Factors influencing usage of urban blue spaces: A systems-based approach to identify leverage points.

**Highlights**

- Understanding the factors influencing the usage of urban blue spaces is important to maximise their health-promoting potential
- Combining network analysis and systems mapping is an innovative approach
- *Exercise & Health* and *Urban Nature* were the main factors influencing usage
- *Cleanliness & Maintenance* was the factor which could be improved
- This method could be replicated to understand other public health issues
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Abstract
Urban blue spaces may have salutogenic health benefits. It is crucial to understand the factors that influence the use of urban blue spaces so that urban populations can benefit equitably. A system map of factors influencing usage was developed by qualitatively analysing 203 intercept interviews conducted with people actively using the towpath along the canal in North Glasgow, Scotland. Network analysis was used to analyse the system map’s structure identifying Exercise & Health and Urban Nature as key leverage points and Cleanliness & Maintenance as the key area for improvement. Findings could be used to inform the management, governance and revitalisation of urban blue spaces with the ultimate aim of maximising their potential to be equitable, sustainable and salutogenic.

Keywords
Blue Space; Urban Environment; Public Health; Systems Analysis, Qualitative Data

Introduction
Global population health is improving incrementally; we see increased life expectancy and reductions in infant and child mortality rates worldwide (World Health Organization, 2018a). While overall statistics show an improvement, there are still many growing threats to human health. Non-communicable diseases, most of which are preventable, are the leading cause of deaths globally, with coronary heart disease and stroke contributing to a combined 15.2 million deaths a year (World Health Organization, 2018a). Physical inactivity is a modifiable behavioural risk factor of premature non-communicable diseases; 1.6 million deaths are attributed to insufficient physical activity each year (Forouzanfar et al., 2016). Also, physical inactivity is the fourth leading risk factor associated with heart disease, after high blood pressure, smoking and high blood glucose (World Health Organization, 2018a). Mental health also poses a significant risk to public health; one in four people will be affected by a mental health disorder in their lifetime (World Health Organisation, 2001). The disadvantaged in society are disproportionately affected by both physical and mental health issues and are most vulnerable to ‘syndemics’: synergistic health problems that affect a population’s health due to deep-rooted and persistent social and economic inequalities (Mendenhall et al., 2017). Therefore, to strive towards health equity, we must understand the wider systems in which health exists. Systems-based approaches recognise that some public health issues are complex, involving multiple interacting pathways and feedback loops acting at individual, community and policy levels. Systems-based approaches provide an alternative way to inform public health policy and action by understanding the structure and internal dynamics of the system that underlies a specific issue. Instead of trying to study individual factors that influence health in isolation, systems-based approaches seek to map and model many different factors and their interconnectedness.
By 2050, more than 70% of the world will live in urban environments (United Nations (UN), Department of Economic and Social Affairs, 2018). Consequently, cities play a critical role in health promotion. To accommodate increased numbers of residents, cities must grow sustainably, equipped with the infrastructure for people to live healthy and happy lives. The United Nation’s Sustainable Development Goals for 2030 include ‘good health and wellbeing’ and ‘sustainable cities and communities’ as two of the goals for a sustainable, prosperous and peaceful future (United Nations, 2015). Such goals cannot be achieved in isolation, and healthy, safe and sustainable urban environments will undeniably support good health and wellbeing. Cities tend to offer greater employment prospects, essential services, and social networks than rural areas. Conversely, cities can exacerbate health risk factors, including poor quality housing (World Health Organization, 2018b), higher exposure to air pollutants (Beelen et al., 2015; van der Zee et al., 2016), heat exposure due to the Urban Heat Island phenomenon (Heaviside et al., 2017) and increased risk of serious mental illness (Gruebner et al., 2017). Finally, densification within cities causes competition for land and preserving natural environments for people to improve their health may become challenging.

The importance of natural outdoor spaces in cities is popularly recognised. Natural outdoor spaces can promote mental, physical, and social wellbeing, and it has been argued that having universal access to natural outdoor environments is a fundamental environmental justice issue (Smardon et al., 2018). Various systematic reviews of the literature have reported on the beneficial effects of nature on human health, including helping reduce stress (Yao et al., 2021), contributing to positive affect (McMahan and Estes, 2015), reducing blood pressure and risk of diabetes (Twohig-Bennett and Jones, 2018) and reducing mortality rates (Rojas-Rueda et al., 2019).

Blue spaces, defined as all forms of natural and manmade surface water, are part of the urban fabric of most cities, with 50% of the world’s population living within 3 km of a body of fresh water and only 10% living more than 10 km away (Kummu et al., 2011). Research into the health benefits of blue spaces is gaining traction. Current blue space literature supports the salutogenic benefits of blue spaces through improving physical and mental health and wellbeing (Gascon et al., 2017; Nieuwenhuijsen et al., 2018; Smith et al., 2021; Völker and Kistemann, 2011). In their systematic review and meta-analysis of quantitative papers, Smith et al. (2021) found that living near blue spaces was associated with better self-reported mental health and wellbeing, better self-reported general health, reduced mortality rates, and reduced levels of obesity. Such benefits may be distinct and complementary to those provided by green spaces. As well as the direct health benefits attributed to blue space exposure, researchers have identified the following mechanisms through which health can be impacted by blue space: blue spaces may encourage physical activity, increase social connectivity and interaction, reduce stress and reduce harmful environmental exposure (Georgiou et al., 2021). However, living near blue spaces does not necessarily mean that local populations will use them (Tillmann et al., 2018). We also do not know the best ways to use blue spaces to maximise their health-promoting potential.

The posited benefits of blue spaces may not be shared equitably by all populations. A cross-sectional study conducted in the UK found that people who frequently visit blue spaces are likely to have university degrees and better overall health (de Bell et al., 2017). Similarly, researchers found that although Hispanic people with lower socio-economic status lived closer to urban blue spaces in Utah, USA, white people with higher socio-economic status spent more time in and had a greater awareness of urban blue spaces (Haefner et al., 2017). Such evidence illuminates the disparities across different demographics; people who are systemically disadvantaged also may miss out on the health benefits of urban blue spaces.
There is a dearth of literature on the factors influencing the usage of blue spaces; however, research into the use of green spaces is extensive (Schipperijn et al., 2010). Residential distance to green space has commonly been associated with how much it is used (Björk et al., 2008). Schipperijn et al. (2010) investigated the factors influencing people’s usage of green spaces in Denmark and found that the primary reasons were to enjoy the weather and get fresh air. A recent study in Portugal found that the tranquillity and the attractiveness of an urban green space contributed to usage (Pinto et al., 2021). Studies into green space usage have predominantly used traditional quantitative survey methods (Schipperijn et al., 2010). Residential distance to blue spaces has been shown to directly relate to blue space visits; the closer people live to blue spaces, the more likely they are to use them (Elliott et al., 2020). However, residential distance is not as modifiable as other potentially influential factors. Although some similarities may exist between the factors influencing green space and those influencing blue space, blue spaces are inherently different to green with regard to geography, spatial distribution, and primary function. Therefore, findings for the usage of green spaces cannot be generalised to blue spaces.

Our research is novel as broader, modifiable factors influencing the usage of blue spaces have not been explored within the literature. Using a systems-based approach, which incorporates in-depth qualitative data, enables us to gain knowledge that would be difficult to attain using conventional causal inference designs.

Systems thinking provides a useful lens to explore the factors influencing usage of urban blue spaces. Systems thinking refers to an approach to help understand complexity by thinking holistically and examining the whole rather than the component parts of a problem (Checkland, 1989). The fields of systems thinking and systems dynamics are extensive, and there is no agreed-upon definition or conventions around what a systems map is. Therefore, we understand 'systems maps' to be an umbrella term for a broad set of tools to represent a system. Systems thinking is increasingly considered a powerful means to explore the complexities of public health problems and has been successfully used to analyse factors influencing sedentary behaviours (Buck et al., 2019; Chastin et al., 2016) and levels of obesity (Levy et al., 2011; McGlashan et al., 2016; Vandenbroeck et al., 2007).

Although standard systems analysis is purely quantitative, it is argued that the fundamental nature of researching relationships between data is rooted in sociology and other social sciences. Heath et al. (2009) argue that relational data and how relationships affect human behaviours are integral to social science. Crossley and Edwards (2016) promote mixed methods approaches within network analysis. To understand the system maps and statistical analyses, researchers must understand the content of the relationships between factors influencing usage, not just their structure.

The interconnected factors influencing usage make up a 'system of factors influencing usage', which is visualised in a system map. Leverage points can be identified through topological analysis of the system map structure (Murphy and Jones, 2020). Leverage points are components of a system that, when altered, can create lasting change and have positive ripple effects through the system (Meadows, 1999). These leverage points become the focus of interventions that could promote equitable use of urban blue spaces.

We use 'factors influencing usage' to describe the factors which facilitate and constrain the use of urban blue spaces. The health benefitting potential of urban blue spaces can only be harnessed when we can more fully understand these modifiable factors influencing usage. People’s behaviour and whether they use urban assets such as green or blue spaces are influenced by personal, environmental and political factors, which are often nested and interconnected (Rutter et al., 2019).
This paper aims to develop a system map of the influencing factors that facilitate and constrain the use of urban blue spaces. Specifically, we ask the following questions: (i) What are the main factors influencing usage of urban blue spaces? and (ii) Where can changes be made in the system to increase usage of urban blue spaces? Local decision-makers can leverage the key influential factors to inform local policy and action.

**Methods**

**Design**

This study involved a two-stage process. First, we constructed a system map of factors influencing usage based on the qualitative analysis of intercept interviews. The structure of this map was then analysed using network analysis methods to identify leverage points (eigenvector), elements sensitive to change (degree), resilient elements (closeness) and bottlenecks (betweenness) (Murphy and Jones, 2020).

**Data acquisition**

We modelled our intercept interviews on previous studies investigating the salutogenic impact of urban blue spaces (Finlay et al., 2015; Flint et al., 2016; Vaeztavakoli et al., 2018; Völker and Kistemann, 2011).

Data collection took place at access points to the Glasgow Canal, a part of the Forth and Clyde Canal in Glasgow, the largest city in Scotland. The Forth and Clyde Canal was closed to navigation in 1963. The canal has been under regeneration since the early 2000s as a result of the Millennium Link Project, and today it serves as an area of recreation in the city. The canal is surrounded by some of the most deprived areas in Glasgow, as defined by the Scottish Index of Multiple Deprivation (SIMD), an example of the legacy of de-industrialisation in North Glasgow (Figure 1). We chose three sites for data collection: Stockingfield Junction, Maryhill Road and Applecross. These sites are the main access points to the canal and provide insight into usage patterns across multiple geographies.
Intercept interviews were conducted at these three sites with people who were actively using the canal towpath. Public intercept interviews are commonplace in consumer research but are less frequently used in academic research. Given our existence in an accelerating world, where potential participants generally are unwilling to engage in lengthy encounters, making data collection processes streamlined and efficient is key to engagement (Dillman et al., 2014). Flint et al. (2016) discuss the benefits of using intercept interviews to assess place-based perceptions of natural environments. They conclude that the quotations “made the project come to life”, helping them tell a human story of real-life experience and made their research more digestible to academic and layperson audiences alike.

Participants were randomly sampled, with a similar number of participants interviewed across each site. Trained fieldworkers gained informed consent from participants before administering the structured interview using the Epicollect 5 mobile app (Imperial College London, 2009), which had been piloted. Intercept interviews were conducted between 12 October and 10 November 2019, between 09:00 and 17:00, across weekdays and weekends, spanning a combined total of 60 hours. This allowed researchers to capture hourly and daily variations in categories of users and types of visits (Blair and Blair, 2014). The intercept interview, detailed in Supplemental Item 1, included multiple-choice and open-ended questions (which were audio-recorded) designed to capture canal users’ perceptions of the space. We asked how often participants used the canal, the duration of trips and what the reasons were for their visit. We asked open-ended questions about the perceived accessibility of the canal and if there was anything that would make them visit more often. The use of open-ended interview questions provided organic, inductive data, and researchers prompted for clarification as needed (Flint et al., 2016). Participants were asked to rate their general health from excellent to poor (Cella et al., 2010) and were asked an open-ended question about whether they considered the canal to affect their physical and mental health. We incorporated demographic
questions into the interview to assess the representativeness of participants when compared with the local population of Glasgow (Flint et al., 2016). Demographic information was collected solely for summary use and reporting and was not used within our qualitative analysis (Flint et al., 2016).

Ethics were obtained from the School of Health and Life Sciences at Glasgow Caledonian University (ethical approval code: HLS/PSWAHP/17/144).

Data analysis
Each participant was ascribed a number identifier to allow for anonymous reporting. These identifiers are in superscript following quotations and ideas in the results. Audio files were transcribed using intellectual verbatim transcription. A denaturalised approach to transcription was adopted to present ‘clean’ data, free from speech disfluency like stutters, breaks, or fillers (Oliver et al., 2005). This approach was appropriate as the research aimed to understand opinions and perceptions rather than emotions or body language (Davidson, 2009). Transcripts were read thoroughly, and preliminary semantic thematic coding took place inductively using NVivo™ software (Bazeley and Jackson, 2013; Braun and Clarke, 2006). This process was data-driven and captured patterns in the entire data set to provide a rich description of the topic (Braun and Clarke, 2006). Initial codes were refined, and related ideas were combined to create themes (Braun and Clarke, 2006). We identified these themes as factors that influenced why and how people use the canal.

Factors influencing usage were organised using a socio-ecological framework model (SEM) (Mcleroy et al., 1988). Contrary to most health behaviour frameworks, which focus predominantly on attitudinal variables at the intrapersonal level, the SEM argues that individual behaviours are influenced by factors at multiple levels, including personal perceptions, inter-social factors, the built environment and the natural environment and other external influences (e.g., policies). Reflexive iteration is a key part of qualitative analysis, and revisiting the data and connecting them with emerging themes and ideas allowed for refined focus (Srivastava and Hopwood, 2009). Following reflection on this analysis, we discerned that actually the data was not fixed within these factors but that the factors influencing usage were inextricably entwined instead of being standalone variables (Rutter et al., 2019). We, therefore, conducted a follow-up round of coding where participants’ responses were attributed to more than one factor. Examples of how data were coded are provided in Supplemental Item 2. Regarding the ‘trustworthiness’ of the research process, thick descriptions of the study area are provided, allowing the reader to assess the transferability of the research to different contexts (Guba and Lincoln, 1989). The methods are described sufficiently to allow another researcher to conduct the study, thus highlighting dependability (Guba and Lincoln, 1989).

Furthermore, intercoder reliability was obtained by having a second author code a subset of data, prompting reflexivity and dialogue within the research team (O’Connor and Joffe, 2020).

This paper used systems thinking to analyse the interactions between factors influencing usage in a system, using qualitative data. This novel approach was appropriate as the qualitative intercept interview data do not merely complement the quantitative analysis but were fundamental to understanding the system within a real-world context and thus bridged "soft" and "hard" systems traditions (Murphy and Jones, 2020). In our context, the system was the sum of all the factors influencing usage and the relationships between them. System maps enable us to understand the interactions between factors influencing usage and allow us to move from evidence to action.
Participants’ responses were analysed to explore links between factors influencing usage. The number of responses relating to each connection was collated and imported to Kumu, a powerful data visualisation platform, to create an interactive system map of factors influencing usage (Kumu, 2020). The map consists of elements (the factors influencing usage) and connectors (the links between the factors influencing usage). The weight of each connector depended on how many participants made the link between the factors influencing usage.

There are many types of systems maps and conventions for how to use them. Each type of map offers different ways of visualising relationships between component parts of a system and different opportunities to identify leverage points (Meadows, 1999). Causal Loop Diagrams (CLDs) are perhaps the most commonly known systems map. Such maps explore cause and effect relationships from a qualitative point of view. CLDs are a foundational tool within the field of systems dynamics, helping us visualise the intricate processes and interrelatedness of factors in a problem (Forrester, 1961; Senge, 1990). They can also provide a basis for creating quantitative system dynamics models (Forrester, 1961). Polarity is a key feature of CLDs; directional arrows connect variables, and the arrows can be marked ‘+’, (when A increases, B increases and when A decreases, B decreases) or ‘−’ (when A increases, B decreases and when A decreases, B increases). Within our system map, polarity was not considered for the connections between factors. The narrative analysis identified undirected connections between factors; one factor was not necessarily affecting the other or affected by the other; they were simply related. Therefore, the map is not a CLD but is instead a visualisation to aid in understanding the intersectionality of our qualitative data.

The structure of systems maps can be analysed to identify leverage points: modifiable components in a system that, when changed, can lead to sustained improvement in the system’s functioning (Meadows, 1999). Identifying these points is fundamental to understanding where to intervene in a system, and various tools have been adopted (see Malhi et al., 2009; Meadows, 1999; Nobles et al., 2021; Senge, 1990), while others propose further critique and deliberation is required to learn better how to interpret leverage points (Leventon et al., 2021). Murphy and Jones (2020) proposed and piloted the use of centrality metrics as potential “leverage measures” to pursue alternative, quantitative ways to understand leverage within systems. Our system map was complex and convoluted, and quantitative techniques were deemed helpful in understanding the map’s topography by using centrality algorithms to identify leverage points, making it easier to untangle the complexity (Murphy and Jones, 2020). While Murphy and Jones (2020) conducted centrality analyses on a CLD, the metrics we use (eigenvector, degree, betweenness and closeness) are not reliant on directional relationships and are therefore also suited to our type of system map.

We analysed the map’s structure using built-in network analysis algorithms within Kumu to derive the eigenvector, weighted degree, closeness and betweenness centralities (see Table 1 for definitions). Such metrics are ordinarily used within network analysis involving relationships between people or organisations. Increasingly, however, the relationships between non-social networks have been quantified using such network analysis techniques (Murphy and Jones, 2020).

Network analysis allows for a quantitative summary of the structure of a network. Murphy and Jones (2020) suggest that such metrics can be used to quickly uncover structurally important parts of a system (Murphy and Jones, 2020). We adopt their proposed translations of network centrality techniques into metrics that can be used within systems thinking. These translations are detailed in Table 1. This approach helps us understand how changes to one part of the system will likely affect
other parts of the system, allowing us to quantify the importance of factors influencing usage within the system.

Table 1 – Centrality leverage metrics for interpreting system maps (Murphy and Jones, 2020). Network map column added by authors.

<table>
<thead>
<tr>
<th>Definition</th>
<th>Systems function</th>
<th>Use in systemic design</th>
<th>Network Map (dark elements = high rank)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvector</td>
<td>Connectedness to other well-connected elements</td>
<td>Influence of highly influential elements (Newman, 2010)</td>
<td>High-eigenvector phenomena are powerful; these are good candidates for leverage across the rest of the system</td>
</tr>
<tr>
<td>Degree</td>
<td>The number of connections</td>
<td>Higher connectivity to the rest of the network; influence, access, prestige (Newman, 2010)</td>
<td>Changes to high-degree phenomena will translate more quickly to more phenomena; high-degree phenomena are more sensitive to changes throughout the system</td>
</tr>
<tr>
<td>Closeness</td>
<td>Average length of the shortest paths between the given vertex and every other vertex in the graph</td>
<td>High visibility to the rest of the network, information spreads easily from this node; independence from the rest of the graph (Freeman, 1979)</td>
<td>High-closeness phenomena are resilient or independent, resisting change coming from elsewhere in the system; likewise, the system may resist change coming from these phenomena</td>
</tr>
</tbody>
</table>
Betweenness | Frequency of participation in the shortest path between two other elements | Member has a high degree of control; the network is dependent on the member; bottlenecking, control, influence (Freeman, 1979) | High-betweenness phenomena are gateways or bottlenecks for change; change strategies must consider how to address these gateways

Within network analysis, indicators of centrality are used to identify the most critical elements within a system (Murphy and Jones, 2020). In the context of our study, centralities indicate which factors hold the most influence on the system. We carried out the analysis in two stages. Firstly, we weighted connectors based on all participants' comments. Secondly, we weighted connectors based on comments that suggested how the canal could be improved to increase usage. These can be thought of as points of leverage whereby a small change can lead to impactful shifts in the system as a whole (Meadows, 1999). Identifying these reveals key factors influencing usage, which could significantly change the usage of urban blue spaces if acted upon.

Results
The demographic descriptors of the participants are detailed in Figure 2. There was a fairly even representation of participants interviewed across the three sites: 71 at Stockingfield Junction, 80 at Maryhill Road and 52 at Applecross. Of the 203 participants who agreed to complete the intercept interview, 109 identified as male and 93 as female and the majority (91%) of participants identified as ‘White/Scottish/British’. Seventy-one participants were aged between 18 and 34, 99 were between 35 and 64 and 33 participants were 65 or over, and 6% of the sample considered themselves to have a disability. We collected postcodes from all participants and estimated SIMD from these. The mean, median and mode SIMD scores were 4.64, 4, and 1, respectively. Although this project likely includes an over-representation of people who recreate near urban blue spaces, our sample had comparable demographics to the broader Glasgow population (Flint et al., 2016).

The postcodes and associated SIMD figures show that canal users are local residents of more deprived neighbourhoods. In more deprived neighbourhoods, poor health outcomes and socio-economic challenges cluster. Therefore, if we can understand the factors influencing residents’ usage of the canal, we can leverage these and promote usage among other local residents.
Figure 3 details the 26 identified factors influencing usage on the SEM. The SEM is centred around an individual’s usage of the canal and illustrates the breadth of identified factors influencing usage.
Figure 3 - Socio-ecological model (SEM) of factors influencing usage

Personal Factors

Personal factors refer to those which influence perceptions at an individual level, such as knowledge, attitudes, and behaviour (Mcleroy et al., 1988). People reported using the canal because it was close to their home, i.e., "on my doorstep" or "it’s practically in my garden, that’s why I’m always here!". Others reported spending work breaks on the canal.

Participants reported that the canal is an excellent place for "keeping active", for example, "You can get up a good walking speed". Having this space also allowed participants to benefit from the mental health benefits of exercise; "Cycling is good for mental health as well", "It helps definitely with mental health, that’s why I run". Furthermore, the wellbeing benefits of nature were noted; "It definitely lifts your spirits, you get to see more nature than you otherwise would."

Feelings of (un)safety can influence the usage of particular spaces. One participant reported the cyclical nature of canal usage; "the more people using it makes more people use it". While some people expressed feeling safe, others noted that the canal could feel "a bit dodgy". Safety concerns were highlighted by several participants who would not walk along the canal alone. Predominantly, worries of safety related to time of day, with 25 participants describing feeling unsafe in the dark and calling for better lighting. However, one participant noted the changing use and perception of the canals in recent years: "I’m very pleased over the last few years to see single female joggers because before it was a notoriously dangerous place for them, so that’s improved, so I’m glad to see that."

A lack of awareness emerged as another theme, highlighting that the canal may not be as well-known as other blue and green spaces in the city: "I stayed in Glasgow four years before I even knew it was here"; "it’s not really on peoples’ radar as much as cycling along the Clyde or using the river".
Kelvin" 125, "I just moved up here about a year ago, and I was kind of aware there was a canal here, but I didn’t actually realise how nice it was, that there was the path" 31.

Inter-social

Inter-social factors refer to social influence from friends, family and norms within social networks, which affect an individual’s behaviour (McLeroy et al., 1988). People commented on using the canal as a social space. In contrast, people also noted that the canal provided a place where one could get away from others and described it as “peaceful” 70, 135.

Some participants experienced conflict with other canal users; cyclists, walkers and dog walkers had differing needs and expectations of the space. Some people, it was noted, "cycle too fast along the canal and don’t respect people walking their dog or jogging,” and "the path is for everybody” 185. Although it was noted that "most cyclists are reasonably courteous, there’s some people, particularly at the commuting times, who go far too fast, ... and they’ve actually collided with pedestrians and dogs before" 45.

The industrial history of the canal reportedly contributed to its use. There is a "fantastic history; how it was built, who built it, and the history of Mary Hill” 86, after whom the area is named. Personal histories and fond memories of the canal also encouraged usage: "I’ve used the canal since I was a boy, we used to play and swim down here” 111.

Built environment

We defined the built environment as the manmade infrastructures, features, and facilities present in the urban environment. The built environment around the canal affected how people used the space. Most users considered the canal to be accessible, with there being many different options for joining the canal path. Participants spoke of how the canal is connected to the River Kelvin, allowing them to traverse the city off-road 8, 69.

People described enjoying the unique experiences brought to them by the canal as they see “the boats... something a little different from normality” 113. The kayaking club also “adds a really nice atmosphere to the canal” 182. Canal users wanted to see more activity on the water, with participants suggesting boat parties 11 and leisure cruises that could share the canal’s history 199.

It was suggested that bridges could make the canal area more accessible. Four participants referenced a new bridge at Stockingfield Junction, which would “make a difference” 199, make the canal “even more accessible” 130 and would “make it easier to ride to Falkirk and Bowling.” 99. Others did not mention the potential new bridge specifically but spoke of the difficulty in access at the same junction, where it is “a bit inconvenient” 171 as “you have to go down, then under the bridge and come back up again” 26, which can be “awkward” 122.

The quality of the towpath emerged as an important factor in encouraging people’s use of the canal. The path is flat and straight, as it runs parallel to the canal, which makes it suitable for all users. Many participants were concerned about the condition of the paths. Parts of the paths have maintained their historic cobbles, which was viewed as problematic in the winter as they were icy and more challenging for walking, running and cycling (n=4), while other tarmacked stretches of path were dotted with potholes. Participants described enjoying features of the canal and suggested that businesses selling refreshments would enhance the area. Also, 15 participants suggested that more seating would enrich their visits to the canal, making it “more enjoyable for someone tired, to sit down and relax” 119.
How clean and well-maintained an area is may affect its usage. Some viewed the canal path as dirty and littered with "dog poo everywhere"\(^{56}\). Discrepancies emerged around who held responsibility for ensuring the canal was clean and well-maintained. Some indicated that "people should respect the canals more; keep it tidy, keep it nice"\(^{185,190}\), while others thought more could be done by those managing the area, including clearing litter, having additional litter bins, and maintaining the banks of the canal and the surrounding trees.

The canal has been under regeneration for the last 20 years. Such changes have not gone unnoticed: "It’s really coming on up here. I’ve lived around here for 15 years, and the improvements have been brilliant. More people come down here to walk and exercise than they ever have"\(^{107}\). Historically, the canal was viewed as "a real mess"\(^{67}\), but participants noted that it is now much more inviting. However, one participant cautioned against continual development, noting a decline in available green and blue space in Glasgow: "every little green area now is being developed and built on... I would say, Keep. It. Rural."\(^{12}\) As well as redevelopment, the canal accommodated arts and culture, including the Glasgow Canal Festival, and had been used as a site of public art\(^{46}\).

Natural Environment

The research team defined the natural environment as encompassing all green and blue spaces and all natural phenomena such as the weather and time of day. Many people enjoyed the canal as a natural area in an otherwise dense, urban environment. The canal was perceived as a "green corridor through the city"\(^{42}\), where "you feel like you’re in the countryside when you’re in the centre of the city"\(^{88}\).

Having a traffic-free environment was valued by participants, for example: "Why would you walk along Maryhill Road- no harm to Maryhill Road- when you can walk along the canal? It’s a no brainer; you’re in nature"\(^{8}\). The canal was a popular commuting route for work, favoured over driving\(^{95}\), taking public transport\(^{36,103,187}\) or using active travel along roads\(^{22}\). Urban green and blue spaces may have the potential to improve air quality, and participants commented on experiencing the fresh air along the canal (n=22). The canal was also poetically described as a "natural artery"\(^{77}\) through the city and "a bit like a lung"\(^{85}\).

Human engagement with the natural environment and non-human actors is a crucial feature of urban life. It was noted that the canal was home to wildlife (n=5), including birds (n=9). People delighted in seeing swans "flying along the canal and landing"\(^{185}\), while others enjoyed the sound of flowing water (n=7). The wildlife and their habitats visually changed over the passing of a year, and participants tended to use the canal more during the summer months when there was more daylight. Regular visitors revelled in seeing swans have their cygnets and watching them grow up\(^{14}\).\(^{181}\) Weather, both daily and seasonal, affected how people viewed spending time on the canal. Glasgow is the UK’s rainiest city, averaging 170 days of rain a year (Freeflush, 2015). While some people were quick to criticise the Scottish weather, preferring sunny days (n=6), others were not discouraged and felt “it’s good to be able to go out in all weathers and try to stay fit and active”\(^{132}\).

System Map of Factors influencing usage

Figure 4 shows the system map of factors. The colours and positioning are consistent with the SEM for comparability. The line thickness indicates the strength of the relationship, weighted by how many participants linked the factors.
The map shows a complex web of 141 interactions between the 26 factors. An interactive version of the map, showcasing all of the qualitative data from participants, can be found at: *Kumu link omitted for anonymity*. Table 3 shows the top three influential factors influencing usage, as measured by eigenvector, degree, closeness, and betweenness centralities.

Table 2 - Ranked results of centrality leverage analysis. Values for the respective metric are reported in parentheses. Elements have been colour-coded to represent their colour within the SEM and system map (pink – personal, purple – inter-social, orange – built environment, green – natural environment).
Eigenvector

Murphy and Jones (2020) recommend eigenvector analysis be initially examined when analysing points of leverage within a system as it reveals powerful, high-impact elements. Elements with a high eigenvector are closely connected to other impactful elements. Therefore, high eigenvector rankings should highlight phenomena that, if altered, may spark change in the rest of the system. Participants’ desire to engage in exercise and live healthily (Exercise & Health) appeared as the top result for eigenvector, followed by peoples’ desire to experience Urban Nature. If interventions address these factors influencing usage, the system map may respond significantly. Exercise & Health was linked to Urban Nature (n=20), Traffic-free Space (n=18), Path Surface (n=12) and Quietness and Calm (n=10).

Fauna was the third-highest ranked factor influencing usage when measured by eigenvector; having an abundance of wildlife was connected to many other high-impact factors in the system. These three high ranking factors represent places in the system with high-yield opportunities to improve the system’s functioning (Murphy and Jones, 2020).

Degree and Closeness

Exercise & Health, followed by Urban Nature, ranked as the top factors in degree and closeness centrality metrics. Degree centrality is a simple measurement of the number of connectors. High-degree elements are well-connected; they can affect other elements quickly and are more sensitive to changes around the system. Closeness centrality measures the shortest path from an individual towards all separate other individuals within the network. Closeness centrality considers not only direct connections; high closeness can not only be reached through direct ties but also through relatively short indirect ties. Exercise & Health and Urban Nature are thus well connected in the system.

Betweenness

Elements with high betweenness centrality can be considered as gateways or bottlenecks within the system. These elements are key in making sure changes can move around the system; interventions must consider how to address these gateways/bottlenecks. The factors that ranked highest in betweenness centrality was Cleanliness & Maintenance, followed by Urban Nature and Exercise & Health.

Suggestions concerning improving the canal space’s usage

We analysed the map further to understand which parts of the system could be altered to improve its functioning. We focused on participants’ suggestions on improving the canal space and lifting barriers to its use. Table 4 displays the top three factors, as measured by degree and closeness. It also provides suggestions proposed by participants on improvements to the canal space. Degree centrality highlighted Cleanliness & Maintenance as the most significant area of improvement, followed by having access to a range of Features & Amenities and increased Safety. Time of Day was the highest-ranked factor when calculating closeness centrality, indicating a phenomenon that cannot be changed (Murphy and Jones, 2020). However, improved lighting infrastructure may positively affect usage. Betweenness centrality could not be calculated as there were insufficient data, and the eigenvector metric could not be weighted within Kumu, hence their absence in this analysis.
Table 3 - Centrality rankings of comments containing suggestions and improvements, weighted by the number of comments

<table>
<thead>
<tr>
<th>Degree</th>
<th>Closeness</th>
<th>Suggestions concerning improving usage</th>
</tr>
</thead>
</table>
| Cleanliness & Maintenance (47) | Time of Day (14.1) | ✓ Less rubbish, more litter bins  
✓ More cafes, restaurants, toilet facilities, children’s activities  
✓ Designated cycle path  
✓ Improved path surface  
✓ Improved signage  
✓ More picnic benches and other seating  
✓ Better lighting |
| Features & Amenities (32) | Features & Amenities (9.5) |  |
| Safety (30) | Awareness (2) |  |

**Leveraging Exercise & Health, Urban Nature and Cleanliness & Maintenance**

*Exercise & Health* and *Urban Nature* were key factors influencing urban blue space usage, and these two elements were strongly interconnected. We, therefore, discuss ways these leverage points could potentially be exploited.

The duality of the natural and urban world may appear contentious, but worldwide examples dictate that urban design can simultaneously be dense and natural (Lehmann, 2021). Nature-based Solutions (NBS) are “actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits” (Walters et al., 2016). We see here that NBSs can synergistically benefit the natural environment and promote human health and wellbeing. NBS is an umbrella concept encompassing wide-ranging ecosystem approaches (Cohen-Shacham et al., 2019), and urban NBSs may provide opportunities to alter the *Urban Nature* factor in our system and encourage increased *Exercise & Health*, leading to increased usage. Along the canal and most similar riparian spaces, land and water come together, so there is potential for adopting green and blue urban NBSs. NBSs can be implemented through innovations in ecology, society, technology and systemic change. Addressing the *Cleanliness & Maintenance* of urban blue spaces may better connect the system as a whole as its high betweenness centrality positioned it as a gateway/bottleneck in the system. It also ranked highly in degree when weighted on suggestions for improvements. NBSs may also improve the *Cleanliness & Maintenance* and therefore increase usage.

Table 5 outlines examples of how NBSs could potentially be used to leverage *Exercise & Health*, *Urban Nature* and *Cleanliness & Maintenance* to increase usage of the Glasgow Canal and similar urban blue spaces.

Table 5 - Implementing Nature-based Solutions (NatureScot, 2021 - third column added by authors)

<table>
<thead>
<tr>
<th>Implementation of NBSs</th>
<th>Description</th>
<th>Potential innovations for Glasgow Canal (and similar urban blue spaces)</th>
</tr>
</thead>
</table>
| Ecological innovations | the creation of new green or blue natural spaces, better management of existing green and blue spaces, and the restoration of functional ecosystems to deliver a wider range of | - **Re-wilding**: "It's not too over manicured, it's nice and wild, you see all the wildlife"[^45]  
- **Protected natural spaces** (e.g. Local Nature Reserves like the newly opened Hamiltonhill Claypits): “Less building! I don’t know if you’ve noticed that every little green area now is being developed and built on... Keep. It. Rural”[^12] |

[^45]: "It's not too over manicured, it's nice and wild, you see all the wildlife"[^45]  
[^12]: "Less building! I don’t know if you’ve noticed that every little green area now is being developed and built on... Keep. It. Rural"[^12]
| Ecosystem services and benefits | Ecological enhancements which preserve aesthetics: “Some of the bits of it are a little bit derelict, so if they were improved that would help”  
- Community owned and run urban gardens and crofts (Cumbers et al., 2018) |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Social innovations              | Awareness campaigns around the presence of recreational urban natural spaces and as a traffic-free commuting route: “It would be nice if more people knew about it and more people used it because it is a really lovely space”  
- Signage showcasing the biodiversity: “a few more notices about any of the wildlife that’s lurking around or the plants that are growing along the edge”  
- Capitalising on the heritage, culture and character of urban nature: “I mean, I love the historical signs. I think that’s cool… I’m also an artist, so there is some great creative infrastructure down here, but I’d like to see more public art”  
- School use of urban natural spaces for education and recreation: “I’m a teacher, so it’s quite a good educational tool, I can bring the kids down here as my school’s just quite near”  
- Campaigns and volunteer drives to reduce littering: ‘Keep Scotland Beautiful’ campaigns, organised litter picks |
| Technological innovations       | Infrastructure to improve access to and around urban nature: “The bridge that is going to be coming on the other side of the canal it’s going to make a big difference to the accessibility”  
- Increased waste management solutions: “there actually aren’t that many litter bins, and I’ve noticed further along the canal, actually someone sometimes puts a black bin bag up, just unofficially, and when it’s there it’s used by people who want to dispose of their litter correctly, but there’s just not the facilities to do it”  
- Integrated water management system: Glasgow’s Smart Canal aims to establish Glasgow as a ‘sponge city’ to reduce flooding |
| System innovations              | Adopt a whole systems approach to resilient, nature-rich urban environments:  
  - Reduce silo-working |
effectively to help deliver resilient nature-rich places.

- Improved partnership working across the private, public and third sector
- Encourage locally-grown solutions and support local communities with bottom-up projects
- Mitigate the impact of unintended consequences of interventions through consideration of the whole system.

Urban NBSs, like those outlined above, may provide multiple benefits to urban residents, including mitigating pressures of air and water pollution, heat-island impact, noise, flooding and increased opportunities for recreation and physical activity.

Discussion

Our results provide an understanding of factors that influence the usage of the Glasgow Canal. Through a synthesis of results, the most influential factors were Exercise & Health, Urban Nature and Cleanliness & Maintenance. Our system map has the potential to help policymakers develop possible policy options to boost public usage of urban blue spaces, and in turn, improve the physical, mental and social health of urban populations.

It is interesting to note that the factors that influence usage of blue spaces (Exercise & Health and Urban Nature) are the same drivers we know to be associated with improved mental health and wellbeing (van den Bosch and Ode Sang, 2017; Völker and Kistemann, 2011). The Biophilia theory suggests that humans hold an intrinsic tendency to seek connections with nature and our systems map suggests that people gravitate towards urban blue spaces because of their intrinsic therapeutic and natural benefits (Wilson, 1984). Smith et al. (2021) found evidence of the health benefits of urban blue spaces. Their systematic review and meta-analyses found that living near blue spaces was associated with some improved health outcomes. Although residential distance to blue space can increase opportunities to visit (Elliott et al., 2020), it does not necessarily equate to usage (Tillmann et al., 2018). It was therefore important to explore the more modifiable factors which influence the usage of blue spaces. Knowing that people use urban blue spaces to experience nature in the city and as a space to exercise and improve their health is beneficial in motivating wider populations to experience the benefits of these spaces.

Implications of the study

The focus of research to date on factors influencing usage has been carried out for parks. Traditionally, park accessibility and usage have been measured purely quantitatively, examining physical proximity to parks from residents’ homes or available hectares per population (Park, 2017). However, other factors affect usage, including size, location, local amenities, the surrounding environment, and people’s perceptions of the area (McCormack et al., 2010). Our research corroborated this as people’s perceptions of keeping active to improve their health and their perceptions of the urban natural space were leverage points in the system. Ries et al. (2009) found that park usage was not affected by park proximity. Although we identified proximity to work and proximity to home as factors, our research indicated that they were not leading factors influencing usage.
Some researchers argue that perceptions of an area are more influential than physical proximity (Ries et al., 2009). Such evidence highlights that access to and usage of outdoor green and blue spaces is multi-dimensional, incorporating both physical factors and users’ perceptions of the space. Our study highlighted that planners must not rely on the assumption that more green and blue space is always better but should consider the broader picture of usage patterns and the factors influencing usage.

Contemporary urban environments often struggle with a shortage of land for new green and blue spaces while having to justify budgets for new projects (Park, 2017). Korfmann et al. (2015) recognise that preserving public access, which ultimately makes the land less economically valuable, can be challenging when faced with offers from private investors. With limited space for new developments, coupled with limited resources to build new green and blue infrastructure, planners must opt for more innovative measures, including refurbishing existing areas that could be better used (Kabisch et al., 2016). Glasgow is fortunate in that the Glasgow Canal is a prime example of an area that has been repurposed. The “Smart Canal” scheme constructed in 2018 has combined the historic canal with innovative technology to mitigate flood risk and enable regeneration, thus combining opportunities for economic development and climate adaptation infrastructures while aiming to empower communities and minimise gentrification (Scottish Canals, 2021). Maintaining the canal space so that it can be accessed and used to benefit the health of a diverse demographic constantly competes with strong private economic interests, which must be reflected in future changes. There is a global trend toward the regeneration and rejuvenation of urban waterways, mainly driven by economic and climatic concerns. However, if public health and health equity are not included in these changes, there is a significant risk of increasing socio-economic disparities and health inequalities. The types of people involved in the design, building, management and governance of urban blue spaces is also of interest. For example, British architects are predominantly white and male (Architects Registration Board, 2020), and this lack of representation of other groups within the industry may lead to white-centric, androcentric city spaces. Any future changes to the canal should also be culturally responsive, maintaining the spaces as a valued community resource. Smardon et al. (2018) adopt the term “revitalise” when describing making changes to urban waterways (rather than redevelopment or restoration), commenting that this term means “making something alive once again” and therefore encompasses both the structural changes to the waterways as well as the changes that will affect a community. Efforts to “revitalise” the Glasgow canal, and similar urban blue spaces, should have a community and public health focus.

Strengths and limitations of this study

This study’s main strength is the large sample size, with 203 people being interviewed along the canal towpath across three sites. To our knowledge, it is the largest study of its kind concerning urban blue space usage. The rich qualitative data generated during intercept interviews provided a breadth of perspectives on factors that influence usage. Using qualitative data to construct a system map through weighting connections based on the number of participants is a novel approach grounded in the literature that suggests the benefits of combining qualitative and quantitative methods within systems thinking and network analysis (Crossley and Edwards, 2016). We acknowledge that due to the practicality and safety of researchers, we did not conduct interviews 24/7. Our findings, therefore, may not reflect the perceptions of other users, such as commuters, who travel along the towpaths into the evening. As well, our approach might not have identified all barriers to usage, which non-users may have more readily voiced. Using centrality analysis to quantify the most influential factors within the system is also a novel approach and provides a straightforward way to draw out significant leverage points from complex system maps. However,
using metrics to understand a system has limitations, and researchers cautiously interpreted the
findings within the broader context, as suggested by Murphy and Jones (2020). We acknowledge
that this system map is set in time and is specific to the Glasgow Canal. Replicating this study design
in other urban blue spaces would enhance the generalisability of findings. Furthermore, the analysis
of techniques posited by Murphy and Jones (2020) may be applied to other system maps in future.

Conclusions

This study is the first to our knowledge to explore the clustering and interplay between factors that
influence usage of urban blue space, using network analysis of a system map devised using
qualitative intercept interview data. The main leverage points were Exercise & Health and Urban
Nature, and interventions aimed at these points in the system may increase usage. People enjoyed
using the canal space for walking, cycling, running, dog walking and commuting and also found the
canal to benefit their mental health. Participants also welcomed the natural environment, which
they found to be a welcome escape from the bustling city. Planning development, interventions and
future regeneration of urban blue spaces should note these factors as, if exploited, the system may
respond positively to such changes. Finally, addressing the Cleanliness & Maintenance of urban blue
spaces may better connect the system of factors as a whole and thus increase the system's
effectiveness. In doing so, more people could be encouraged to use urban blue spaces and gain from
their salutogenic benefits.

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Supplementary Material

FactorsInfluencingUsage_Supplemental Material.docx