
Delivery of Cycling Infrastructure: Using Geospatial Information to Identify and Prioritise Projects

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Abstract

Strategic long-term planning of cycle infrastructure investment is essential in building the right infrastructure in the right place. Where previously an opportunity and demand based approach was used, an objective evidence-based network approach has now been adopted.

The lack of cycle parking in Glasgow was identified as a barrier to cycling in early 2009 following consultation with those who already cycled in and around Glasgow. Following a survey of existing installed racks, these locations were analysed in GIS with a 50 metre buffer to identify gaps in cycle parking provision. This, in association with identified trip generators provided theoretical “best fit” locations for installation. Ongoing monitoring of usage shows the effectiveness of this method and has contributed to an increase in cycling levels across the city.

Another identified barrier to cycling was the incoherence of the cycling network. A network audit was undertaken in 2014/2015, which mapped around 800 kilometres of streets in Glasgow for their suitability for cycling. Using a bespoke GPS app to create a spatial dataset, features such as speed limits, surface quality, and Bikeability level required were recorded. This data has enabled the Council to identify gaps in the cycling network.

A method of prioritisation was required to progress projects within the limited resources available. This was developed using the audit data in combination with other geospatial information from the National Census, Scottish Household Survey, mass GPS cycle data and road traffic data. Scores were given to: relation to existing network, safety for cycling, propensity to cycle, current use, and feasibility of infrastructure, with the sum of scores denoting the priority.

This has provided the backdrop to make informed and objective decisions on long term programme planning which has been received well by stakeholders and politicians, leading to top level support for long term investment.

1 Introduction

It is desired to promote an increase in levels of active travel for reasons of environmental impact and improved health of residents and visitors to the target area. A reduction in car use and transit speeds would not only render improved air quality but through lower noise levels would provide a significant improvement in the perceived quality of the immediate environment and improved short and long term health through greater levels of physical activity.

How we initiate a shift in the travel behaviour of individuals’ and their default mode of transport is a subject under frequent discussion. The factors that influence how travellers decide which mode(s) of transport to use for their journeys are many and, whilst some are logical, may be due to personal bias which itself can be influenced from various sources, for example pro car media.

The individual choice on how to travel is frequently made via an assessment, consciously or unconsciously, of a combination of perceived and actual factors including: reliability, suitability to purpose (utility), time, distance, comfort, weather etc. Of these, the Scottish Household Survey has given an indication of these reasons that form a negative influence and result in the choice not to cycle (Transport Scotland, 2016).

These include:

- trip distance
- poor weather
- safety
- lack of trip end facilities
- lack of bike ownership

Many journeys made by car are of short distances and fall within those journeys that could be easily walked or cycled: For example, 73.1 percent of all trips in the Glasgow area are shorter than 5 kilometres (Cycling Scotland, 2017). In order to make a more compelling case and achieve a higher mode share for cycling we require to address the negative bias held by many and increase the perceived value of making a trip by bike compared to other modes of travel. This needs to highlight those health and fiscal benefits to the individual and raise good health as an achievable aspiration for all.

To make cycling viable as a means of transport, a few essential prerequisites should be in place:

- Access to a bike:
 - Own bike –safe storage at residence
 - Cycle Hire Scheme – docking station proximate to residence
- Route to destination:
 - Convenient connection between the origin and the destination
 - Perceived as safe (relative to individual abilities)
- Trip end facilities:
 - On street cycle parking – perceived as secure
 - Secure cycle parking – easy to use and perceived as secure
 - Proximate docking station – in the case of hire bikes

Should any of these aspects not be in place, or not provided to sufficient quality, the likelihood of a person choosing a bike over an alternative mode of travel would be reduced. Therefore it is important to look at improving trip ends and connecting links in the development of a cycle network.

2 Cycle Infrastructure Planning

Pressures from available resources, both financial and staff, reduce the rate at which a network can be designed and delivered, thus cycling infrastructure cannot happen all at once. In light of this, Glasgow City Council have introduced a more transparent, evidence-based decision making approach. This is helping inform the relative priority of which projects are delivered rather than using an “on demand” project delivery approach.

This paper discusses the backgrounds of this approach and its methodology of incorporating spatial data in a multi-criteria decision analysis, MCDA, to assist the decision making process.

Planning facilities to support cycling relies on some sort of model or reasoning. This could be as simple a reasoning as ‘all major roads should have cycle lanes’, or ‘cycle parking needs to be provided in shopping areas’, but could also be based on a more intricate analysis of data.

Rybarczyk & Wu (2009) divide bicycle facility planning models into two groups: demand-based and supply-based. Supply-based models consider the network vision and quantitative analyses on safety and level of service whilst demand based models look into use, latent demand and trip attraction. With

a vision to deliver accessible, safe and attractive cycling infrastructure, aspects from both supply and demand sides need to be considered.

Incorporating a variety of aspects in decision making can result in a complex problem, with competing objectives, and potentially conflicting views of stakeholders. A systematic, consistent approach is required, using transparent and evidence-based processes.

By using a combination of GIS, spatial analysis and MCDA, comprehensive decision tools were developed to aid decision making for infrastructure improvements at trip ends and along network links which included both supply and demand aspects. Unlike other widely used methods, such as cost effectiveness analysis (CEA), and cost-benefit analysis (CBA), the decision making tools used in Glasgow do not incorporate monetary aspects such as project costs. These and other constraints, such as staff resource and infrastructure limitations are considered after the identification of locations that could use improvement.

The processes involved in determining criteria and using data, through group decision making whilst incorporating the above mentioned opportunities and constraints, to arrive at a prioritised list to progress cycling infrastructure improvements is shown in figure 1.

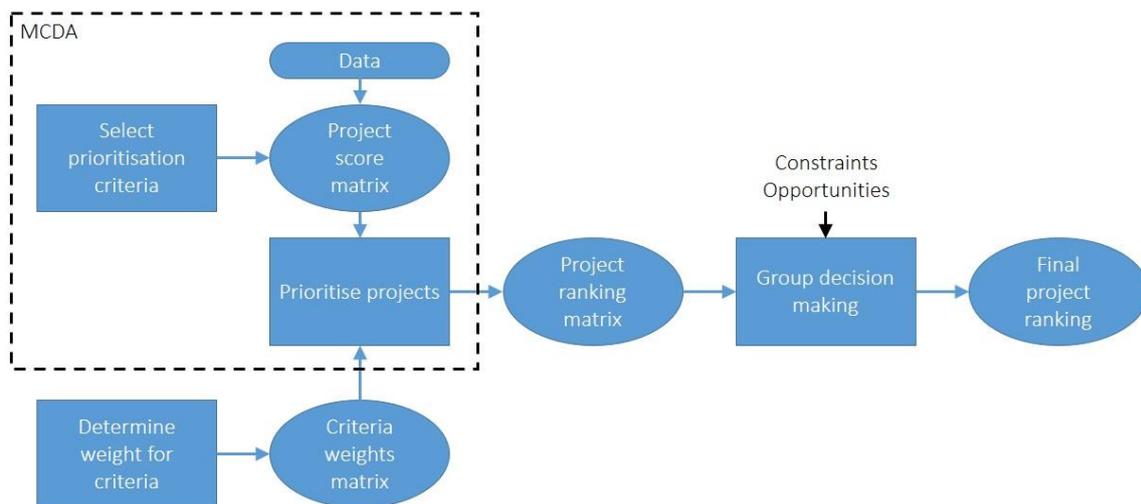


Figure 1: Prioritisation flow diagram (To: Liu et al., 2015)

3 Network development - Improving links

3.1 Link analysis

A network audit was undertaken over the course of 2014 and early 2015. This was done on a ward-by-ward basis by bicycle. Using a bespoke smartphone app, GPS tracks of individual streets were generated, with certain attributes of that street added manually to the track in the app. Attributes included were:

- Type of infrastructure (e.g. Segregated cycle lane, Bus & cycle lane, Unmarked)
- Speed limit
- Surface quality (acceptable, poor, hazardous)
- Lighting (yes, no)
- Bikeability level (based on Cycling Scotland training levels: 1, 2, 3, 3+)
- Length of section

In addition to these tracks, location markers could be added for specific opportunities like dropped kerbs, or for localised infrastructure issues like potholes. The audit data was transferred to a GIS database providing an overview of the location, length, type and quality of the existing cycle infrastructure.

The database included survey information out-with the existing infrastructure, providing a comparable assessment for the development of a proposed network. Opportunities now existed to identify gaps in the network, improvements required to existing infrastructure, and opportunities for quick wins for local filtered permeability.

3.2 Link prioritisation

In total, a distance of 800 km was audited. This included 310 km of existing cycling infrastructure of various type with the remainder being made up of all road types and shared paths. A target to develop and expand the cycle network to 400 kilometres by 2025 has now been expressed by Glasgow within the Strategic Plan for Cycling 2016-2025 (Glasgow City Council, 2016).

In order to help deliver the Scottish Government's vision of 10% of all trips by bicycle in 2020 (Transport Scotland, 2017), a robust method of prioritising cycling infrastructure was required to objectively identify where best to improve and extend the network. A number of criteria were identified, in a combination of supply-based and demand-based (see Table 1).

Several data sources were used to identify aspects of these factors:

- Network plan: vision for the cycling network
- Network audit: detailed information of roads
- Land & building data: local area information on trip generators
- Scottish Household Survey: local area information on households
- National Census: local information on households and travel behaviour
- Mass GPS cycle data: such as Strava and the European Cycling Challenge
- Road traffic data: speeds, volumes and traffic collision data

Table 1: Prioritisation criteria for link improvements

Criteria	Scoring priority	Supply or Demand
Type of network	Extension of the identified primary network should have priority over other parts	Supply
Cycling potential	Links that have a higher potential for attracting cycling should be prioritised, based on household density, the number of trip generators, and being in an origin-destination corridor	Demand
Link to existing infrastructure	Extension of the existing network should have priority over building isolated infrastructure	Supply
Nearby parallel provision	Links with no nearby parallel provision should have priority over links that do have a viable alternative	Supply
Safety	Links that are deemed less safe should be prioritised, taking into consideration traffic volume, speed and existing type cycling infrastructure	Supply
Current use	Links that are already well used by cycles should be prioritised	Demand
Feasibility	Links that do not fulfil design guidelines and/or of poor quality should be prioritised	Supply/Demand

Link priority was assessed using various data sources. These are identified in table 3. Where possible, criteria were cross referenced.

Table 2: Data sources for link prioritisation

Criteria	Source						
	Network plan	Network audit	Land & building data	SHS	National Census	Mass GPS cycle data	Road traffic data
Type of network	•						
Cycling potential			•	•	•		
Link to existing		•					
Parallel provision		•					
Safety		•					•
Current Use						•	
Feasibility		•					

A scoring matrix was required to be developed for overall assessment. This was based on a specified points range for the scored criteria with the cumulative total indicating the greater level of priority for development.

Network Contribution.

For the purpose of route priority analysis scoring from 0 to 10 was chosen. Four out of the seven criteria were readily translated into this method with definable categories (type of network, link to existing, parallel provision and current use). Correlation between these was done cumulatively with equal weighting

The remainder were not as straight forward due to the high levels of subjectivity. These were removed from the matrix as applied but utilised as discussion criteria.

Cycling Potential.

From extensive consultation in regard to cycling potential, this was simplified to three factors:

- a) trip attraction of a zone, i.e. number of trip destinations;
- b) trip generation of a zone, i.e. number of households;
- c) corridor function for trips starting and ending in other zones.

Each of these aspects was given a positive scoring of 0 to 10, This was applied as a cumulative total to provide an overall score for cycling potential.

Risk.

Safety for cycling was considered to be dependent on the infrastructure already available. This was scored 0 - 10.

Overall Risk was assessed based on road conditions versus existing cycling infrastructure (from safety) that would serve to mitigate the risk presented. This used a modified vehicle speed and flow diagram from Cycling by Design (Transport Scotland, 2011), a risk score was given to combinations of speed and flow. See Figure 2.

Existing infrastructure provision would reduce the risk, with the type of infrastructure determining by how much. Table 3 shows the scores that were used.

Risk was derived as:

$$\text{Road Conditions} - \text{Safety} = \text{Risk}$$

This serves to reduce the score level of a road that may have high transit speeds but, for example, have an existing segregated route alongside. Example: a 30 mph high vehicle flow road with advisory cycle lanes would have a road condition score of 8, with a safety score of 4 due to the existing infrastructure. The Risk score for this road would therefore be 4.

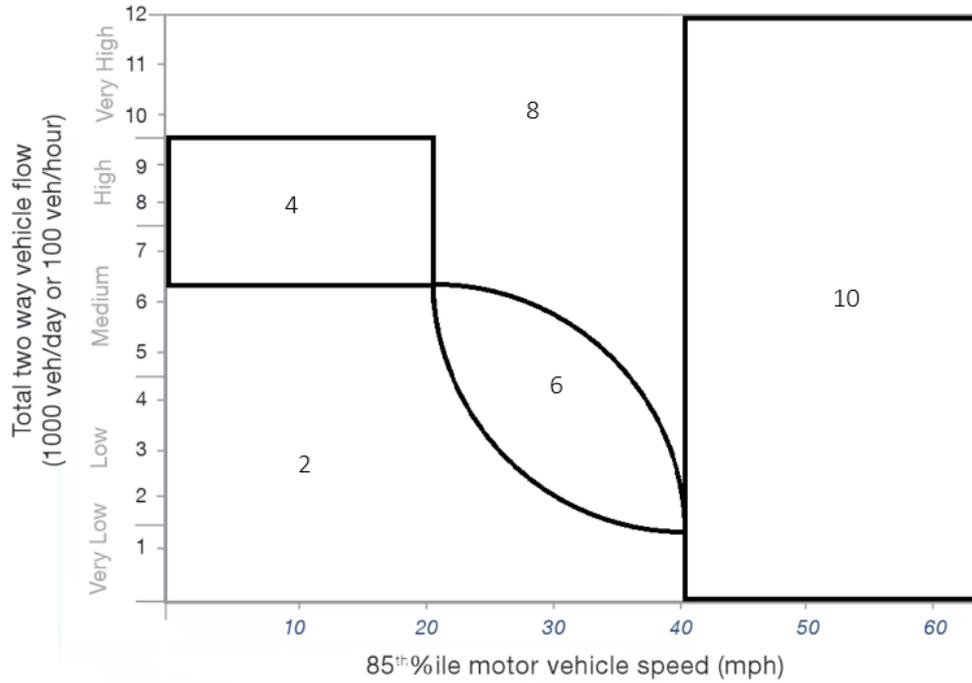


Figure 2: Infrastructure risk score

Table 3: Infrastructure Safety score

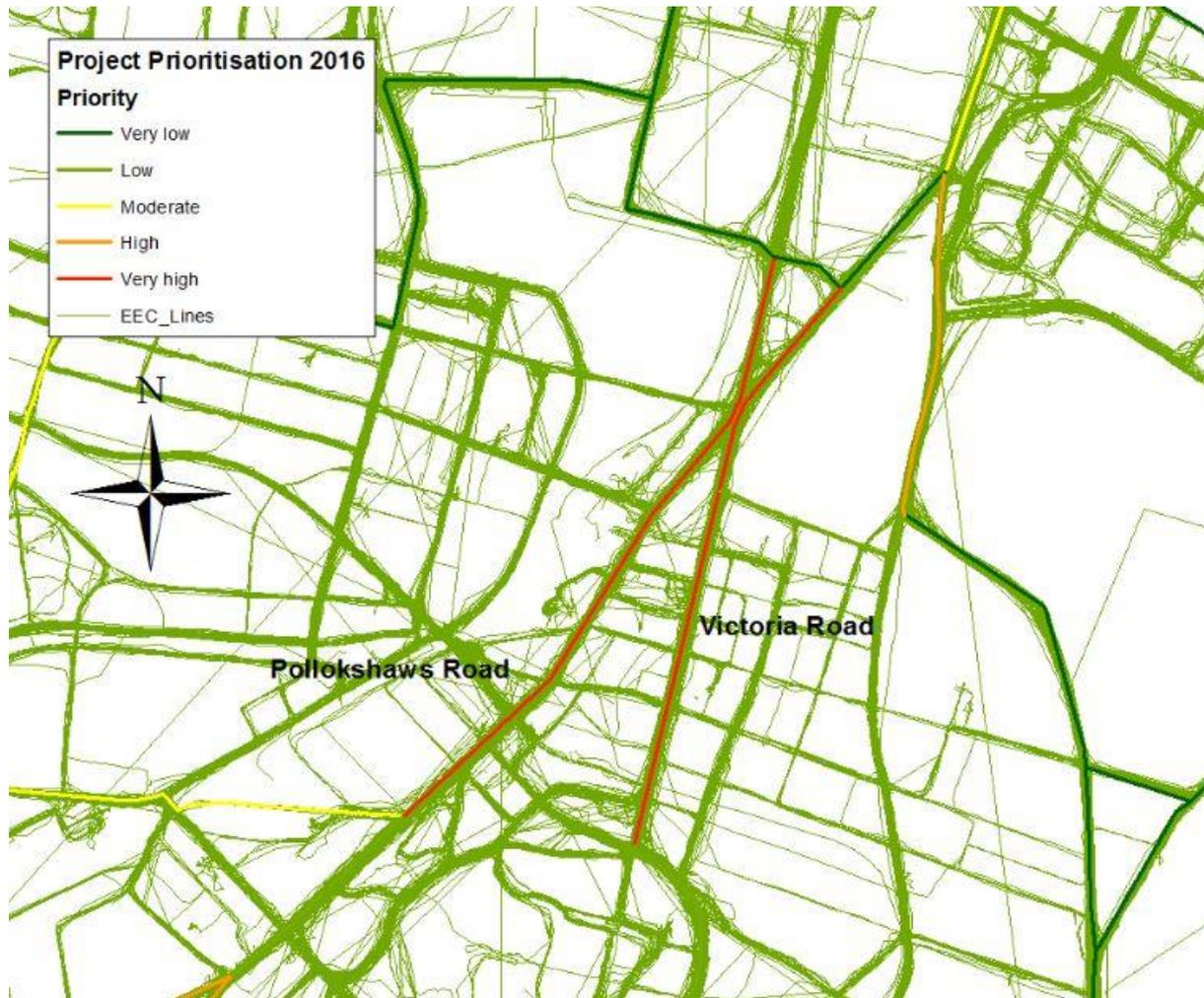
Infrastructure type	Infrastructure score
Segregated with verge	10
Segregated	8
Mandatory cycle lanes	6
Advisory cycle lanes	4
Bus and cycle lane	2

Feasibility.

The final criteria considered was feasibility. This was felt to comprise of a combination of road surface condition and suitability, with the latter incorporating compliance to design guidance. See Table 4 below.

Table 4: Infrastructure adequateness score

Infrastructure	Surface condition	Suitable for use	Score
No existing infrastructure	N/A	N/A	10
Existing infrastructure	Poor	No	8
	Poor	Yes	6
	Good	No	4
	Good	Yes	0



4 Network development - Application

Case study – Pollokshaws Road vs. Victoria Road

Table 5 and Table 6 show the scoring for Pollokshaws Road and Victoria Road. These roads are almost parallel to each other, pass through similar architecture and would serve very similar purposes, resulting in similar scoring.

The main difference between these options is in regard to safety and feasibility. Pollokshaws Road is a very high flow road (>950 veh/hour) and a maximum speed of 30 miles per hour and has bus lanes along most of the section. Therefore safety score is 6. Victoria Road has a high flow road (800 veh/hour), with a maximum speed of 30 miles per hour and no infrastructure: its safety score is 8. Feasibility for the development is higher for Victoria Road as it has wider roads and footways. From the European Cycling Challenge (ECC) data, the current use by bicycles is good on both roads, even though there is hardly any infrastructure at the moment. This data and manual counts have shown that the cycle flow on Victoria Road is higher than on Pollokshaws Road: Victoria Road scores 8, Pollokshaws Road scores 6.

Table 5. Pollokshaws Road

Criteria	Description	Component score
Network Contribution: Development	Primary network	10
Network Contribution: Extension to network	Linking to existing primary network	10
Network Contribution: Parallel provision	None	10
Network Contribution: Current Use	No infrastructure	10
Feasibility	Medium	6
Cycling potential: Household density: very high	Household density: very high	10
Cycling potential: Trip Generators	Trip generators: very high	9
Cycling potential: Origin / Destination Journeys	Origin-destination: very high	10
Risk	Risk: 30 mph road with high to very high flow	6
Total		81

Table 6. Victoria Road

Criteria	Description	Component score
Network Contribution: Development	Primary network	10
Network Contribution: Extension to network	Linking to existing primary network	10
Network Contribution: Parallel provision	None	10
Network Contribution: Current Use	No infrastructure	10
Feasibility	Medium-high	8
Cycling potential: Household density: very high	Household density: very high	10
Cycling potential: Trip Generators	Trip generators: very high	10
Cycling potential: Origin / Destination Journeys	Origin-destination: very high	10
Risk	Risk: 30 mph road with high to very high flow	8
Total		86

Based on these figures Victoria Road has a higher priority for cycling infrastructure improvements. This, combined with the evidence of high levels of localised travel in the Victoria Road location and the more pronounced buildability of the preferred segregated infrastructure due to wider pavements and roads resulted in a Victoria Road being favoured as the route that would deliver a high standard of route that satisfies the criteria for network development.

Consequently, this route was advanced for funding which was ultimately granted.

This Victoria Road project is currently being advanced under the title South City Way.

5 Cycle Parking - Improving trip ends

In order to normalise cycling as a default method of transport it is essential that it becomes at least as easy to use as the method we wish to generally supplant, in this case, the car.

In the initial stage of development of infrastructure most cycle parking was placed in response to requests from existing cyclists. This method was recognised as ineffective in satisfying the latent demand for cycling infrastructure and so was potentially resulting in a reduction in uptake of cycling. A survey of existing cycle racks locations was undertaken in the 2010. These were input to GIS for maintenance and expansion. Figure 3 illustrates the extent of cycle parking in Glasgow city centre in 2010 as blue points.

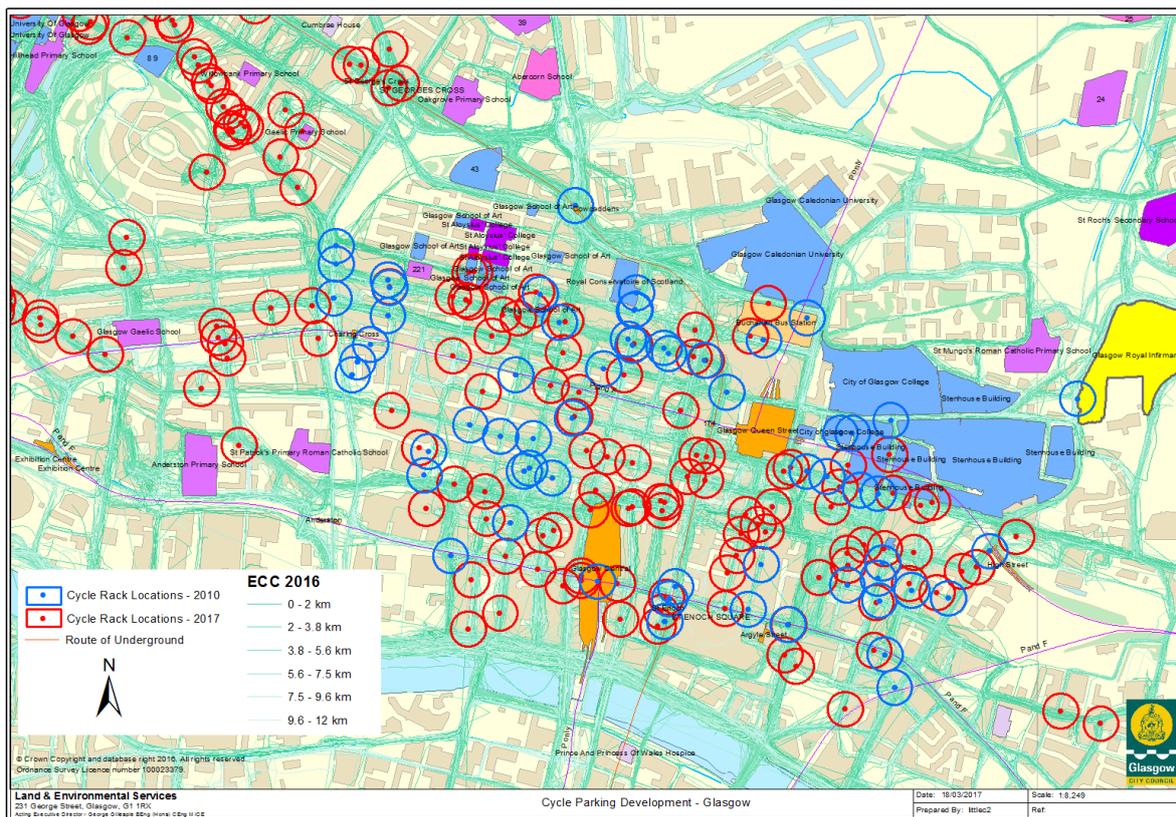


Figure 3: Cycle parking locations in 2010 and 2017

Consultation with members of the public who stated the desire to cycle and existing cyclists identified concerns of security and a lack of existing parking facilities as a barrier to cycling. Observation of cycle parking behaviour showed that where formal cycle parking facilities were provided, at a distance of greater than 60 m (approximately) from a destination the use of posts and railings closer to the

destination was more prevalent. This was in response to a perception of high levels of thefts, with the ability to see the bike giving peace of mind.

Associated issues with using posts or railings are: the lack of physical support provided for bicycles leading to cycles falling over and becoming a trip hazard for footway users. The use of listed features such as Victorian cast iron railings which are easily broken but difficult and expensive to repair. These issues serve to exacerbate hostility to cycling from users of the area and building owners. Providing formal on-street cycle parking facilities therefore is important to improve the attractiveness of cycling.

Considering the concerns put forward by stakeholders and observed behaviour of existing cyclists' parking habits, distance between cycle parking locations and proximity to destinations are of importance. Table 7 elaborates on these criteria.

Table 7: Prioritisation criteria for cycle parking

Criteria	Priority	Supply or Demand
Nearby provision	Locations further away from existing cycle parking locations should be prioritised (gap analysis)	Supply
Proximity to trip generator	Locations closer to major trip generators should be prioritised	Supply
Current use of racks in direct area	Locations with demand higher than current provision should be prioritised	Demand
Current use of network	Locations on a streets with high cycle usage should be prioritised	Demand

The architecture of the city centre of Glasgow is largely built on a 90 m square grid. Considering this and the previously mentioned observations regarding distance to cycle parking facilities, 50 metres was considered to be maximum appropriate distance. Gap analysis in GIS revealed areas where this distance would be exceeded. Figure 3 shows 50 metre radii around cycle rack locations. This facilitates overlap of the expanding provision and allows corners be used for cycle rack provision.

This method has been augmented and applied out with the city centre by taking into account the potential demands of trip generators, such as:

- Commercial properties: staff and customers
- Retail facilities and pedestrianised areas: staff and customers
- Educational locations: staff and students
- Train stations: staff and customers
- Bus stations: staff and customers
- Subway stations: staff and customers
- Car club bays: customers
- Cafés: staff and customers
- Religious centres: staff and visitors

Using monitoring data from cycle parking audits and GPS cycle data, the current use of the infrastructure is also included in the prioritisation of cycle parking locations.

The combination of these four criteria in the decision analysis has led to city wide expansion of cycle parking, Figure 3 shows the locations added between 2010 and 2017 in red, with a clear preference for high trip generating locations and along busy cycle corridors.

In addition to the benefits for prioritising installation and expansion of cycle parking, the use of GIS has also given the opportunity to share information on cycle parking with the general public. An online map is being kept up to date on the existing provision, accessible via the council's cycling website¹.

6 Conclusions

Strategic long-term cycle infrastructure planning, based on a more transparent, evidence-based approach has helped Glasgow to identify and improve infrastructure in a more structured way. With different stakeholders having different views on what should be included in prioritising locations, using a multi-criteria approach incorporating both supply- and demand-orientated aspects was enabled the council to include these views in the decision making process.

Data supporting the criteria has proven to be readily available, such as the National Census and Scottish Household Survey, or relatively easy to obtain, e.g. cycle usage data and street audit data, with scoring a fairly straight-forward task, and mostly automated in GIS software.

The approach has been used successfully to expand cycle parking provision with between 100-150 racks per annum since 2010. Network improvements have been using this decision making process since 2016, and led to identification of unconsidered gaps in the network to improve. The continuation of this approach will lead to a growth in the amount of infrastructure where it matters most, and should therefore lead to a faster growth in cycle mode share compared to an ad-hoc approach.

An additional benefit of using GIS software is that accurate statistics can be compiled on e.g. the location and numbers of cycle racks, and the length, type and quality of the developing cycle network. This information can also be made public, such as the online cycle map on Glasgow City Council's website.

To keep this decision making process accurate, the data used will need to be kept up to date. There is therefore a need to update GIS data pertaining to cycling infrastructure for quality and use, as well as updating other data sources when these become available.

The auditing of infrastructure still includes some degree of subjectivity. Auditors, for example, are making a personal decision on whether the quality of infrastructure is acceptable or not. A better, more objective, system for auditing the quality of existing infrastructure could help to refine this method.

7 References

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¹ Website: www.glasgow.gov.uk/cycling