Review of On-Site Bike Parking Provisions & Technologies

ACE CONSULTING

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Presentation Overview

Introduction

Part A: Bike Parking Rate Revision

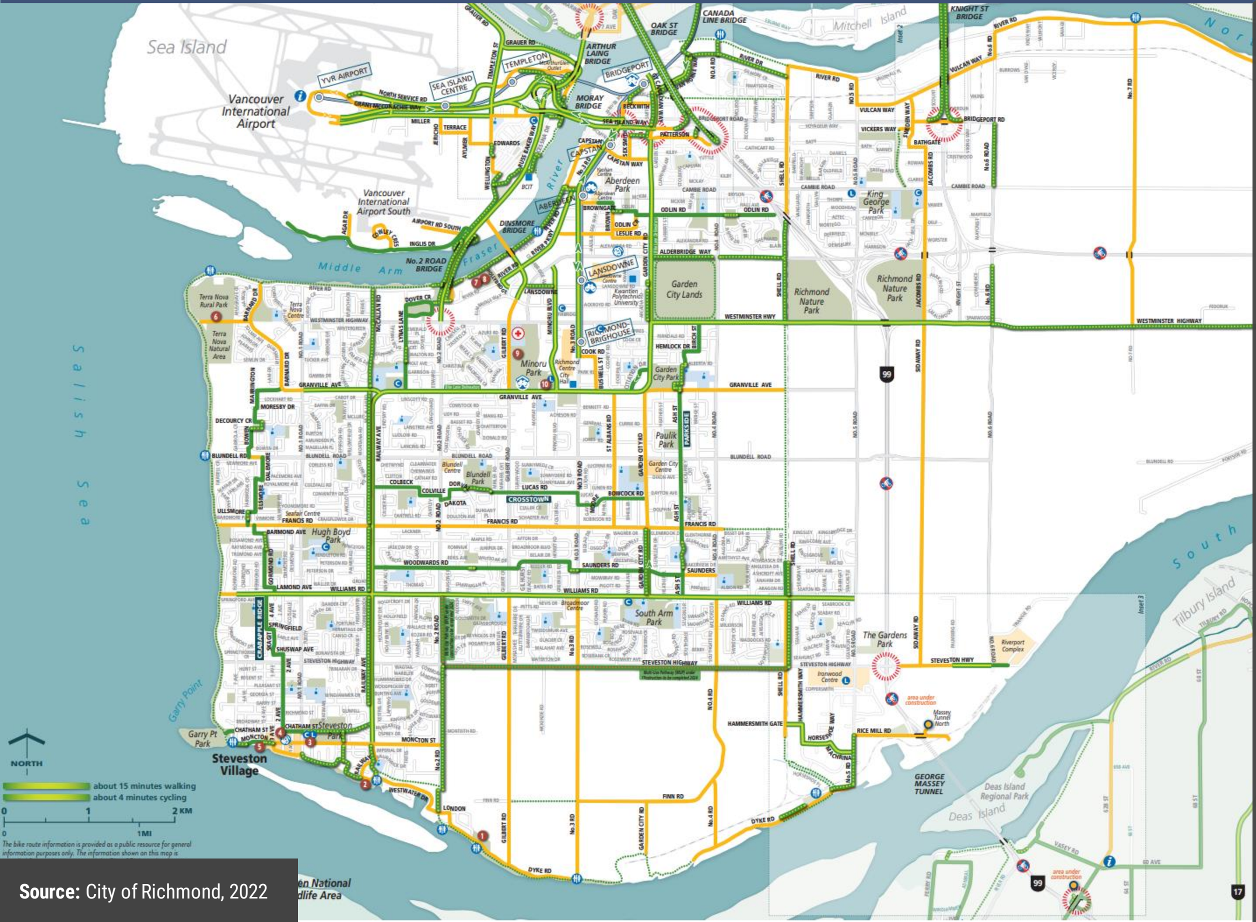
1. Overview
2. Analysis
3. Recommendations

Part B: Bike Parking Technologies

1. Methodology
2. Technologies
3. Conclusion

Introduction

1 – City of Richmond (CoR)



Source: City of Richmond, 2022

Bike Infrastructure: 338 lane-km

Bike Mode Share:

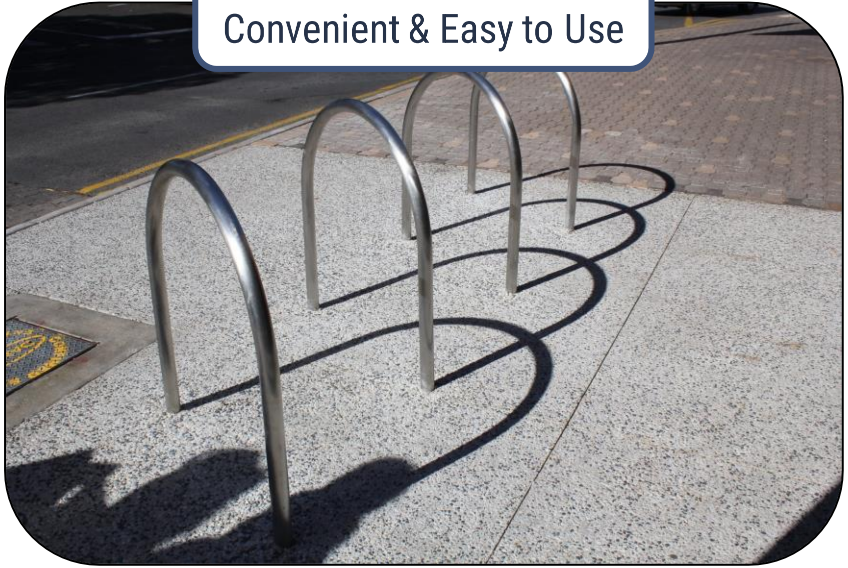
- **2016:** 1%
- **2041 Goal:** 10%

Energy & Emissions Plan:

- GHG Emission Reduction Target: 50% by 2030 & Net zero by 2050
- Prioritize & Invest into Active Transportation

2 – Bike Parking Types

Short-Term
Convenient & Easy to Use



Source: Terrain Group, n.d.

Long-Term
Secure & Sheltered

Source: NACTO, 2022

Parking Time

3 – Problem Statement

Part A: Bike Parking Revision

Problem: Insufficient Bike Parking in Residential Buildings

Scope: Update Bike Parking Rates for Long-Term Parking

Part B: Bike Parking Technology

Problem: Lack of Secure Public Short-Term & Long-Term Parking

Scope: Review of Available Bike Parking Technologies

Part A: Bike Parking Rate Revision

A1 – Introduction

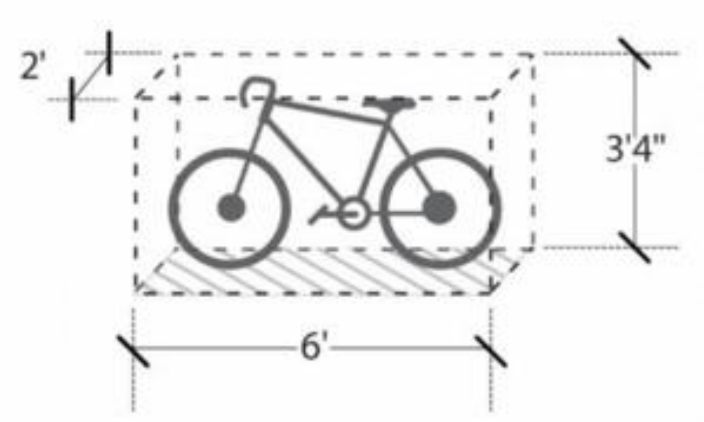
Bike Parking Rate Definition & Existing Rates

A1.1 – Bike Parking Rate Definition

Bike Parking Rates Example:

Land Use Type	Rate	Unit
Commercial	X	Per 100m2
Multi-Family Residential	Y	Per Dwelling Unit
Schools	Z	Per 10 Students

Typical Bike Parking Dimensions:



Source: City of Portalnd, n.d.

A1.2 – Existing CoR Bike Parking Rates

	Minimum Number of On-Site Bike Parking Spaces Required	
Use	**Long-Term**	**Short-Term**
Town Housing	1.25 Spaces per Dwelling Unit	0.2 Spaces per Dwelling Unit
Apartment Housing		
Mixed Commercial / Residential Uses		

Source: City of Richmond, n.d.

A2 – Regression Analysis

Approach, Ensemble Regression, & Key Takeaways

A2.1 – Approach

1. **Quantitative Assessment of Parking Rates to Support Mode Share Goals**

   [No Existing Methodologies Found in our Research]

2. **Provide Flexibility Across Regions in the City of Richmond**

3. **Develop a Replicable Methodology**

A2.2 – Ensemble Regression

Step 1: Gather Data on a Total of 27 'Similar' Cities

Step 2: Multivariate Linear Regression Model

Step 3: Random Forest Regression Model

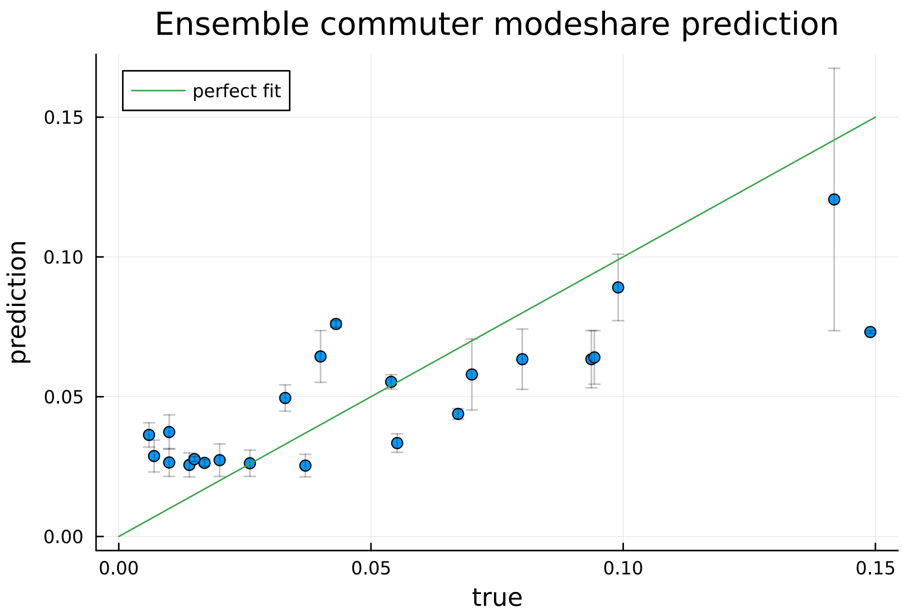
Step 4: Combine Predictions for a more Robust Recommendation

location	bike parking rate	commuter mode share	...	bike network length	population
Vancouver	1.50	0.08	...	627291.12	710918
Victoria	1.00	0.14	...	765806.82	97056
Saanich	1.00	0.09	...	169888.17	126719
...	...	...	...	...	...

Sources: OD Surveys, Zoning Bylaws, Strategic Plans, & many more

MAE: 0.020 (2.0%)

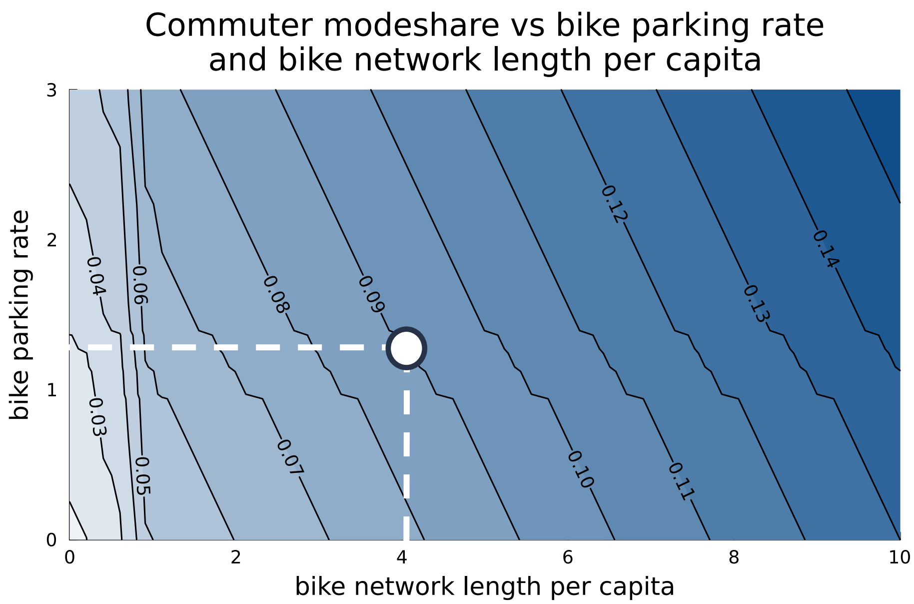
RMSE: 0.024 (2.4%)



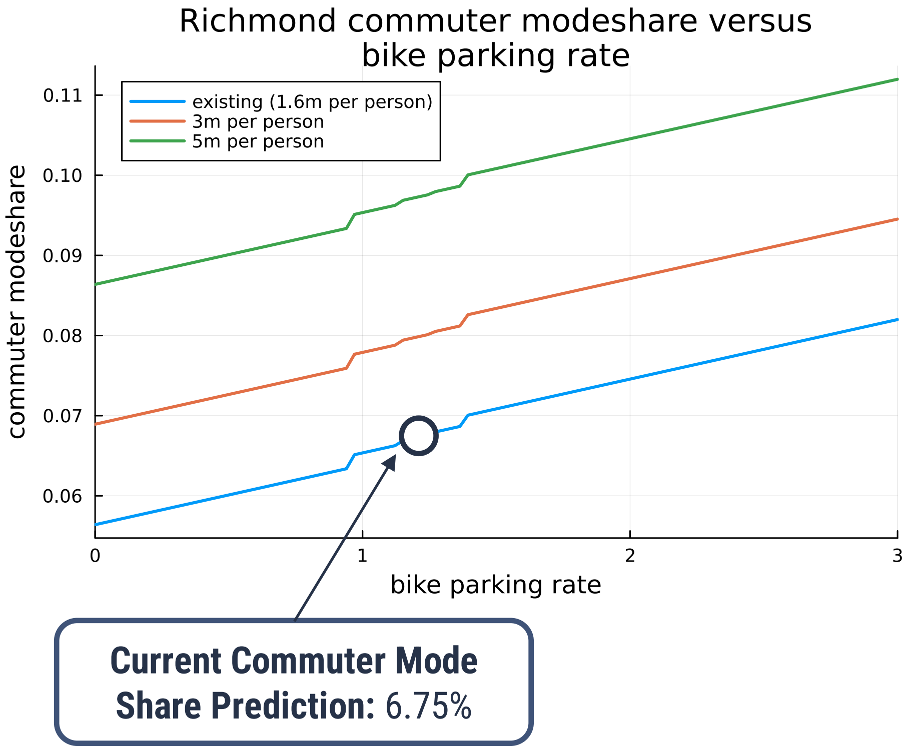
- Predicted Commuter Mode Share from the Ensemble Regression Plotted Against Actual Commuter Mode Share

- Error Bars Indicate Linear Regression & Random Forest Regression Predictions

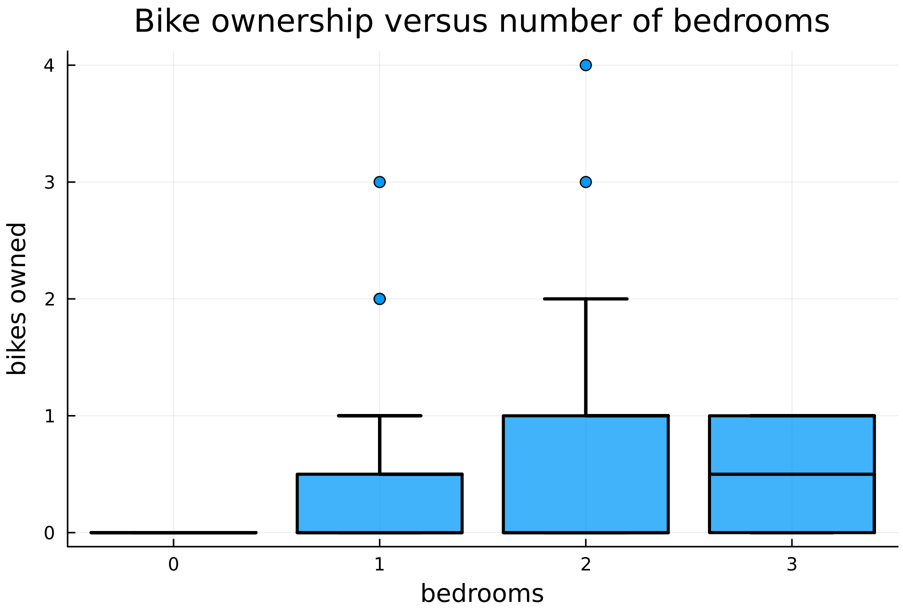
- Contour Plot of the Ensemble Regression Model Predictions
- Darker Blue Indicates Higher Commuter Mode Share
- Ex: A City with a Bike Network Length per Capita of 4 m & a Bike Parking Rate of 1.25 is Predicted to have a Commuter Mode Share of 9%



- With the Existing Bike Network (1.6 m/person) & Bike Parking Rate (1.25/unit), the Predicted Commuter Mode Share for Richmond is 6.75%
- Bike Parking Rate is Not a Strong Predictor of Commuter Mode Share
- Model Indicates that Higher Bike Parking Rates Support Higher Commuter Mode Shares



- Bike Ownership Versus Number of Bedrooms from a Survey of Richmond Households
- Few Households in Richmond Possess >2 Bikes
- A Bike Parking Rate of >2 is Unnecessary



A2.3 – Key Takeaways

01 1.25-1.75 Bike Spaces/Unit to Support Increased Mode Share

02 Bike Parking Rates are not the Strongest Predictor for Mode Share

03 Richmond Households Typically have <2 Bikes

04 Limitations Outlined in the Final Report

A3 – Spatial Analysis

Existing Condition, Bike Attractions, Proposed Bike Rate Zoning, & Zonal Land Use

A3.1 – Existing Condition

Source: Statistics Canada, 2021

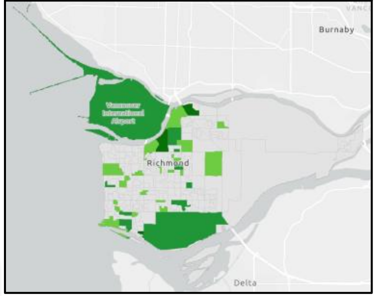
2021 Census Data

Step 1: Obtain Richmond Shapefiles at Dissemination Area (DA) Level

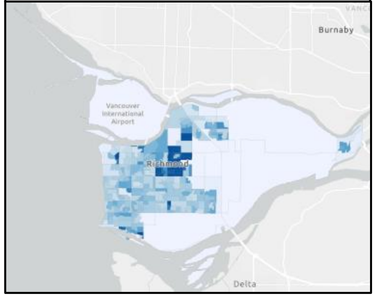
Step 2: Extract 2021 Census Data Related to Bike Parking Rates

Step 3: Append Census Data to each Dissemination Area to Assess Current Conditions

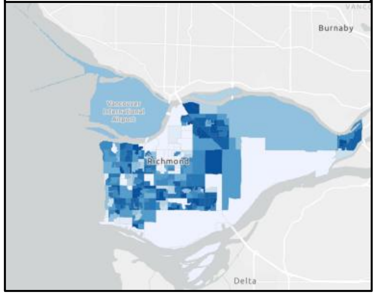
Bike Mode Share (Commute)



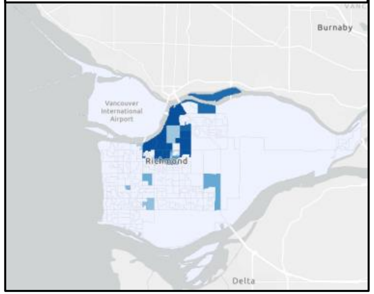
Population Density



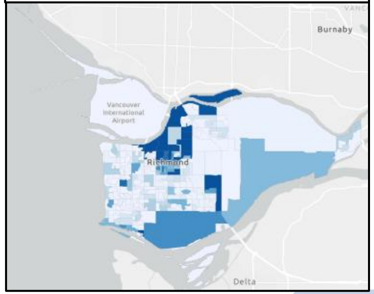
Household Size



Apartments with 5+ Storeys



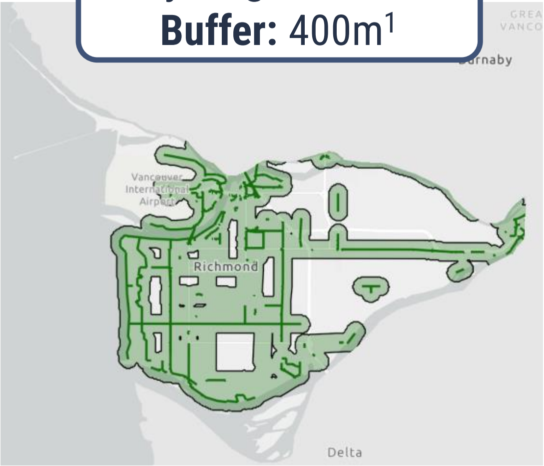
Number of Condos



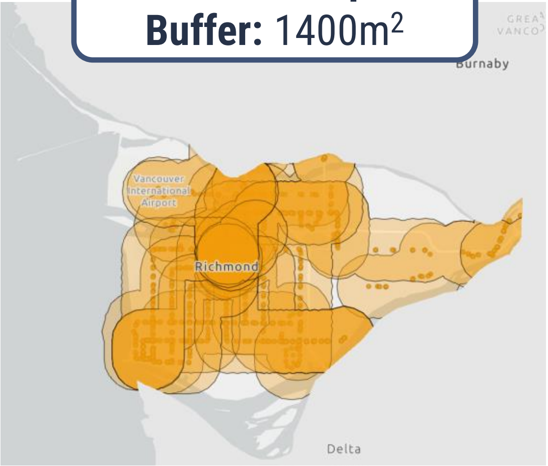
A3.1 – Existing Condition

Cycling Trip Attractors

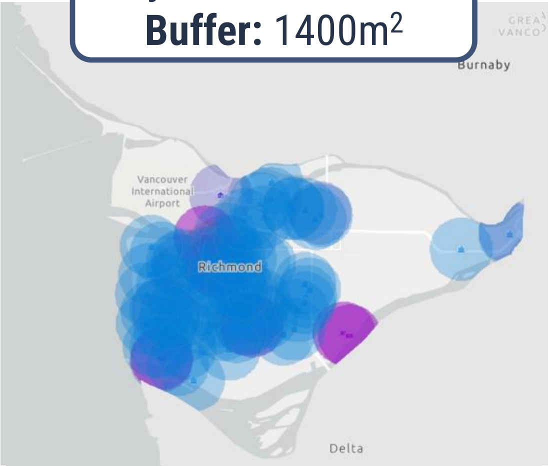
Cycling Network
Buffer: 400m[1]



Transit Stops
Buffer: 1400m[2]



Key Service Centers
Buffer: 1400m[2]

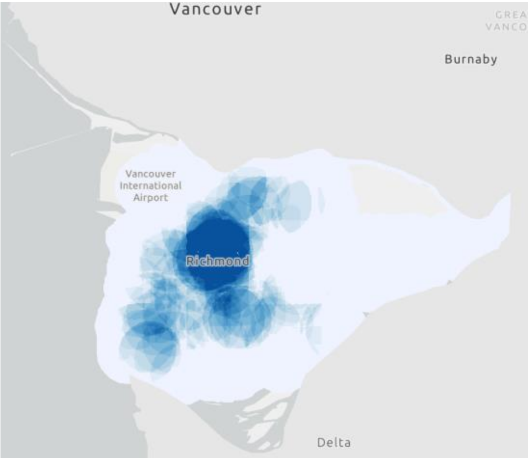


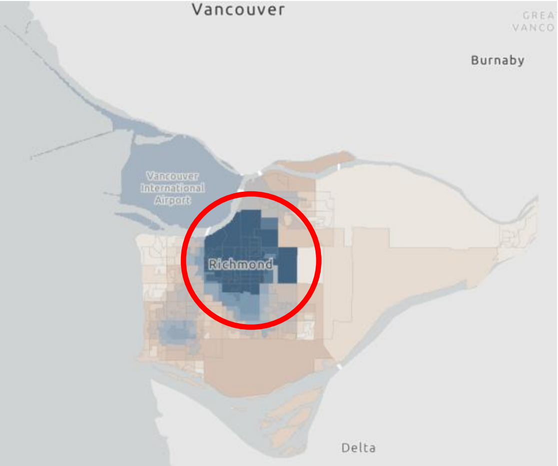
[1]400m: Range Criteria for Cyclists' Willingness to use the Cycling Network.
[2]1400m: Range Criteria for Average Cyclists to Access Transit Exchange or Services.

Source: City of Richmond, 2023

A3.2 – Bike Attractions (per DA)

Count Total Number of Buffer Overlaps + Project Buffer Density onto Richmond DA's = Obtain Bike Attractions by Dissemination Area





A3.3 – Proposed Bike Rate Zoning

1 **Attractions by Dissemination Area**

2 **Number of Condos**

3 **Number of Apartments 5+ Stories**

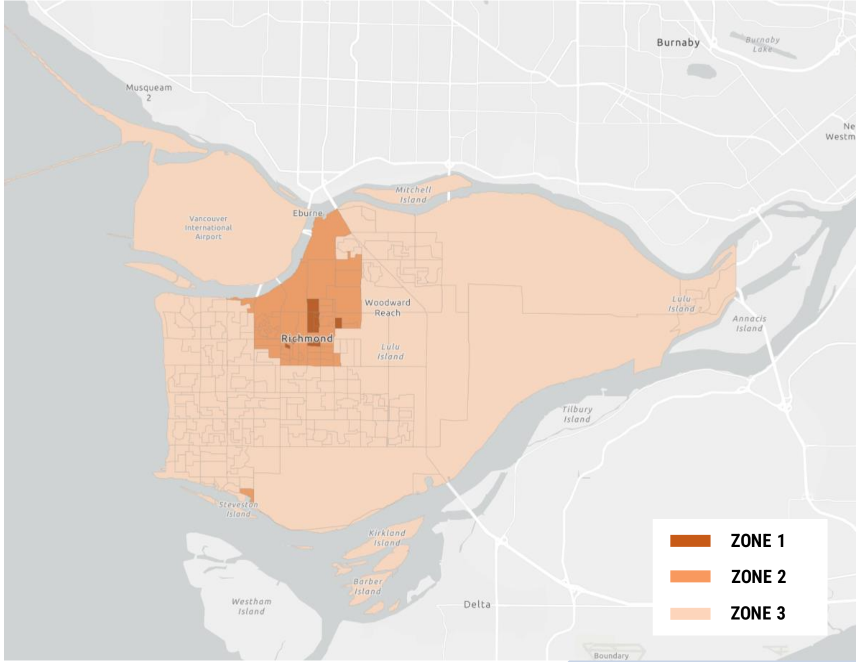
Normalize

Sum Z-score + 100

- No. of Condos/Sqm Area
- No. of Apt5+/Sqm Area

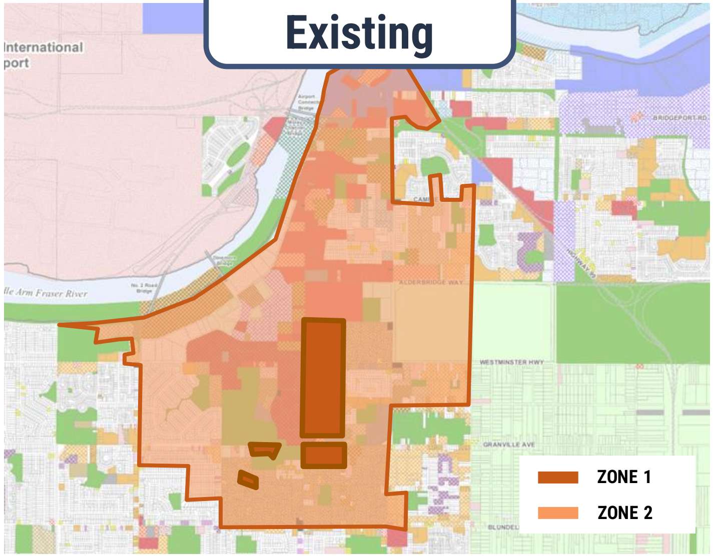
$$z = \frac{x - \mu}{\sigma}$$

μ = Mean
σ = Standard Deviation



A3.3 –Zonal Land Use

Land Use Existing



Source: City of Richmond Zoning Map, 2024

ZONE 1

Mixed Use Commercial

High Rise

ZONE 2

Mixed Use Commercial

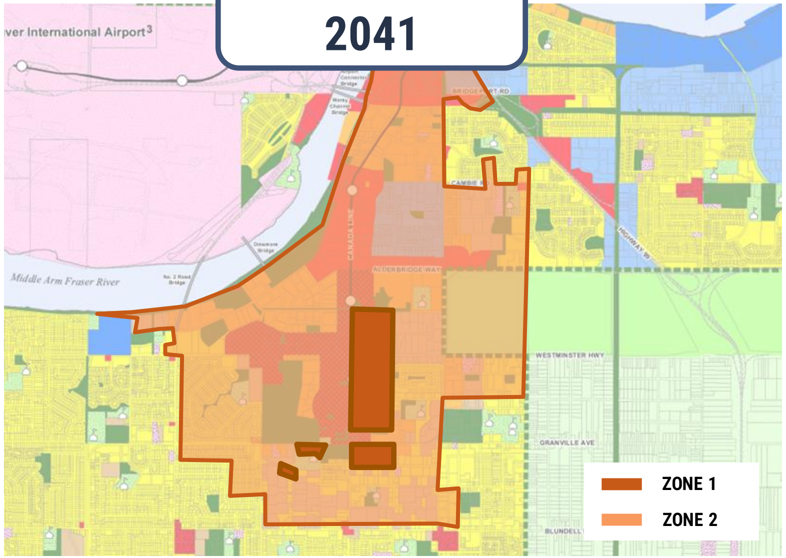
High Rise

Low Rise

Neighbourhood

Park

Land Use 2041

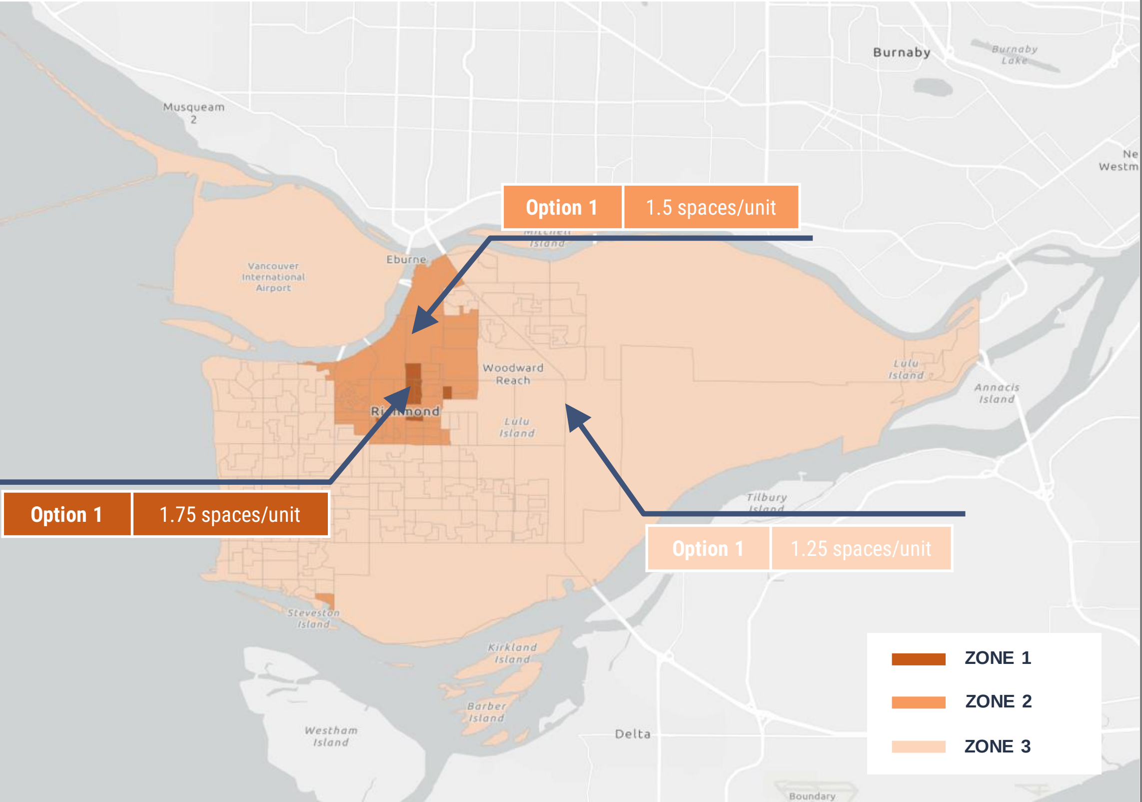


Source: City of Richmond 2041 OCP Land Use Map, 2024

A4 – Recommendation

Bike Parking Rates Recommendation & Study Limitations

A4.1 – Bike Parking Rates Recommendation



Recommended

Option 1: Applying Different Rates per Zone

[1.25, 1.5, and 1.75 spaces/unit]

Option 2: Applying an Overall Rate

[1.5 spaces/unit]

A4.2 – Study Limitations

01 Data Availability

Availability & reliability of data may be limited, leading to potential inaccuracies in the analysis.

02 Methodology

Over-reliance on simplified models or limited historical data may overlook important factors.

03 Accurate Forecasting

Predictive models to estimate future bike parking rate requirements cannot account for all variance in the true mode share for a city.

04 Correlation vs. Causation

Predictive model outputs should be considered as correlational only.

05 Stakeholder Engagement

Ex: Proposing too high of a rate could propose limitations with developers due to cost.

06 Behavioural Factors

Difficult to capture the complex interplay of factors impacting cycling behaviour in the spatial analysis.

Part B: Bike Parking Technology

B1 – Methodology

Terms & Definitions & Physical Technology Steps

B1.1 – Terms & Definitions

Physical Technology	**Definition:** Technologies that directly provide parking for bikes and/or micromobility devices.	**Example:** A bike rack offers short-term bike parking.
Non-Physical Technology	**Definition:** Technologies that facilitate the parking of bikes and/or micromobility devices but do not directly provide parking.	**Example:** An app that facilitates the user to register and schedule bike parking.

B1.2 – Physical Technology: Approach

Step 1: Listed out physical technologies & summarized their key features

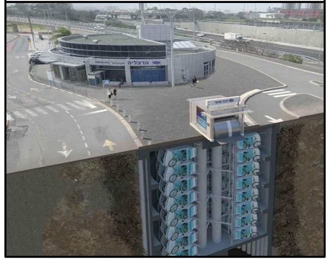
Step 2: Categorized physical technologies into 5 main categories

Step 3: Narrowed physical technology list from ~60 to 25 technologies

Step 4: Scored & ranked the physical technologies based on 7 key criteria

/35

Automated



Source: Biceberg, n.d.

Compartment

Source: metroSTOR, n.d.

Rack

Source: Bikeep, n.d.

Walk-in Parking

Source: Oonee, n.d.

Other

Source: metroSTOR, n.d.

B1.2 – Physical Technology: Scoring

1. Scored technology using a 5-point scale under each criteria with respect to their categories

2. Averaged scores among the team

[Technology]	Accessibility	. . .
Person 1	3	. . .
Person 2	4	. . .
Person 3	3	. . .
Average	(3 + 4 + 3)/3	. . .

3. Tallied the averaged scores: /35

4. Ranked the technologies within their categories

B2 – Physical Technologies

Automated, Compartment, Rack, Walk-in Parking, & Other

B2.1 – Automated

Source: Biceberg, n.d.

Product: Biceberg Down

Parking Type: Long-Term

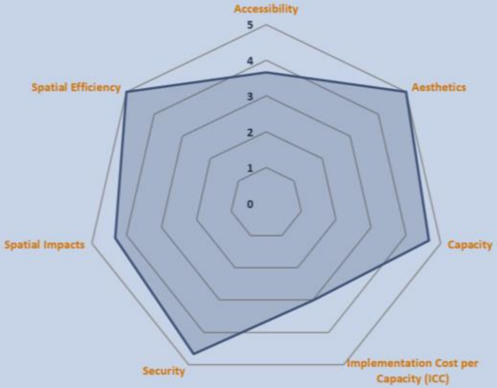
Accessibility: Bikes / e-bikes / e-scooters can be accommodated, devices can be retrieved within 30 seconds in succession, no lifting required as users' slot in their devices, user-friendly interface & smart card technology

Security: Excellent security as the user's devices are out of reach from the public. Each user is assigned a compartment & their devices can only be retrieved with a unique identification code.

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Item	1 Level	9 Levels
Capacity	24 bikes	216 bikes
Implementation Cost	$88,320 CAD	$794,880 CAD
ICC	$3,680 CAD/bike space	
Spatial Impacts	50.3 m² (L x W) x 1.5 m (H) per Level	
Spatial Efficiency	0.5 bike/m²	4.3 bikes/m²

Score:



B2.2 – Compartment

Product: metroSTOR Bike-S Street Cycle Storage Modules

Parking Type: Long-Term

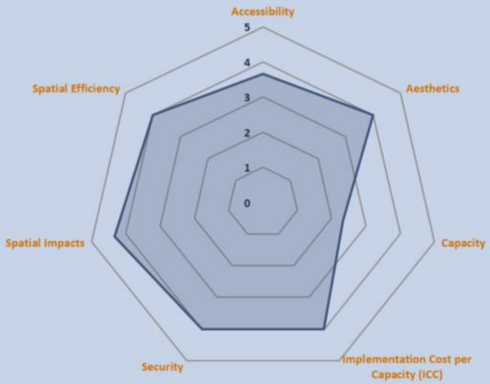
Accessibility: No lifting required, key security option may pose issues for users with certain physical limitations, may accommodate other micromobility devices that fit on tray, may not be suitable for cargo bikes or bikes with large accessories

Security: Good security due to full enclosure and traditional door security system, may be more susceptible to theft due only partial concealment, slight risk of theft by other users of same module

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Capacity	6 bikes
Implementation Cost	$7,140 CAD
ICC	$1,190 CAD/bike space
Spatial Impacts	4.5 m^2 (L x W) x 1.5 m (H)
Spatial Efficiency	1.3 bikes/m^2

Score:



Source: metroSTOR, n.d.

B2.3 – Rack

Source: Bikeep, n.d.

Product: Bikeep Smart Bike Parking Station

Parking Type: Short-Term

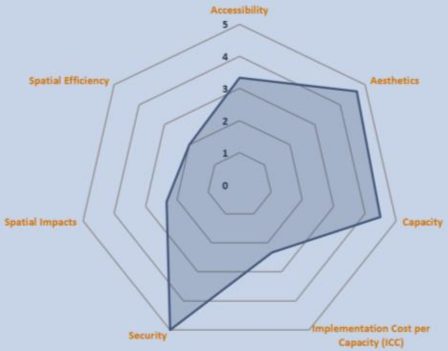
Accessibility: Bikeep mobile app informs users of real-time dock availability, accommodates bikes & e-bikes, no lifting required, app / phone reliant, restricted access, typically placed at locations for convenient user access

Security: Bikes are exposed to the public & are susceptible to theft, the security system does not require the user to bring their personal security devices & it discourages thefts from stealing or vandalizing bikes, the rack supports both the bike frame & its front wheel

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Item	5 Docks	10 Docks
Capacity	5 bikes	10 bikes
Implement Cost	$16,200 CAD	$25,400 CAD
ICC	$3,240 CAD/bike space	$2,540 CAD/bike space
Spatial Impacts	9.8 m^2 (L x W) x 1.1 m (H)	18.4 m^2 (L x W) x 1.1 m (H)
Spatial Efficiency	0.5 bike/m^2	0.5 bike/m^2

Score:



B2.4 – Walk-in Parking (1)

1. Shelter

Source: Oonee, n.d.

2. Cage

Source: Oonee, n.d.

3. Store

Source: Oonee, n.d.

4. Parkade

Source: TransLink, 2016

5. Garage

Source: The Verge, n.d.

B2.4 – Walk-in Parking (2)

Source: Oonee, n.d.

Product: Oonee Pod

Parking Type: Long-Term

Accessibility: No strenuous lifting required, on-demand systems may affect reliability of available capacity, may not be suitable for cargo bikes or bikes with large accessories, vertical bike racks may not be suitable for micromobility devices, app / phone reliant, restricted access

Security: Strong structural materials, security of access depends on the security protocols of the app, slight risk of theft by other users of same facility

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Item	Standard Model	Expandable Model
Capacity	24 bikes	48 bikes
Implement Cost	[$$$]	[$$$]
ICC	[$$$]	[$$$]
Spatial Impacts	22.1 m² (L x W) x 3.7 m (H)	44.2 m² (L x W) x 3.7 m (H)
Spatial Efficiency	1.1 bikes/m²	

Score:

B3 – Non-Physical Technologies

Types & Examples

B3.1 – Types

2 Types of Non-Physical Technologies:

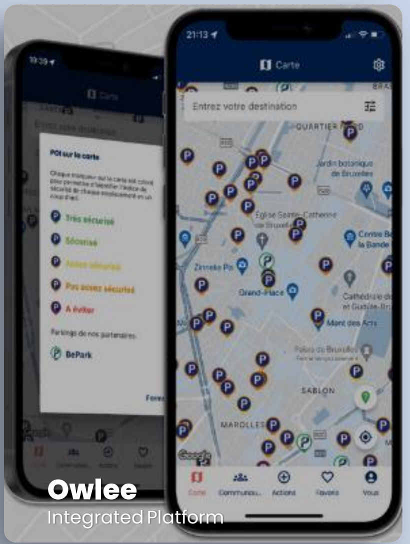
Integrated Platforms	**Definition:** A platform that integrates bike parking registration, payment, and/or availability checks with the existing transportation system.	**Example:** Compass Card.
Non-Integrated Platforms	**Definition:** A platform that is exclusively designed to provide services for one or more Physical Technologies from the same manufacturer.	**Example:** EVO car share app.

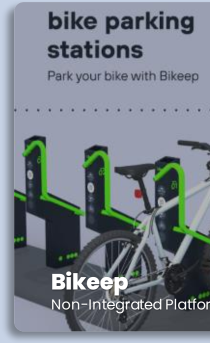
Owlee

Owlee is an international non-physical technology, bringing together more than 250.000 bike parking spots available in Belgium, France, Italy, Luxembourg, Netherlands, Germany & UK. Users can register their bikes & look for available bike parking spots on this publicly available application.

Features

- Bike registration to report & identify thefts
- Rating bike parking facilities according to the reviews & ratings shared by the community
- Other: Insurance, assistance, repairs





Source: Owlee, n.d.

B3.2 – Examples

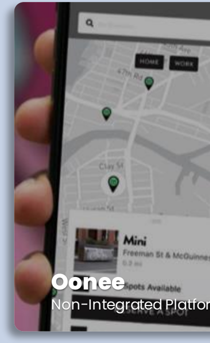
BikeLink

The BikeLink app is used to access & pay for e-lockers available at 40 BART (Bay Area Rapid Transit) stations with over 1800 spaces of secure bike parking spaces. This app integrates all bike parking facilities within BART & registered customers can use the application to find available on-demand parking spots including bike hangers, e-lockers, & group parking available throughout the region.

Features

- All components run on AC power or batteries
- Integrating lockers, racks, or cage enclosures
- Works with or without a network

BikeLink
Integrated Platform



Source: BikeLink, n.d.

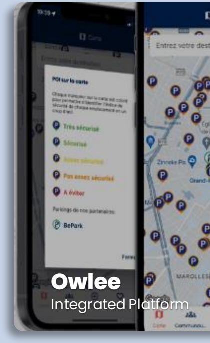
B3.2 – Examples

Bikeep

The Bikeep mobile app is meant for users parking at Bikeep designated facilities (racks, lockers, & e-scooter stations). Users park, secure, and/or retrieve their devices (bikes, e-bikes, & e-scooters) by using the app to lock or unlock the Bikeep facilities.

Features

- Allow users to open, close, or reserve the Bikeep parking space
- Allow users to obtain real-time information (statistics) on their parked devices
- Available globally, in all the countries where it provides bike parking services



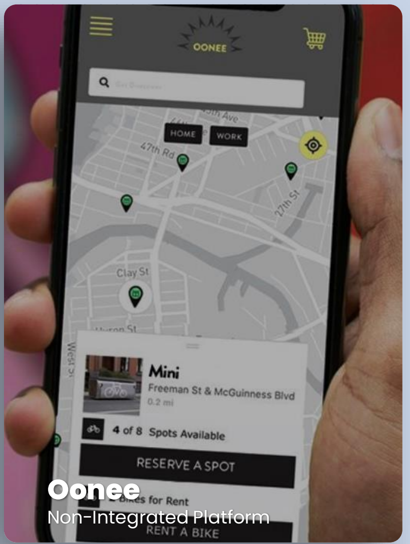
Source: Bikeep, n.d.

Oonee

Oonee's mobile app enables cyclists to easily find Oonee parking facilities, along with some side partnerships. It offers one central dashboard for city leaders and property management. This central dashboard is powered by a new IoT system, which provides unprecedented visibility into system usage, trends, & analytics.

Features

- Easy registration for new customers of Oonee bike parking facilities
- Find nearby parking options
- Locks / unlocks the dock through the app
- Connect with services like insurance, maintenance, & repair from local vendors
- Provide management dashboard



Source: Oonee, n.d.

B4 – Conclusion

Key Takeaways & Limitations

Conclusion

Key Takeaways

01 Technologies have Strengths & Weaknesses

02 Choosing Technology Depends on Context

03 Physical and Non-Physical Technologies should Complement Each Other

04 Innovative Technologies ≠ Best Solution

Limitations

01 Cost Data

02 Equal Scoring Weights

03 Lack of Exhaustive List

04 Personal Judgement

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Thank You!

ACE CONSULTING

Appendix A

Part A: Bike Parking Rate Revision

AA1 – Reseach & Data Collection

1. **Researched Methodologies for Developing Bike Parking Rates → Nothing Found**

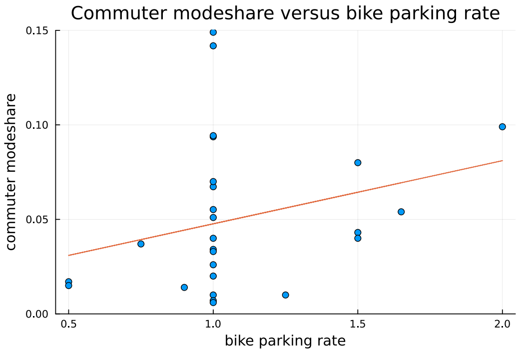
2. **Performed Extensive Data Collection**

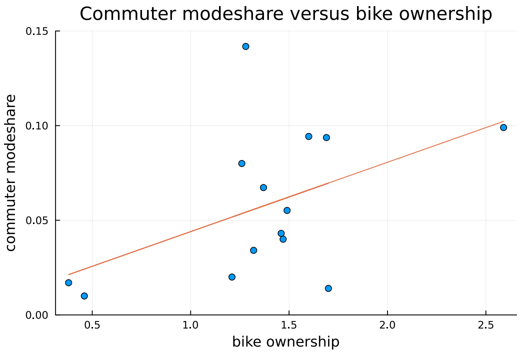
   a) 27 Cities across North America

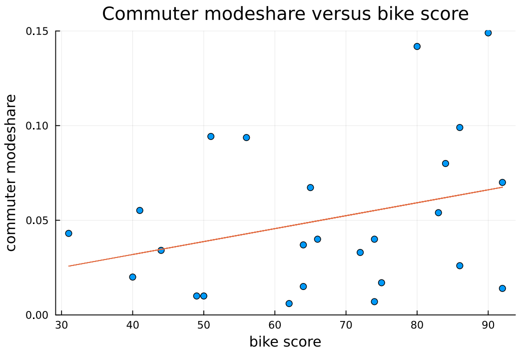
   b) Collected:

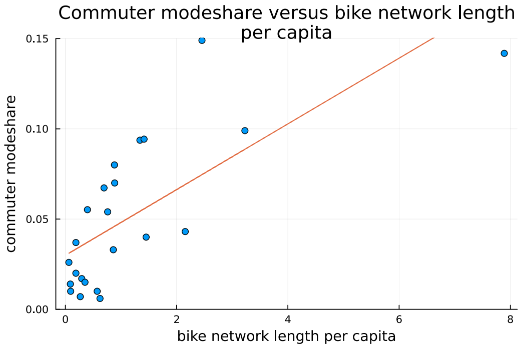
   - Bike Parking Rate
   - Mode Share
   - Population
   - Bike Score
   - Bike Network Length
   - Bike Ownership

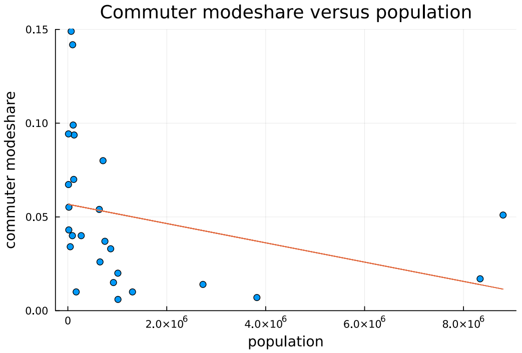
Location	Bike Parking		Modeshare				Normalized Bike network (use this for the analysis)		Population (same as modeshare region)	
	Rate	Rate (Dwelling unit, bedroom, sq.m)	Overall		Commuter		Length in meters	Year	Number	Year
			Rate	Year	Rate	Year				
Vancouver	1,5	unit (<65 m2)	7,0%	2022	8,00%	2022	627 291	2022	710 918	2022
	2,5	unit (>65 m2)								
	3	unit (>105 m2)								
Victoria	1	unit (< 45 m^2)	11,6%	2022	14,18%	2022	765 807	2022	97 056	2022
Victoria	1,25	unit (> 45 m^2)	13,0%	2022						
Saanich	1	unit	8,0%	2022	9,37%	2022	169 888	2022	126 719	2022
Central Saanich	1,5	unit	3,2%	2022	4,31%	2022	40 580	2022	18 834	2022



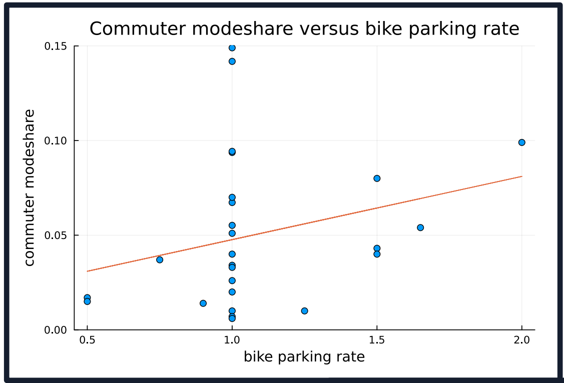


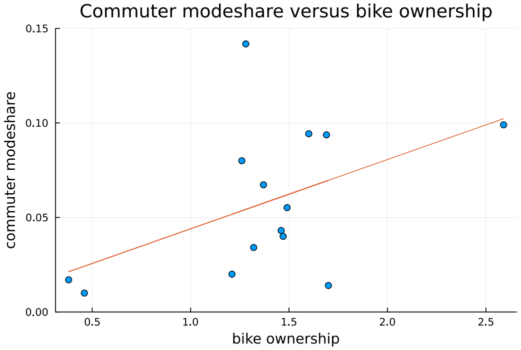


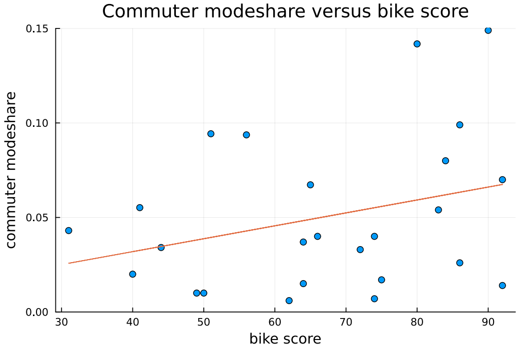


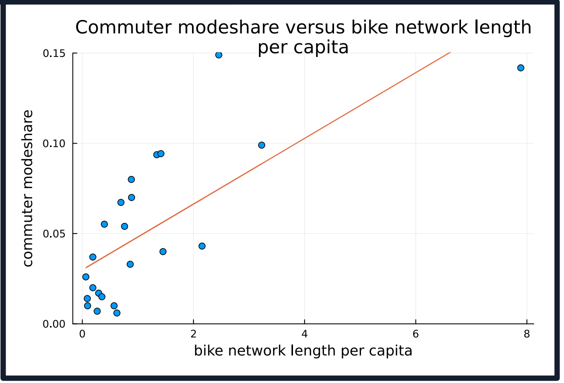


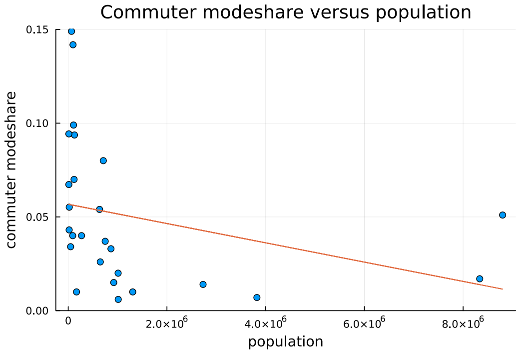
AA2 – Ensemble Regression: Relationships with Commuter Mode Share (1)


Commuter modeshare versus bike parking rate
commuter modeshare
bike parking rate

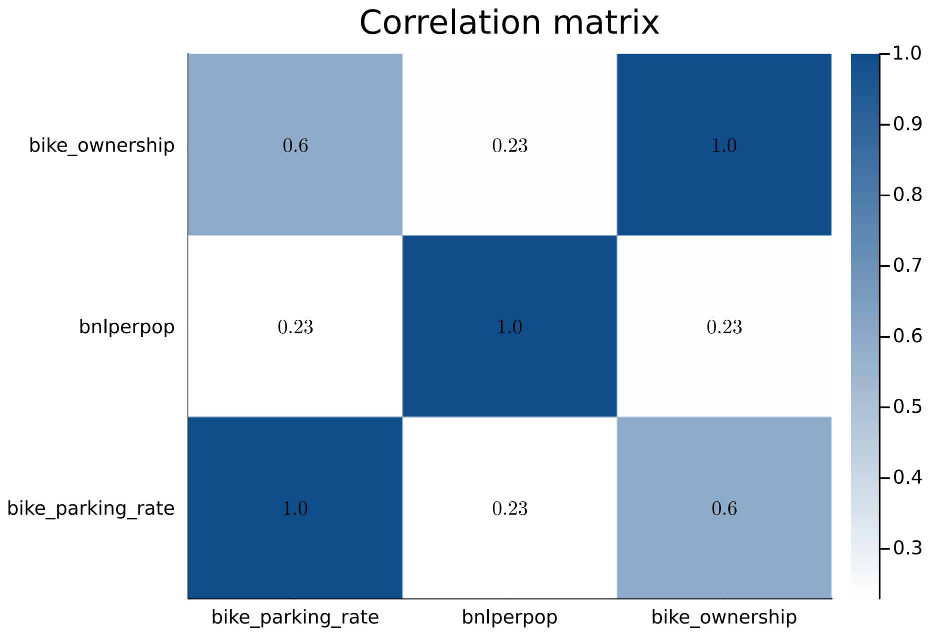

Commuter modeshare versus bike ownership
commuter modeshare
bike ownership


Commuter modeshare versus bike score
commuter modeshare
bike score


Commuter modeshare versus bike network length per capita
commuter modeshare
bike network length per capita

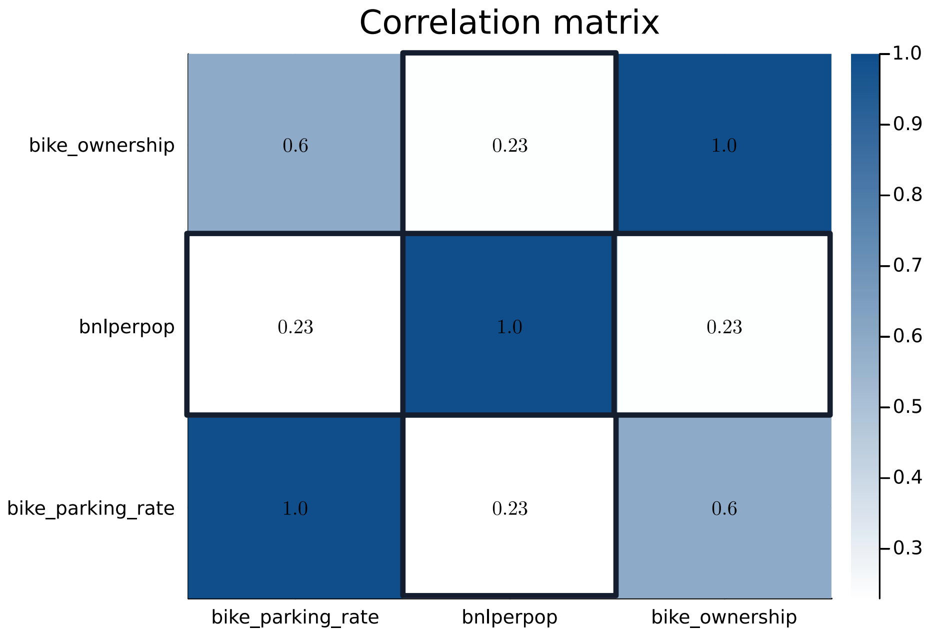

Commuter modeshare versus population
commuter modeshare
population

Why Choose Bike Parking Rate & Not Bike Ownership?

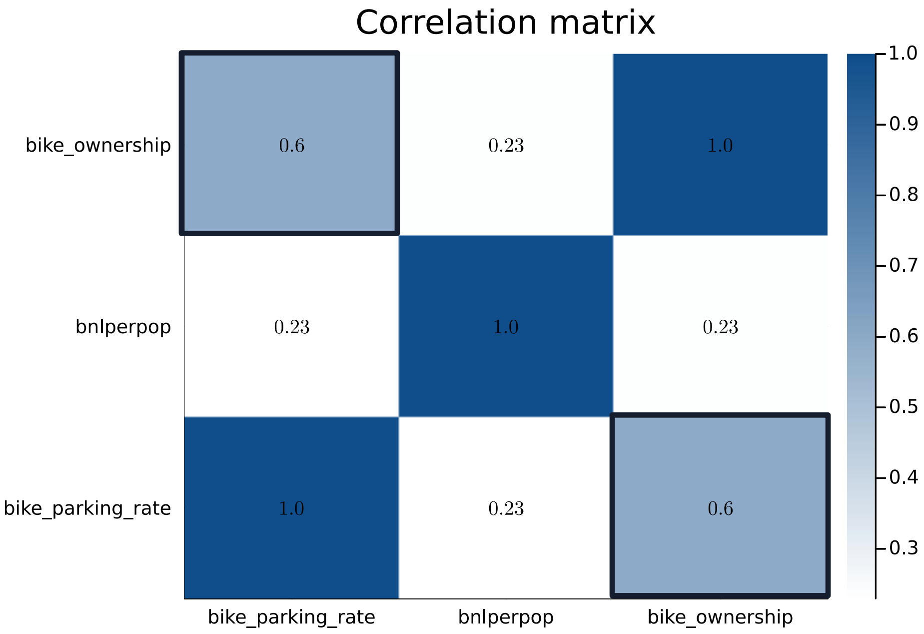


- Low Correlation between Bike Network Length per Capita & Both Bike Parking Rate/Bike Ownership

- Bike Network Length per Capita has the Strongest Individual Relationship with Commuter Mode Share

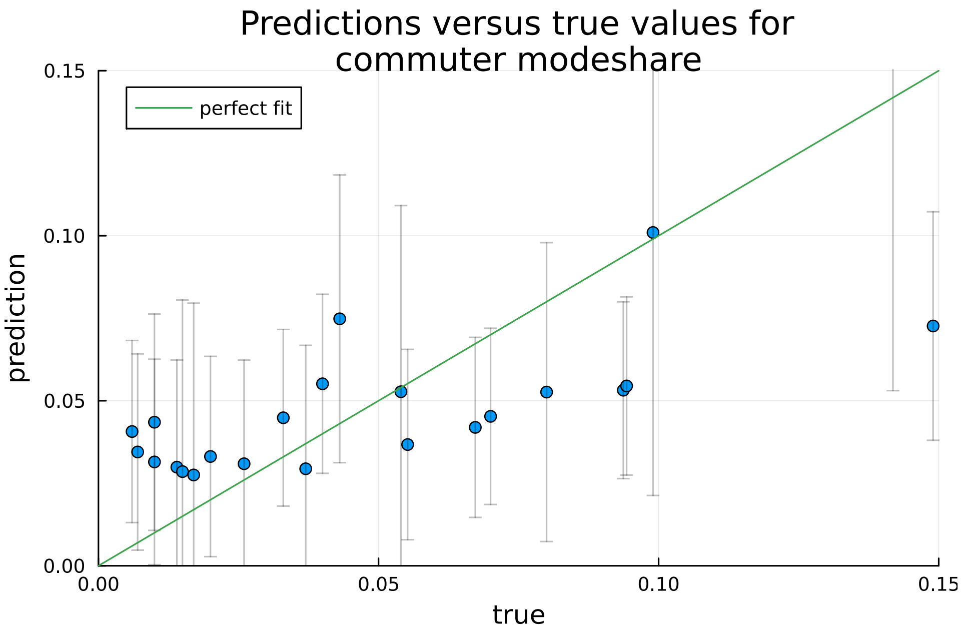


- Higher Correlation between Bike Parking Rate & Bike Ownership; Including both may Degrade Performance
- Bike Parking Rate is the Predictor of Interest for Richmond



R-Squared: 0.54

F-Test: 11.81



- Predicted Commuter Mode Share from the Multivariate Linear Regression Plotted Against Actual Commuter Mode Share

- The Fit could be improved with Additional Data

MAE: 0.026 (2.6%)

RMSE: 0.033 (3.3%)

- Predicted Commuter Mode Share from the Random Forest Regression Plotted Against Actual Commuter Mode Share

- Decision Tree Regression Predictions shown for Comparison

- Overall Good Performance, but could be improved with more Data

Appendix B

Bike Parking Technology

AB1 – Scoring: Rules

1. General

a) Criteria: Accessibility, Aesthetics, Capacity, Implementation Cost per Capacity (ICC), Security, Spatial Impacts, and Spatial Efficiency
b) 5-Point Scale: 1 = Very Bad, 2 = Bad, 3 = OK, 4 = Good, 5 = Very Good
c) Total Score: Total Score = Sum(Accessibility, Aesthetics, Capacity, ICC, Security, Spatial Impacts, Spatial Effiency Scores)
d) Ranking: Rank technologies within their respective categories / sub-categories, with higher Total Scores having a higher rank (vice versa).

2. Score Technologies Relative to Each Other

Assign points to each criteria for each technology within their respective categories or sub-categories. Assign N/A for technologies that have nothing to be compared to within their respective categories or sub-categories.

a) Automated: Score technologies relative to each other within their category (Automated)
b) Compartment: Score technologies relative to each other within their sub-category (Locker and Module)
c) Rack: Score technologies relative to each other within their sub-category (Horizontal, Vertical, and Diagonal)
d) Walk-in Parking: Score technologies relative to each other within their sub-category (Shelter, Cage, Store, Parkade, and Garage)
e) Other: Score technologies relative to each other within their sub-category (E-Bike Storage, E-Scooter Storage, and Mobility Scooter Storage)

For example, only score the locker technologies relative to other locker technologies (NOT MODULES). These relative comparisons have been colour coded above for your reference.

3. Special Rules for Technologies with Multiple Models

For each Physical Technology with a range of models (i.e. Smallest vs Biggest Models), please use the averaged Capacity, averaged ICC, averaged Spatial Impacts, and averaged Spatial Efficiency for comparison with other Physical Technologies within the same category or sub-category (relative comparison defined above). Please refer to the following:

- Higher Capacity = Better = Assign Higher Points
- Lower ICC = Better = Assign Higher Points
- Lower Spatial Impacts = Better = Assign Higher Points
- Higher Spatial Efficiency = Better = Assign Higher Points

For example, we will compare the average Capacity of one Physical Technology with the average Capacity of another Physical Technology and/or the Capacity for Physical Technologies with only one model within their respective category or sub-category (relative comparison defined above).

AB1 – Scoring: Table

PART A: TECHNOLOGY				PART B: BENNY ORR SCORES								
ID	CATEGORY	SUB-CATEGORY	PRODUCT	ACCESSIBILITY	AESTHETICS	CAPACITY	IMPLEMENTATION COST PER CAPACITY (ICC)	SECURITY	SPATIAL IMPACTS	SPATIAL EFFIENCY	TOTAL	REASON
1	Automated	Below Ground	Biceberg Down	3	5	4	3	4	4	5	28	1. Accessibility: Retrieval time is 20s longer than Biceberg Bigloo. 2. Capacity: Offers moderate capacity. 3. ICC: All Biceberg products have the same ICC and the ICC is expected to be a lot higher than traditional bike parking technologies. 4. Security: All Biceberg products have similar security mechanisms. The unique identification can be stolen and used by others. 5. Spatial Impacts: Only the small user interface machine is located above ground. Majority of the facility is below ground, which maximizes the space above ground but may interfere with future construction projects. 6. Spatial Efficiency: On average, it can store 2.4 bikes/m2, which is higher than traditional bike parking technologies.
2	Automated	On Ground	Biceberg Bigloo	4	2	3	3	4	3	2	21	1. Accessibility: Retrieval time is 20s faster than other Biceberg models, but users can only retrieve their devices sequentially. 2. Capacity: Offers the least capacity. 3. ICC: All Biceberg products have the same ICC and the ICC is expected to be a lot higher than traditional bike parking technologies. 4. Security: All Biceberg products have similar security mechanisms. The unique identification can be stolen and used by others. 5. Spatial Impacts: Smaller footprint and height compared to Biceberg Up, but it still intereferes with above ground activities. 6. Spatial Efficiency: On average, it can store 0.6 bike/m2, which is lower than the other Biceberg products.
3	Automated	Above Ground	Biceberg Up	3	3	5	3	4	2	5	25	1. Accessibility: Retrieval time is 20s longer than Biceberg Bigloo. 2. Capacity: Offers the most capacity. 3. ICC: All Biceberg products have the same ICC and the ICC is expected to be a lot higher than traditional bike parking technologies. 4. Security: All Biceberg products have similar security mechanisms. The unique identification can be stolen and used by others. 5. Spatial Impacts: Higher footprint and height compared to Biceberg Bigloo, and it still intereferes with above ground activities. 6. Spatial Efficiency: On average, it can store 2.4 bikes/m2, which is higher than traditional bike parking technologies.
4	Compartment	Locker	Bart Individual Electronic Locker	5	3	N/A	3	4	3	3	21	1. Accessibility: Great accessibility features, especially for the fact that it does not require users to lift their bikes. 2. Capacity: Bike lockers store 1 bike only. 3. ICC: Lower ICC, but still relatively high compared to other bike parking technologies. 4. Security: Good security overall, but the partially concealing doors may encourage theft. 5. Spatial Impacts: Locker requires more footprint. 6. Spatial Efficiency: Lower spatial efficiency (0.7 bike/m2) compared to SecuraBike Vertical Bike Locker.
5	Compartment	Locker	SecuraBike Vertical Bike Locker	1	2	N/A	2	4	3	4	16	1. Accessibility: Poor accessibility features, especially for the fact that it requires users to lift their bikes. 2. Capacity: Bike lockers store 1 bike only. 3. ICC: Higher ICC and still relatively high compared to other bike parking technologies. 4. Security: Good security overall, but it may be more susceptible to break-ins due to the use of a thin sheet metal. 5. Spatial Impacts: Locker requires more height. 6. Spatial Efficiency: Higher spatial efficiency (1.0 bike/m2) compared to Bart Individual Vertical Bike Locker.
6	Compartment	Module	metroSTOR Bike-S Street Cycle Storage Modules	3	4	2	3	4	4	4	24	1. Accessibility: Lifting is not required, but key security may pose issues for users with certain physical limitations and that it may not be suitable for non-standard sized bikes. 2. Capacity: Offers the least capacity. 3. ICC: Moderate ICC. 4. Security: Good security overall with strong build, but may be more susceptible to theft due partial concealment. 5. Spatial Impacts: Requires the least footprint (4.5 m2) and height (1.5 m) out of all three modules. 6. Spatial Efficiency: Good spatial efficiency (1.3 bike/m2).
7	Compartment	Module	metroSTOR PCM 12 Cycle Storage Unit	1	1	4	4	3	3	5	21	1. Accessibility: Poor accessibility features, especially for the fact that it requires users to lift their bikes. 2. Capacity: Offers the most capacity. 3. ICC: Lowest ICC. 4. Security: Good security overall, but does not have a strong build compared to the metroSTOR Bike-S Street Cycle Storage Modules. 5. Spatial Impacts: Requires a larger footprint (5.5 m2) and height (2.1 m) compared to the metroSTOR Bike-S Street Cycle Storage Modules. 6. Spatial Efficiency: Excellent spatial efficiency (1.6 bike/m2).
8	Compartment	Module	Oonee Mini	3	5	3	2	4	2	3	22	1. Accessibility: Lifting is not required, but it is heavily reliant on the mobile app. Users may not know how to use the app and/or may not have access to the product once their phone is out of battery. 2. Capacity: Offers moderate capacity. 3. ICC: Expected to be the most expensive. 4. Security: Good security overall with Oonee mobile app security protocols and fully concealed design. There is still a slight risk of theft by other users of the same module. 5. Spatial Impacts: Requires a large footprint (9.5 m2). 6. Spatial Efficiency: Poor spatial efficiency (0.9 bike/m2).
9	Rack	Horizontal	Bikeep Smart Bike Parking Station	3	5	4	2	5	2	2	23	1. Accessibility: Restricted access and mobile app reliant - not everyone may know how to use the app. However, no lifting is required. 2. Capacity: Doubles in capacity compared to the SecuraBike Compact Flat Pack 4 Bike Rack (8 bikes vs 4 bikes). 3. ICC: Expected to be expensive. 4. Security: Excellent security system. The security system includes state of the art features like an integrated locking bar, alarm system, and security cameras (optional), which help deter thefts. 5. Spatial Impacts: Requires a relatively large footprint (14.1 m2). 6. Spatial Efficiency: Poor spatial efficiency (0.5 bike/m2).
10	Rack	Horizontal	SecuraBike Compact Flat Pack 4 Bike Rack	5	4	3	5	3	5	5	30	1. Capacity: Accessible by everyone, user friendly, and no lifting is required. 2. Capacity: Only 4 bikes can be parked. 3. ICC: Relatively cheap ($179 CAD/bike space). 4. Security: Personal security devices are required to secure the bikes to the racks and the rack does not come with a state of the art security system. 5. Spatial Impacts: Requires a relatively small footprint (2.2 m2). 6. Spatial Efficiency: Excellent spatial efficiency (1.8 bike/m2).

	PART C: ERIC BROCK SCORES								
ID	ACCESSIBILITY	AESTHETICS	CAPACITY	IMPLEMENTATION COST PER CAPACITY (ICC)	SECURITY	SPATIAL IMPACTS	SPATIAL EFFIENCY	TOTAL	REASON
1	4	5	5	3	5	4	5	31	1. Accessibility: Easy to understand. No lifting or strenuous movements required. Accommodates a wide range of devices. Only one storage/retrieval can be performed at a time (30 sec). 2. Capacity: High average capacity. Wide range of options. 3. ICC: All reviewed products have the same cost. 4. Security: Break-ins expected to be virtually non-existent. Devices are fully obscured from non-owners. 5. Spatial Impacts: Below-ground, it requires a similar area to other reviewed technologies. At the street level, the footprint is extremely small (negligeable spatial impacts). However, it requires civil excavation and is a permanent structure. 6. Spatial Efficiency: Excellent average spatial efficiency (2.4 bikes/m2).
2	5	2	2	3	5	4	2	23	1. Accessibility: Easy to understand. No lifting or strenuous movements required. Accommodates a wide range of devices. Only one storage/retrieval can be performed at a time (10 sec). 2. Capacity: Low capacity. Only one option. 3. ICC: All reviewed products have the same cost. 4. Security: Break-ins expected to be virtually non-existent. Devices are fully obscured from non-owners. 5. Spatial Impacts: Somewhat small footprint compared to other reviewed automated technologies. Structure does not require civil excavation and can be moved. 6. Spatial Efficiency: Unremarkable spatial efficiency (0.6 bikes/m2)
3	4	4	5	3	5	3	5	29	1. Accessibility: Easy to understand. No lifting or strenuous movements required. Accommodates a wide range of devices. Only one storage/retrieval can be performed at a time (30 sec). 2. Capacity: High average capacity. Wide range of options. 3. ICC: All reviewed products have the same cost. 4. Security: Break-ins expected to be virtually non-existent. Devices are fully obscured from non-owners. 5. Spatial Impacts: Similar footprint to other reviewed automated technologies Requires a permanent street-level structure. 6. Spatial Efficiency: Excellent average spatial efficiency (2.4 bikes/m2).
4	5	3	N/A	3	4	3	3	21	1. Accessibility: Easy to understand, particularly for locals as it is designed to be integrated with transit cards. Accommodates a wide range of devices, provided that they fit within the constrained internal dimensions. 2. Capacity: Bike lockers generally store 1 bike (N/A). 3. ICC: Reasonable cost per bike space. 4. Security: Full enclosure. Strong materials/construction. Reliable security mechanism. Devices are partially visible. 5. Spatial Impacts: Small / compact with low height. 6. Spatial Efficiency: Good spatial efficiency for a bike locker (0.7 bikes/m2).
5	2	2	N/A	3	4	3	4	18	1. Accessibility: Easy to understand, but not the most easy to use (traditional security systems) unless client requests custom options. Due to small footprint dimensions, can only accommodate small devices or ones that can be stored vertically. Most devices require lifting/tipping, making this option inadequate for users with mobility restrictions. 2. Capacity: Bike lockers generally store 1 bike (N/A). 3. ICC: Reasonable cost per bike space. 4. Security: Full enclosure. Reliable security mechanism. Devices are fully obscured. Thin sheet metal. 5. Spatial Impacts: Very small spatial impact due to vertical orientation, but taller. 6. Spatial Efficiency: Very good spatial efficiency for a bike locker (1.0 bikes/m2).
6	4	4	2	4	4	4	4	26	1. Accessibility: No lifting or strenuous movements required. Simple security mechanism. Devices that can be stored are limited by design of interior tray. May not accommodate cargo bikes or larger micromobility devices due to compact form. 2. Capacity: Adequate capacity. 3. ICC: Cheap. 4. Security: Reliable security mechanism. Strong materials. Devices (nearly) fully concealed. 5. Spatial Impacts: Relatively compact. Regular shape. 6. Spatial Efficiency: Great spatial efficiency (1.3 bikes/m2)
7	1	1	4	4	4	3	5	22	1. Accessibility: Lifting/tilting required for storage on vertical bike racks. Simple Security mechanism. Small footprint limits devices to those that can be stored on racks -- may not accommodate cargo bikes or larger micromobility devices. 2. Capacity: Great model-average capacity. 3. ICC: Very cheap. 4. Security: Reliable security mechanism. Strong materials. Devices fully concealed. 5. Spatial Impacts: Large/tall. Regular shape. 6. Spatial Efficiency: Excellent spatial efficiency (1.6 bikes/m2).
8	4	5	3	2	4	3	3	24	1. Accessibility: No lifting required. Reliable due to remote access to parking locations and capacity information. Horizontal bike racks may limit accommodated devices to bikes or similar devices. Mobile app security may be an issue for equitable access. 2. Capacity: Good capacity. 3. ICC: No cost information documented. Expected to be high cost. 4. Security: Reliable security mechanism. Strong materials. Devices (nearly) fully concealed. 5. Spatial Impacts: Low height, but large footprint. Regular shape. 6. Spatial Efficiency: Reasonable spatial efficiency (0.9 bikes/m2).
9	3	4	5	2	5	2	2	23	1. Accessibility: No lifting required. Reliable due to remote access to parking locations and capacity information. Accommodates bikes and e-bikes. May not accommodate alternative micromobility devices or bulky devices. Mobile app security may be an issue for equitable access. 2. Capacity: Great model-average capacity. 3. ICC: No cost information documented. Expected to be high cost. 4. Security: No user-provided personal locking devices required. Frame-locking bar. Security alarm and cameras. 5. Spatial Impacts: Very large footprint. Low height. Visibly unobtrusive. 6. Spatial Efficiency: Poor spatial efficiency (0.5 bikes/m2).
10	5	3	3	5	3	5	5	29	1. Accessibility: No lifting required. Standard design: intuitive to use. Accommodates bikes and e-bikes. May not accommodate alternative micromobility devices or bulky devices. 2. Capacity: Good capacity. 3. ICC: Extremely low cost. 4. Security: Relies on user-provided personal locking devices. Capable of frame locking. 5. Spatial Impacts: Very small footprint. 6. Spatial Efficiency: Excellent spatial efficiency (1.8 bikes/m2).

	PART D: PEGAH GHANE SCORES								
ID	ACCESSIBILITY	AESTHETICS	CAPACITY	IMPLEMENTATION COST PER CAPACITY (ICC)	SECURITY	SPATIAL IMPACTS	SPATIAL EFFIENCY	TOTAL	REASON
1	4	5	5	3	5	5	5	32	1. Accessibility: longer retrieval time -doesn't require lifting 2. Capacity: offering high capacity 3. ICC: same ICC in all Biceberg products and a higher cost compared to conventional facilities 4. Security: high security with unique identification code 5. Spatial Impacts: does not take much space on the ground 6. Spatial Efficiency: high spatial efficiency compared to other types and even categories
2	5	4	3	3	5	3	3	26	1. Accessibility: small retrieval time 2. Capacity: : Low capacity without flexibility 3. ICC: same ICC in all Biceberg products and a higher cost compared to conventional facilities 4. Security: high security with unique identification code 5. Spatial Impacts: the whole facility is on the ground, taking mich space 6. Spatial Efficiency: low efficiency (0.6 bikes/m2)
3	4	5	5	3	5	2	5	29	1. Accessibility: longer retrieval time -doesn't require lifting 2. Capacity: offer large capacity 3. ICC: same ICC in all Biceberg products and a higher cost compared to conventional facilities 4. Security: high security with unique identification code 5. Spatial Impacts: it takes a huge space on the ground and also adding to the floors can interfere with above ground activities (utilities in particular) 6. Spatial Efficiency: high spatial efficiency compared to other types and even categories
4	4	2	N/A	5	3	4	4	22	1. Accessibility: integrted trnasit system needs some familarity with transit and having a transit card (no other option through application) 2. Capacity: it does not apply to Bike lockers as they are mostly for 1 bike. 3. ICC: lower implementation cost per capacity (cheaper than vertical type, onsidering that even a better material is used) 4. Security: Full enclosure but partially transparent walls - Strong materials/construction - no mechanism to notice theft or incidents. 5. Spatial Impacts: larger area which takes more space on the ground 6. Spatial Efficiency: lower spatial efficiency compared to locker with vertical orientation (0.7 bike/m2)
5	3	2	N/A	4	4	5	5	23	1. Accessibility: requires lifting and can not accomodate heqavy or bigger devices 2. Capacity: it does not apply to Bike lockers as they are mostly for 1 bike. 3. ICC: reasonable cost for each locker 4. Security: Fully enclosed and concealed design - thin metal (weak material) - no mechanism to notice theft or incidents. 5. Spatial Impacts: very small spatial impact on the ground (1.0 m2), more height 6. Spatial Efficiency: Higher spatial efficiency - good use of space (1 bike/m2)
6	4	4	3	5	4	5	4	29	1. Accessibility: no major accessibility issues other than accomodating non-conventional bikes - devices 2. Capacity: low capacity without flexibility upon request 3. ICC: cheap technology 4. Security: full enclosure but partially concealed - same module is used by more than one user 5. Spatial Impacts: low spatial impact (4.5 m2) 6. Spatial Efficiency: high spatial efficiency - good use of space (1.3 bikes/m²)
7	3	3	5	4	4	4	4	27	1. Accessibility: it requires Lifting - traditional security mechanism- non-conventional devices may not fit - simple access for every one 2. Capacity: highest capacity compared to other modules and flexible upon request 3. ICC: cheap tech 4. Security: fully concealed and strong material 5. Spatial Impacts: tall rectangular shape but higher spatial impact compared to horizantal orientation 5.5 m2 6. Spatial Efficiency: highest spatial efficiency compared to other modules-good use of space (1.6 bike/m²)
8	4	5	4	3	5	3	3	27	1. Accessibility: might be difficult to use for some people (smartphone required) 2. Capacity: meduim capacity without flexibility upon request (8 bikes) 3. ICC: No cost information but expected to be expensive for the technology 4. Security: fully enclosed - access is through the application which 5. Spatial Impacts: larger area compared to similar tech 9.5 m2 6. Spatial Efficiency: medium spatial efficiency (0.9 bike/m²)
9	4	5	N/A	3	5	3	2	22	1. Accessibility: phone reliant but provides real time monitoring of the rack 2. Capacity: it would not apply to the rack category as if a single rack is considered the capacity is one/two 3. ICC: more expensive - requires tech and application development 4. Security: self-locked rack - do not need personal security devices-monitor bike and rack through the application 5. Spatial Impacts: larg spatial impact (14.1 m2) 6. Spatial Efficiency: very low spatial efficiency (0.5 bike/m²)
10	5	4	N/A	5	2	5	5	26	1. Accessibility: AAA design 2. Capacity: it would not apply to the rack category as if a single rack is considered the capacity is one/two 3. ICC: cheap and conventional technology 4. Security: needs personal lock 5. Spatial Impacts: small spatial impact 6. Spatial Efficiency: high spatial efficiency (1.8 bikes/m²)

	PART E: AVERAGE SCORES									
ID	ACCESSIBILITY	AESTHETICS	CAPACITY	IMPLEMENTATION COST PER CAPACITY (ICC)	SECURITY	SPATIAL IMPACTS	SPATIAL EFFIENCY	TOTAL	OUT OF	PERCENT
1	3.7	5.0	4.7	3.0	4.7	4.3	5.0	30.3	35.0	86.7%
2	4.7	2.7	2.7	3.0	4.7	3.3	2.3	23.3	35.0	66.7%
3	3.7	4.0	5.0	3.0	4.7	2.3	5.0	27.7	35.0	79.0%
4	4.7	2.7	N/A	3.7	3.7	3.3	3.3	21.3	30.0	71.1%
5	2.0	2.0	N/A	3.0	4.0	3.7	4.3	19.0	30.0	63.3%
6	3.7	4.0	2.3	4.0	4.0	4.3	4.0	26.3	35.0	75.2%
7	1.7	1.7	4.3	4.0	3.7	3.3	4.7	23.3	35.0	66.7%
8	3.7	5.0	3.3	2.3	4.3	2.7	3.0	24.3	35.0	69.5%
9	3.3	4.7	4.5	2.3	5.0	2.3	2.0	24.2	35.0	69.0%
10	5.0	3.7	3.0	5.0	2.7	5.0	5.0	29.3	35.0	83.8%

PART A: TECHNOLOGY				PART B: BENNY ORR SCORES								
ID	CATEGORY	SUB-CATEGORY	PRODUCT	ACCESSIBILITY	AESTHETICS	CAPACITY	IMPLEMENTATION COST PER CAPACITY (ICC)	SECURITY	SPATIAL IMPACTS	SPATIAL EFFIENCY	TOTAL	REASON
1	Automated	Below Ground	Biceberg Down	3	5	4	3	4	4	5	28	1. Accessibility: Retrieval time is 20s longer than Biceberg Bigloo. 2. Capacity: Offers moderate capacity. 3. ICC: All Biceberg products have the same ICC and the ICC is expected to be a lot higher than traditional bike parking technologies. 4. Security: All Biceberg products have similar security mechanisms. The unique identification can be stolen and used by others. 5. Spatial Impacts: Only the small user interface machine is located above ground. Majority of the facility is below ground, which maximizes the space above ground but may interfere with future construction projects. 6. Spatial Efficiency: On average, it can store 2.4 bikes/m2, which is higher than traditional bike parking technologies.
2	Automated	On Ground	Biceberg Bigloo	4	2	3	3	4	3	2	21	1. Accessibility: Retrieval time is 20s faster than other Biceberg models, but users can only retrieve their devices sequentially. 2. Capacity: Offers the least capacity. 3. ICC: All Biceberg products have the same ICC and the ICC is expected to be a lot higher than traditional bike parking technologies. 4. Security: All Biceberg products have similar security mechanisms. The unique identification can be stolen and used by others. 5. Spatial Impacts: Smaller footprint and height compared to Biceberg Up, but it still intereferes with above ground activities. 6. Spatial Efficiency: On average, it can store 0.6 bike/m2, which is lower than the other Biceberg products.
3	Automated	Above Ground	Biceberg Up	3	3	5	3	4	2	5	25	1. Accessibility: Retrieval time is 20s longer than Biceberg Bigloo. 2. Capacity: Offers the most capacity. 3. ICC: All Biceberg products have the same ICC and the ICC is expected to be a lot higher than traditional bike parking technologies. 4. Security: All Biceberg products have similar security mechanisms. The unique identification can be stolen and used by others. 5. Spatial Impacts: Higher footprint and height compared to Biceberg Bigloo, and it still intereferes with above ground activities. 6. Spatial Efficiency: On average, it can store 2.4 bikes/m2, which is higher than traditional bike parking technologies.

AB2 – Compartment

Source: Oonee, n.d.

Product: Oonee Mini

Parking Type: Long-Term

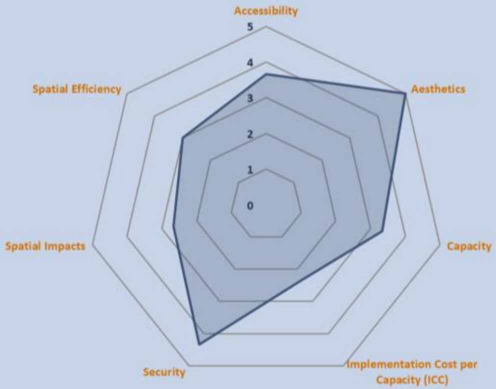
Accessibility: No lifting required, on-demand systems may affect reliability of available capacity, may not be suitable for cargo bikes or bikes with large accessories due to compact form, horizontal bike racks may not be suitable for micromobility devices, app / phone reliant, restricted access

Security: Security of access depends on the security protocols of the app, fully concealed design may deter theft, slight risk of theft by other users of same module

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Item	Standard Model	Wide Model
Capacity	8 bikes	
Implement Cost	[$$$]	[$$$]
ICC	[$$$]	[$$$]
Spatial Impacts	8.5 m^2 (L x W) x 1.8 m (H)	10.4 m^2 (L x W) x 1.8 m (H)
Spatial Efficiency	1.0 bike/m^2	0.8 bike/m^2

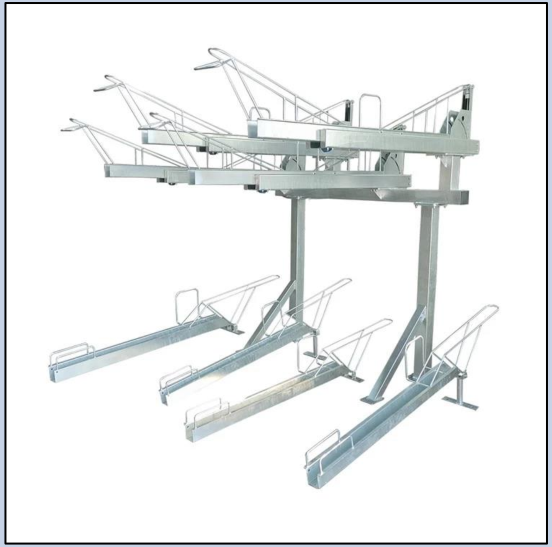
Score:



AB3 – Rack

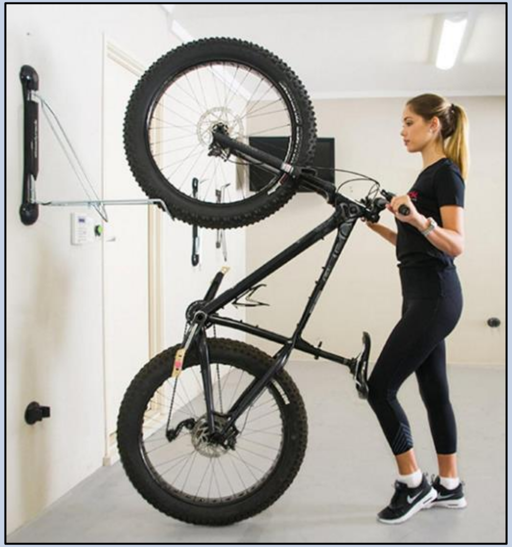
Commonly Used Racks in Walk-in Parking Facilities:

1. Two-Tier Rack



Source: China Bike Rack Manufacturer, n.d.

2. Vertical Rack



Source: Elite Garage Floors, n.d.

3. Semi-Vertical Rack

Source: Made-in-China, n.d.

AB4 – Walk-in Parking (1)

Source: Oonee, n.d.

Product: Oonee Lite

Parking Type: Long-Term

Accessibility: No strenuous lifting required, on-demand systems may affect reliability of available capacity, may not be suitable for cargo bikes or bikes with large accessories, vertical bike racks may not be suitable for micromobility devices, app / phone reliant, restricted access

Security: Strong structural materials, security of access depends on the security protocols of the app, slight risk of theft by other users of same facility

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Item	Standard Model	Expandable Model
Capacity	16 bikes	24 bikes
Implement Cost	[$$$]	[$$$]
ICC	[$$$]	[$$$]
Spatial Impacts	17.1 m² (L x W) x 3.1 m (H)	20.8 m² (L x W) x 3.1 m (H)
Spatial Efficiency	0.9 bikes/m²	1.2 bikes/m²

Score:

AB4 – Walk-in Parking (2)

Source: The Verge, n.d.

Product: Underwater Bike Parking Garage (Amsterdam, Netherlands)

Parking Type: Long-Term

Accessibility: Two-tier bike racks include slide-out trays for top level storage but may still pose issues for users with certain physical limitations, two-tier bike racks may not be suitable for micromobility devices, no designated area for cargo bikes, highly affordable, takes more time to store and retrieve bikes

Security: Sealed room, key fob access, 24-hour video surveillance, slight risk of theft by other users of the same facility but mitigated by compatibility with user-provided personal security devices (wheel locking only) as well as a reimbursement program for stolen bikes.

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Capacity	7,000 bikes
Implementation Cost	$88 million CAD
ICC	$12,575 CAD/bike space
Spatial Impacts	7,350 m^2 (Floor Space)
Spatial Efficiency	1.0 bike/m^2

Score: Not Applicable

AB5 – Other (1)

Product: metroSTOR BIKE-E

Parking Type: Long-Term

Accessibility: Only e-bikes can be accommodated, no lifting required, key security option may pose issues for users with physical limitations, the security loop on the storage tray is located at the front, making it easier for users to lock the wheels of their e-bikes to the tray

Security: Good security due to its full enclosure and traditional door security system, it may be more susceptible to break-ins if it is partially concealed, slight risk of theft by other users of the same locker

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Capacity	3 e-bikes
Implementation Cost	$8,110 CAD
ICC	$2,700 CAD/e-bike space
Spatial Impacts	5.6 m² (L x W) x 1.5 m (H)
Spatial Efficiency	0.5 e-bike/m²

Score: Not Applicable

AB5 – Other (2)

Source: Bikeep, n.d.

Product: Bikeep Personal e-scooter Locking Station

Parking Type: Short-Term

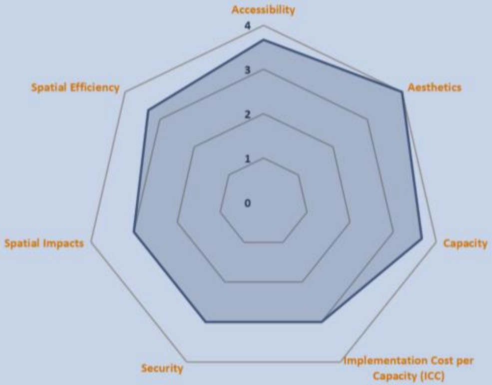
Accessibility: Bikeep mobile app informs users of real-time dock availability, docks can accommodate e-scooters with a frame diameter of up to 75 mm, no lifting required, app / phone reliant, restricted access, typically placed at locations for convenient user access

Security: e-scooters are exposed to the public and are susceptible to theft & the integrated locking bar does not require personal security devices

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Capacity	5 e-scooters
Implementation Cost	[$$]
ICC	[$$]
Spatial Impacts	5.8 m^2 (L x W) x 1.1 m (H)
Spatial Efficiency	0.9 e-scooter/m^2

Score:



AB5 – Other (3)

Source: metroSTOR, n.d.

Product: metroSTOR PSL

Parking Type: Long-Term

Accessibility: Only mobility scooters can be accommodated, no lifting required, door opening may pose issues for users with physical limitations, roof detachment takes time leading to longer storage and retrieval times

Security: Good security due to its full enclosure and traditional door security system options (key, passcode, or RFID), may be more susceptible to break-ins if it is partially concealed, no risks of theft by other users

Capacity, Cost, Spatial Impacts, & Spatial Efficiency:

Capacity	1 mobility scooter
Implementation Cost	$5,750 CAD
ICC	$5,750 CAD/mobility scooter space
Spatial Impacts	2.4 m² (L x W) x 1.2 m (H)
Spatial Efficiency	0.4 e-scooter/m²

Score:

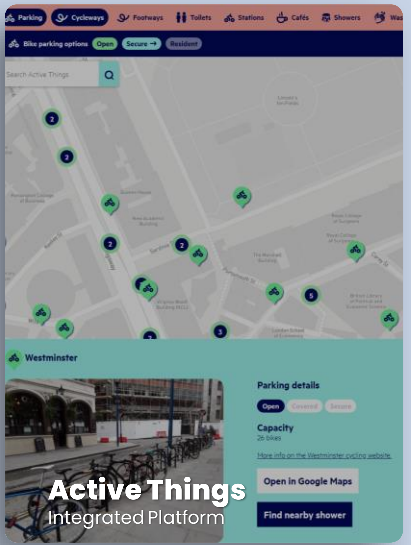
AB6 – Non-Physical Technology Example

Active Things

Active Things is a type of interactive map that provide cyclists with valuable information about the location, availability, & features of bike parking facilities. It is accessible through websites or mobile apps & offer a user-friendly interface for finding & selecting bike parking & route options.

Features

- Provide information on the capacity & type of parking (sheltered & unsheltered)
- Provides picture of the facility
- Linked to Google Maps



Source: Active Things, n.d.