cluster is not orientated toward the more physically secure forms of cycle parking.

5.3.3. Cluster 3: Any parking group (39.9 %)

The largest cluster, members of this group report being "Likely" to use any kind of cycle parking in the county – open, guarded or locked – with no observably differentiated preference pattern for a particular cycle parking type. In this way, and in contrast to the informal parking group, this cohort appears in favour of any kind of formal cycle parking facility.

5.3.4. Cluster 4: Accessible parking group (16.2 %)

Members of this cluster appear to prefer accessible forms of formal parking (i.e. 'Open' and 'Guarded' cycle parking types) over cycle parking that is 'Locked' and therefore would require some form a key/digital access, which is arguably less convenient than parking one's cycle in a guarded or open parking facility since there would be a potentially added step of unlocking the parking facility to access one's cycle.

5.3.5. Cluster 5: Secure parking group (11.1 %)

Lastly, this cluster is characterised by a strong pattern of preference for secure parking styles, with 'Guarded' being scored "Highly Likely" in terms of potential use by members. As 'Locked' parking may be considered significantly more secure than 'Open' parking and 'Guarded' parking may be considered superior in terms of cycle security to 'Locked' parking styles, this cohort is plausibly conceptualised as the 'Secure Parking Group'.

5.3.6. Cluster profiling

Through cross-tabulating broader survey responses by cluster membership, we describe each cluster in terms of its unique composition for socio-demographic characteristics, mobility practices, cycle parking perceptions, and hypothetical practices for several cycle parking-related scenarios. In Table 4, we display the predominant response categories for all variables relating to these thematic areas by cluster, thereby profiling the clusters.

5.4. a. Socio-demographics

Across the five clusters, the socio-demographic profiling variables of *Gender* and *Education* demonstrated similar proportions. "Men" are the predominant gender category across all clusters. However, the 'Informal Parking Group' and 'Secure Parking Group' are particularly comprised of men (66.7 % and 68.8 %, respectively). Using the χ^2 statistic on a transformed version of the gender variable comprising of "Woman" and "Man" categories where other options were assimilated, gender did not demonstrate statistical significance across clusters ($p = 0.157$). For educational attainment, "University" is the predominant category across clusters. 'Informal Parking Group' is a clear standout relative to other clusters in terms of educational attainment, with 72.9 % of members acquiring university-level education – much lower than the second-lowest educational profile of the 'Secure Parking Group' (81.3 %) – thereby indicating that the 'Informal Parking Group' is the least formally

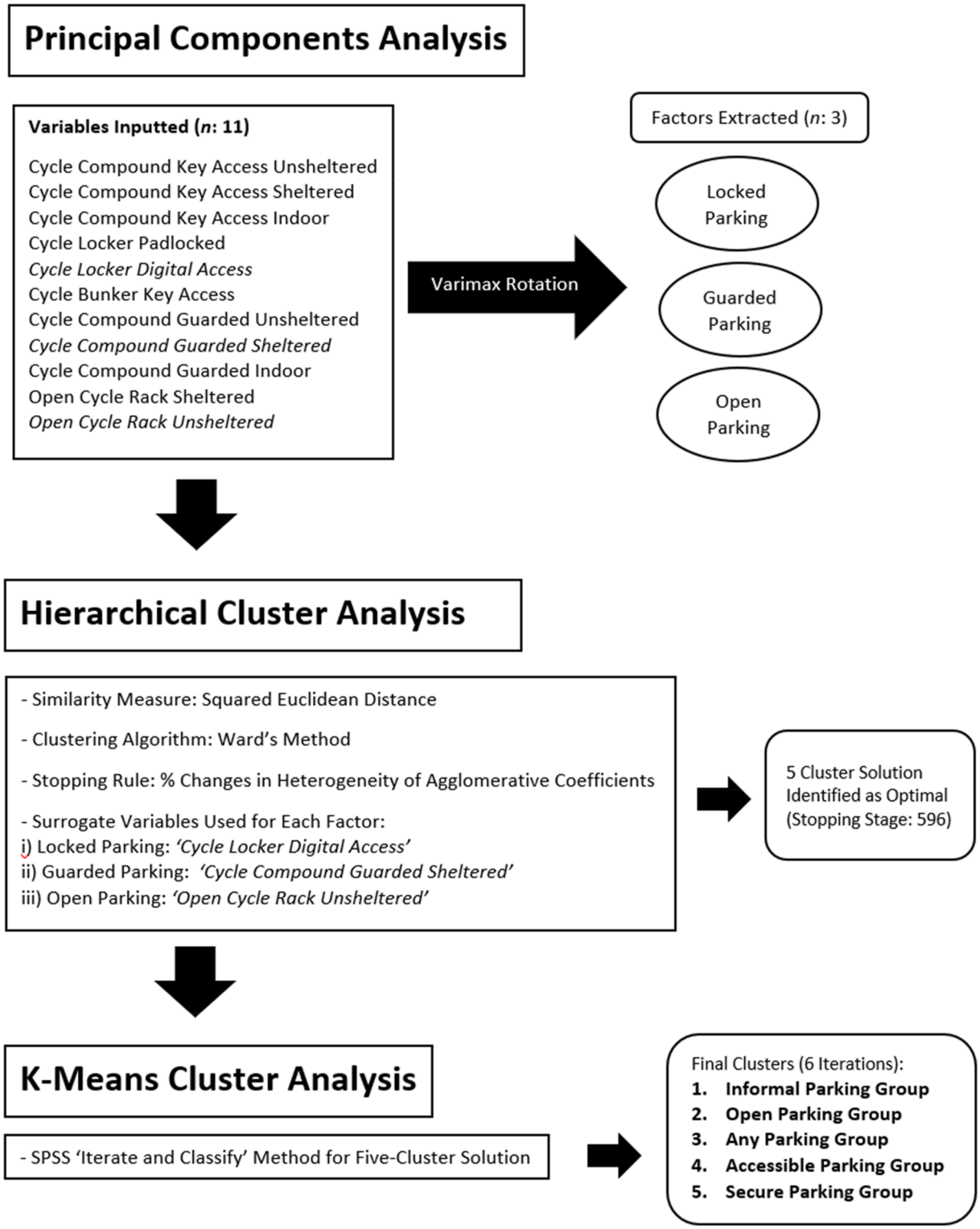

Fig. 2. Data analysis process.

educated cluster. Unlike gender, transformed into a variable involving the category of "University".

educational attainment or "Other" to assimilate all other categories, education was highly statistically significant ($p = 0.005$) with an Cramer's V value of 0.161. Lastly, categories relating to *Age* varied in terms of predominance between the clusters. Both the 'Informal Parking' and 'Any Parking' clusters demonstrate members who were predominantly between 35 and 44 years old in terms of age bracket. The remaining clusters, on the other hand, presented a predominant age bracket of between 45 and 54 years old, although, for the 'Accessible' and 'Secure' clusters, membership was only marginally predominated by this age bracket (e.g., the 'Accessible Parking' group was comprised of 25.8 % 35 to 44 year olds and 29 % 45 to 54 year olds). In keeping with the sample in general, members were primarily between 35 and 55 years old across all clusters. Recoded into three categories (18 – 34, 35 – 54, 55 – 74 year groups), age was not found to be statistically significant in

Table 4
Cluster Profiles by Predominant Category of Response.

Cluster	Predominant Socio-demographic characteristics	Predominant Practices	Predominant Perceptions
Informal	Male (66.7 %) 35–44 years (39.6 %) University (72.9 %) Cycle Type: Utility (45.8 %)	Destination: Cycling (29.2 %) Parking Type: Open Cycle Rack (35.4 %) Parking Duration: 1 – 2 h (27.1 %) Commute Mode: Cycle (43.8 %) Cycle Frequency: "About four or five days per week" (37.5 %)	Sufficiency: Neutral (29.2 %) Security: Strongly Disagree (39.6 %) Accessibility: Agree (33.3 %) Safety: Strongly Disagree (37.5 %) Cycle Use: Strongly Agree (31.3 %) Cycle Access: Strongly Agree (29.2 %) Public Transit: Strongly Agree (29.2 %) Walking: Agree (31.3 %) Payment: Strongly Disagree (33.3 %)
Open	Male (55.7 %) 45–54 years (39.3 %) University (92.9 %) Cycle Type: Utility (63.6 %)	Destination: Cycling (22.9 %) Parking Type: Open Cycle Rack (67.9 %) Parking Duration: 1 – 2 h (27.1 %) Commute Mode: Cycle (46.4 %) Cycle Frequency: "About four or five days per week" (50.7 %)	Sufficiency: Disagree (39.3 %) Security: Neutral (37.1 %) Accessibility: Agree (49.3 %) Safety: Agree (44.3 %) Cycle Use: Neutral (37.1 %) Cycle Access: Agree (32.9 %) Public Transit: Agree (31.4 %) Walking: Disagree (33.6 %) Payment: Disagree (27.1 %)
Any	Male (57.2 %) 35–44 years (41.0 %) University (86.9 %) Cycle Type: Utility (45.9 %)	Destination: Work/ Education (26.6 %) Parking Type: Open Cycle Rack (59.8 %) Parking Duration: 1 – 2 h (24.9 %) Commute Mode: Cycle (52.4 %) Cycle Frequency: "About four or five days per week" (43.7 %)	Sufficiency: Disagree (35.8 %) Security: Disagree (41.5 %) Accessibility: Neutral (39.3 %) Safety: Disagree (36.7 %) Cycle Use: Agree (38 %) Cycle Access: Strongly Agree (45 %) Public Transit: Strongly Agree (45.5 %) Walking: Agree (44.5 %) Payment: Agree (42.4 %)
Accessible	Male (59.1 %) 45–54 years (29.0 %) University (89.2 %) Cycle Type: Utility (61.3 %)	Destination: Shopping (26.9 %) Parking Type: Open Cycle Rack (73.1 %) Parking Duration: 30 m – 1 h (31.2 %) Commute Mode: Cycle (53.8 %) Cycle Frequency: "About four or five days per week" (52.7 %)	Sufficiency: Disagree (44.1 %) Security: Disagree (43 %) Accessibility: Agree (46.2 %) Safety: Agree (31.2 %) Cycle Use: Neutral (30.1 %) Cycle Access: Strongly Agree (41.9 %) Public Transit: Agree (36.6 %) Walking: Agree (32.3 %) Payment: Disagree (26.9 %)
Secure	Male (68.8 %) 45–54 years (32.8 %) University (81.3 %) Cycle Type: Sport (48.4 %)	Destination: Cycling (40.6 %) Parking Type: Open Cycle Rack (26.6 %) Parking Duration: 30 m or less (26.6 %) Commute Mode: Cycle (40.6 %) Cycle Frequency: "About four or five days per week" (35.9 %)	Sufficiency: Disagree (43.8 %) Security: Strongly Disagree (54.7 %) Accessibility: Neutral (42.2 %) Safety: Strongly Disagree (53.1 %) Cycle Use: Strongly Agree (64.1 %) Cycle Access: Strongly Agree (56.3 %) Public Transit: Strongly Agree (51.6 %) Walking: Agree (35.9 %) Payment: Strongly Agree (35.9 %)

relation to the cluster variables ($p = 0.271$). Lastly, for all clusters except for the 'Secure' group, utility cycles were the dominant type of cycle owned/used. The 'Open' and 'Accessible' clusters displayed particular high proportions of utility cycles (63.6 %, 61.3 %) and distinctly low proportions of sport cycles (26.4 %, 25.8 %), whereas the 'Secure' cluster stand out in terms of their high proportions of sport cycles (48.4 %) and e-bikes (17.2 %); this e-bike proportion was followed by the 'Informal' cluster (14.6 %). Assimilating the "Folding Bike" category into the "Alternative Cycle" category to generate a four-category variable, cycle type was a highly statistically significant variable in relation the clusters ($p = 0.001$) with a Cramer's V value of 0.142.

5.5. b. Practices

The cluster members' main cycling destination in the county is of particular interest in terms of cluster profiling. Assimilating the categories of "Public Transit" and "Sport/Fitness" – both of which received low frequencies of selection – into "Other", a χ^2 test of the transformed variable involving eight main destination categories was highly statistically significant ($p = 0.000$), with a Cramer's V value of 0.173. For the 'Informal', 'Open' and 'Secure' clusters "Cycling"– that is, cycling itself as the main trip purpose – was the predominant category selected for main cycling destination. This was especially dominant for the 'Secure' group, in which it comprised 40.6 % of selections. In this way, the 'Secure' group is markedly composed of members who mainly cycle for recreation/sport rather than commuter and/or utilitarian purposes; this is further supported by the aforementioned high composition of sport cycles for this group. This group demonstrated by far lowest rates of cycling for shopping (4.7 %) and outdoor recreation (1.6 %) and the highest rates for social/care (15.6 %) and indoor recreation (12.5 %) as main cycle destinations. The 'Informal', 'Open' and 'Secure' clusters displayed "Work/Education" destinations as their second highest categories for main cycle destination for their members (25 %, 22.1 % and 20.3 %, respectively). However, they differed greatly in terms of "Outdoor Recreation" as a main destination ('Informal' cluster: 4.2 %; 'Open' cluster: 18.6 %; 'Secure' cluster: 1.6 %). Thus, the 'Open' cluster appears to use cycling a good deal as part of a mix of outdoor recreation activities

in the county, unlike the 'Informal' and 'Secure' cluster members. For the 'Any Parking Group', "Work/Education" is the dominant category (26.6 %), followed by "Shopping" (23.6 %), thereby showing a large extent of instrumental cycle use. Lastly, for the 'Accessible Parking Group', "Shopping" is the dominant category (26.9 %), followed by "Outdoor Recreation" (18.3 %); this group demonstrate the lowest rate of "Work/Education" as their main cycle destination (16.1 %), and can therefore be seen as a distinctly utilitarian but non-commuter cluster relative to others.

The use of 'Open Cycle Parking' at one's main cycle destination, a usual commute mode of cycling and a cycle frequency of "About four to five days per week" were predominant across all clusters. In relation to cycle parking use at one's main destination, when four formal secure parking options (cycle bunker, cycle locker, cycle compound - guarded, cycle compound - locked) were consolidated into a single category (i.e. 'Formal Secure'), the transformed five-category variable was highly statistically significant ($p = 0.000$), with Cramer's V value of 0.190. The 'Informal Parking' and 'Secure Parking' clusters have relatively low levels of open cycle parking use at their main destination compared to other groups (i.e. 35.4 % and 26.6 %, respectively). In relation to the other three clusters, members of the 'Informal' and 'Secure' clusters also demonstrated much higher use of informal indoor/outdoor storage to park their cycles (18.8 % for 'Informal' cluster; 23.4 % for 'Secure' cluster) alongside relatively higher practices of "Do not park cycle/do not leave unattended" (10.4 % for 'Informal' cluster; 25 % for 'Secure' cluster). In this way, both of these clusters are characterised in terms of parking practices by the use of unofficial parking and the avoidance of parking; this makes sense in relation to their i) very low mean preference score for open cycle parking preference, ii) the lack of more secure cycle parking facilities in the county, iii) their primary use of cycling for its own sake, and iv) the likely high cost of their cycles, particularly for the 'Secure' group, which displayed a predominant cycle type of "Sport" (48.4 %). Interestingly, both of these groups also demonstrated notably higher uses of the car as their main commute mode (31.3 % for 'Informal' group; 39.5 % for 'Secure' group) compared to the other three clusters, where the third highest percentage among the clusters was only 16.4 % ('Open Parking Group'), along with the lowest rates of cycling "About four or five days per week" (37.5 %; 35.9 %) and highest rates for "Less than once per month" (10.4 %; 14.1 %). Accordingly, these clusters – the most dissatisfied with open styles of cycle parking – appear to be characterised by the lowest usage of cycling compared to the remaining three clusters, who rate open parking – which is widely available in the county – far more favourably as a form of cycle parking. Transformed into a five-category variable comprising of i) Other, ii) On foot, iii) Cycle, iv) Public Transport, and v) Driving, the variable of usual travel mode was highly statistically significant in relation to the clusters ($p = 0.001$) with a Cramer's V value of 0.130. Cycle frequency, on the other hand, was not statistically significant in relation to the clusters ($p = 0.066$).

Cycle parking duration at one's main cycle destination was statistically significant in relation to the clusters ($p = 0.038$), demonstrating a Cramer's V value of 0.119. The most notable differences between clusters were that the 'Secure Parking Group' engaged in considerably more longer-term parking (i.e. over 40 % of parking at main destination was for two hours of more) than other groups and that the 'Accessible Parking Group' engaged in the lowest duration parking (71 % between 0 and 2 h). However, the 'Secure' cluster also engaged in the highest percentage of parking "30 min or less" at 26.6 %. These considerable short-term parking practices may be explained in part by the previously mentioned dominant use of cycling among this cluster for recreational/sport purposes, followed by commuter uses using potentially expensive sport cycles which would involve longer-term parking.

5.6. c Perceptions

In general, all clusters primarily perceived existing parking in the county as insufficient in terms of supply ranging from mildly insufficient ('Informal Parking Group'), to highly insufficient ('Secure Parking Group'). In terms of existing cycle parking security, there was more variation between clusters. While all groups chiefly demonstrated negative assessments of cycle parking security, the 'Informal' and 'Secure' clusters rated cycle parking primarily as extremely insecure whereas the 'Open' parking group demonstrated a predominant category of 'Neutral' (37.1 %) despite an overall negative distribution. Cycle parking in the county was mainly perceived as accessible, particularly for the 'Open Parking Group' ("Dún Laoghaire-Rathdown public cycle parking is accessible": 49.3 % Agree) while only the 'Secure' cluster demonstrated overall higher frequencies of negative versus positive accessibility perceptions compared to the four alternative clusters. Lastly, perceived safety when locking one's cycle in the county was primarily rated negatively for the 'Informal', 'Accessible', 'Any', and 'Secure' clusters. In particular, the 'Secure' cluster reported extremely negative perceptions of safety when locking their cycles ("I feel safe when locking my cycle to public cycle parking facilities in Dún Laoghaire-Rathdown": 53.1 % Strongly Disagree). The 'Open' cluster, in contrast to all other clusters, primarily demonstrated mildly positive perceptions of safety (44.3 % Agree). This is interesting considering this cluster demonstrates the highest proportion of women, for whom personal safety risks in public may be greater (Kearl, 2010), whereas the 'Secure' parking group had the greatest proportion of men despite also displaying the highest perceived personal safety risk. In Fig. 3, we display the cluster average values for existing cycle parking perceptions.

5.7. d. Hypothetical practices

For perceptions of hypothetical cycle practices if more secure public cycle parking was provided in the county, the majority of the 'Informal', 'Any', 'Accessible' and 'Secure' cluster members reported hypothetically higher levels of cycling – particularly the 'Secure' group ("I would cycle more if there were more secure cycle parking facilities near my destination(s) in Dún Laoghaire-Rathdown": 64.1 % Strongly Agree). The 'Open Parking Group', in contrast, provided primarily "Neutral" responses to this statement. Interestingly, 22.5 % of the 'Informal' cluster responded with "Strongly Disagree" to this statement – by far the highest across the clusters. This shows a high degree of divided opinion within this cluster considering the predominant category of response was "Strongly Agree" (31.3 %). For reported interest in using cycling as an access mode to public transit and reported willingness to use public transit more in the scenario where more secure cycle parking facilities were provided in the county, all clusters primarily displayed moderate to strong positive responses. For both public transit related items, the 'Informal' cluster demonstrated outlier responses of "Strongly Disagree" (25 % and 27.1 %, respectively), thereby indicating – similar to their responses to increasing cycle use with secure parking provision – a relative lack of willingness to increase cycling with increased secure parking provision compared to the alternative clusters. The 'Secure' group, in contrast, demonstrated the highest proportion of positive responses to both items ("I would be interested in accessing public transport by cycling if there were more secure cycle parking facilities in Dún Laoghaire-Rathdown": 56.3 % Strongly Agree; "I would be more likely to use public transport if there were more secure cycle parking facilities in Dún Laoghaire-Rathdown near my route": 51.6 % Strongly Agree), thereby indicating that this cluster is the most willing to cycle more in a single and multi-modal fashion with the provision of secure cycle parking in the county.

Lastly, in relation to 'willingness to pay' variables that measured both financial and physical (i.e. walking distance) costs for access to secure cycle parking, the 'Secure' and 'Any' parking clusters were the only clusters that displayed a majority positive willingness to pay for secure cycle parking in relation to an example monetary cost of 2.5 euros per week (a typical rental value which was provided by a leading Irish cycle locker provider) and an unspecified physical cost of walking a

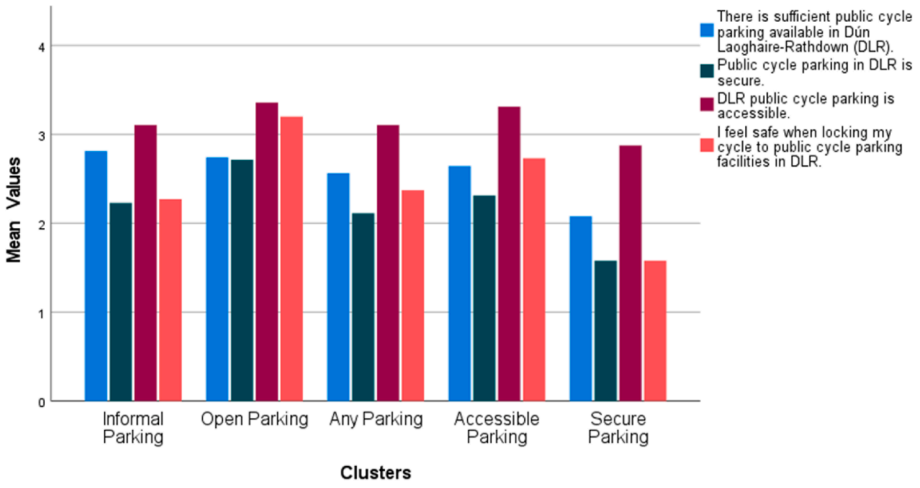

Fig. 3. Cluster averages for existing cycle parking perceptions.

"greater distance" to access such facilities. The 'Open' group displayed a mildly negative orientation in relation to paying for secure parking whereas the 'Accessible' group presented an essentially neutral orientation in relation to financial cost and a mildly positive orientation in relation to greater walking distance. Interestingly, for both items, the 'Informal' cluster displayed the strongest aversion to costs for secure parking ("I would be willing to pay a small fee, such as 2.5 euros per week, to use secure cycle parking (e.g. locker, compound, bunker) rather than a standard cycle stand": 33.3 % Strongly Disagree; "I would be willing to walk a greater distance to my destination to use secure cycle parking": 20.8 % Strongly Disagree). These responses present a clear element of differentiation between the 'Informal' cluster and the 'Secure' cluster, who were the most willing to pay for secure parking. In Fig. 4, we display the cluster average values for hypothetical mobility/cycle parking practices.

6. Discussion

The findings for this study are drawn from a highly educated convenience sample who primarily live in Dún Laoghaire-Rathdown county and engage in a relatively high-level of cycling for an Irish context. Nevertheless, through the identification of clustered patterns of preferences that relate to unique socio-demographic, practice and perception profiles, implications can be interpreted with care in considering the question of how local and national authorities might implement different types of cycle parking more effectively and strategically.

In one respect, cycle parking planning can be enacted with the strategy of maximising cycle journeys as part of a broader modal share. This can be considered cycling promotion in its most general form (Pucher and Buehler, 2008). In this study, the 'Any', 'Accessible' and, most notably, the 'Secure' parking groups stated the greatest intentions to cycle more in general, cycle as a form of public transport access, and increase public transport use in the hypothetical situation in which more secure parking was provided across the county. This makes sense in part due to the relative lack of preference for secure parking of any kind by both the 'Informal' and 'Open' parking groups. However, there is already considerable open cycle parking coverage in the county (Dún Laoghaire-Rathdown County Council, 2021a) and both the 'Informal' and 'Open' clusters perceive cycle parking in the county, in general, to be fairly sufficient in terms of supply, thereby indicating a lack of clear demand from these clusters for more parking facilities of any kind. With this consideration in mind, the findings from this study indicate that the 'Any', 'Accessible' and, most notably, the 'Secure' parking groups may be the best market segments to target in terms of the provision of particularly preferred cycle parking types to increase ridership in the county. This would mean a push to implement secure cycle parking facilities in the form of locked cycle parking facilities or, more unanimously, guarded cycle compounds across the county in relevant locations. Based on the survey results, public transport hubs may be a useful starting point for secure cycling parking provision. Such secure provision in the form of parking compounds, stations and lockers has been widely implemented across high-cycling European contexts (Buehler et al., 2017). Based on the Dutch experience, rail transport is best targeted over bus transport (Martens, 2007). Focusing on the

Fig. 4. Cluster averages for hypothetical mobility/cycle parking practices.

'Accessible' parking cluster in particular, who demonstrate distinctly utilitarian but relatively non-commuter patterns of cycle use, cycle compounds in commercial areas may be well-suited to the needs of this segment – something which, along with a focus on rail hubs, has been considerably implemented internationally to facilitate increased and enhanced ridership (Pucher and Buehler, 2008; Pucher et al., 2010).

However, as Aldred et al. (2016) have revealed in their analysis of reported cycle commuting practices in the UK, increasing cycle ridership does not equate with expanding the diversity of people cycling, at least in terms of gender and age. The relative inclusivity of cycling mobility infrastructures have been explored significantly (e.g. Aldred and Dales, 2017; Aldred et al., 2017; Carroll et al., 2020; Garrard et al., 2008), while, to a lesser extent, some existing cycle parking research is relevant to the question of cycling equity. The study of Lusk et al. (2014), for example, examined the use of and preference for different formal and informal cycle parking types between middle class women and men in Hangzhou, China, in which they found no statistically significant differences. Arbis et al. (2016), on the other hand, investigated the use of open and locker cycle parking at public transport stations in New South Wales, Australia. These researchers found that open parking use at public transport stations was positively associated with income whereas cycle locker use was positively associated with age. Lastly, the cycle parking preference typology study of Molin and Maat (2015) reported that age was the only statistically significant variable in relation to group membership; in particular, the older the respondent, the more likely they were to be a member of the 'paid facility lover' cycle parking segment. In terms of planning cycle parking in a way that promotes greater equity in cycle ridership, some claims can be made on the basis of this study in relation to gender and educational attainment.

First, open cycle parking appears to be the most heavily favoured form of cycle parking provision for women respondents in this study. Namely, the clusters with the highest proportion of women – the 'Open', 'Any' and 'Accessible' parking clusters – all rated open forms of cycle parking highly in terms of preference. In contrast, the clusters with the lowest proportion of women – the 'Informal' and 'Secure' groups – rated open cycle parking as the lowest of all parking forms. This could be related to i) greater concerns among women with being assaulted or the victim of other crimes (Ravensbergen et al., 2019) since secure forms of parking may involve longer periods in order to lock one's cycle, greater enclosure, and/or less passive surveillance then open forms of parking, and ii) greater rates of cycle-activities and end use practices among women that involve shorter durations of cycle parking and may benefit from easier access and egress from parking facilities, such as "household-serving trips" like grocery shopping (Ravensbergen et al., 2020, p.343) that may additionally involve trip-chaining (Ravensbergen et al., 2019). Such a view is particularly supported by the profiling of the 'Any' and 'Accessible' clusters, each of which exhibited high reported of "Shopping" as the main cycle destination in the county (23.6 % and 26.9 %, respectively). In this way, high-quality, robust and widely available open cycle parking is, at least on the grounds of this stated-preference cluster analysis, highly important for facilitating cycle ridership amongst women in the county.

Second, in terms of educational attainment, the 'Informal' cluster demonstrated the lowest proportions of university-level education, thereby indicating that this group may be the least educationally advantaged across the clusters. This finding is problematic in terms of cycle parking planning because it suggests that building formal *public* cycling facilities will not necessarily facilitate greater ridership among groups that are less educationally advantaged in the county. Furthermore, in terms of both average and mode responses, this group rates the sufficiency of cycle parking in the county higher than any of the remaining clusters, suggesting a lack of demand for more public facilities. Examining average values, along with the 'Open' cluster, the 'Informal' cluster appears to be the least interested in increasing their cycle use, cycle access journeys and public transport use with the provision of secure cycle parking facilities; furthermore, they appear – once again along with the 'Open' cluster – the least willing to pay in terms of monetary or physical cost for secure facilities. In this respect, if any provision of secure public parking facilities was developed to serve this cluster, who appear to engage in a good deal of cycle-commuting, this provision would arguably need to minimise costs through free access and maximum proximity to the cluster member's destination.

Lastly, squarely adopting a social practice perspective (Shove et al., 2012), rather than endeavouring to promote either aggregate or group-specific ridership, particular cycle-activities (Cass and Faulconbridge, 2016) and end use practices (Spurling, 2020) could be targeted using this cycle parking type preference typology. For example, if high levels of private car use are exceptionally prevalent for shopping journeys in a specific location, cluster-specific types of cycle parking most suited to 'cycle-shopping' as a practice may be considered. In the case of this study, the 'Accessible' parking group demonstrate the highest rates of shopping-related cycle journeys. In this way, the ample provision of both open cycle parking and guarded cycle compounds in relevant locations could promote this mode-activity, and, in doing so, promote *mode-activity shift* away from car-shopping practices. Of course, mode-activities and end use practices are likely gendered, classed and aged; in this way, considerations for group-specific cycling promotion and unique cycle-activity promotion can be considered in tandem.

7. Conclusion

This research was carried out in Dún Laoghaire-Rathdown – an electoral county of Dublin, Ireland. In this study, we analysed survey data from a highly educated convenience sample who primarily reside in the county and engage in a relatively high-level of cycling for an Irish context (*n*: 574). We carried out several analyses on these data: i) a Principal Component Analysis of 11 cycle parking type preference variables, reducing these variables to *Open, Locked* and *Guarded* cycle parking types; ii) a two-step cluster analysis of cycle parking type preference data in which we derived a five cluster solution comprising of *Informal, Open, Any, Accessible* and *Secure* cycle parking preference clusters; and iii) a profiling of our five cluster solution, examining the demographic composition, current and hypothetical mobility/cycling practices, and perceptions of cycle parking in the county at present for each of the clusters. On this basis of this work, we conclude that our ensuing cycle parking type preference typology could be used to inform local (Dún Laoghaire-Rathdown County Council Municipal Services Department, 2018) and national (National Transport Authority, 2011) cycle parking policy and planning efforts through i) targeting clusters that may yield the greatest increase in aggregate cycle ridership, ii) catering for clusters on the basis of enhancing cycle equity for those demographically underrepresented in cycle ridership and/or potentially marginalised in cycle infrastructure planning efforts, and iii) providing for clusters on the basis of strategically promoting particular cycle-activities (Cass and Faulconbridge, 2016), such as cycle-shopping, and end use practices (Spurling, 2020) that may require unique forms of cycle parking.

CRediT authorship contribution statement

Robert Egan: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Project administration. **Conor Mark Dowling:** Conceptualization, Methodology, Validation, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Project administration. **Brian Caulfield:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

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