RESPONSE TO REVIEWER COMMENTS

We would like to thank the editor and three reviewers for their constructive comments.

In broad terms, the reviewers were in consensus that the paper has a clear scope which aligns with the journal and special issue. We have made the following revisions: i) revised and reorganized the introduction and sharpened the framing of the paper; ii) clarified the methodology and analysis; and iii) emphasized the methodological contributions and policy implications of the findings. In what follows, we respond to the reviewers in turn and describe how the paper was revised (our responses are in blue).

The suggestions from the reviewers helped to improve our manuscript, and we believe it is a stronger paper as a result. For ease of rereading, we have highlighted all substantive changes in the resubmission in yellow.

Reviewer #1: This study examines the equity dimension of the bikeshare system in Hamilton, Ontario. The main contribution of this paper, claimed by the authors, is the application of a balanced floating catchment area approach. Another interesting point may be that the case study system included an equity initiative. This is certainly a relevant topic, and it fits the scope of this special issue. However, there are some significant drawbacks that the authors must address.

1. The major contribution lies in the application of a balanced floating catchment area approach. This approach is NOT original per se, but borrowed from the health equity literature. However, I could not see the benefits of this method after going through the paper. Particularly, there are many accessibility models in the transportation literature. At least a quantitative comparative analysis is needed to persuade me.

The benefits of using the BFCA approach have been further emphasized in the *Literature Review* (page 6-7), *Methods* (page 10 & 12), and *Discussion* (page 29). You are right that the method is not original, but it is sufficiently new that its advantages are still not widely known. Briefly, other common accessibility models in the transportation literature are suitable for capturing the potential for reaching destinations from a given location. Two stage floating catchment area (2SFCA) methods introduce an element of congestion into accessibility calculations. However, these methods are biased due to multiple counting. Balanced Floating Catchment Areas allocate population and level of service proportionally, thus preserving both quantities.

In the revised paper, we have conducted a comparative analysis demonstrating the inflation/deflection effect of multiple counting in conventional 2SFCA. We do this only for the threshold of five minutes – see pages 20-22 – to show the bias incurred when employing the 2SFCA method.

2. This leads to my second comment. Since the paper does not contribute to a new method, the emphasis should then be on the policy implications. However, I could not see much new insights from the current analysis. There are some discussions in Section 6, but I think they could be improved.

Thank you for this comment. We have improved the *Discussion* to highlight the policy implications of the analysis. See pages 30-33.

3. If you use disaggregated data for accessibility modeling, why do you aggregate them for equity analysis? The literature you cited (e.g., Chen et al., 2019) shows that aggregating individual data to zonal levels would lead to biased equity analysis results. There are approaches to disaggregate zonal data using socioeconomic attributes (income in this case) as control variables. This way, you would be able to analyze equity with disaggregated data as well.

The data are not aggregated for accessibility modeling, rather the median household income of the corresponding dissemination area was imputed to the micro-zone. Once accessibility has been calculated it is added for each income group; incidentally, this is another advantage of the BFCA method: since the population and level of service are preserved, we can reliably calculate how much accessibility is produced for the system and for *whom*.

4. The distance threshold seems to be an important factor, but I could not see how it is used in the accessibility modeling. This prevents me from understanding the results. For example, why as the walking distance threshold increases, the accessibility decreases? Why are there no differences between the with equity stations and without equity stations scenarios in figures 6-8 but in figures 9 - 12?

The distance threshold is used as an estimate of how far individuals are willing to walk to a bike share station. See equation (1). There is an interesting effect in play here: when the threshold is small very few people are assumed to be able to reach the stations; since there is little competition for the resource, accessibility is high but for very few people. As the threshold increases, more people are assumed to be able to reach the stations, which means that competition for limited resources increases and as a result accessibility decreases while still being greater than zero for more people. We found that accessibility calculated using the BFCA approach increases with a threshold between two and four minutes, but is then maximized at five minutes. As walking distance threshold increases, accessibility decreases because more people can reach each station which leads to congestion and higher potential demand.

We have improved the plots to better show the differences between the system with equity stations and the system without, which are very small.

As an aside, the code and data are publicly available, so all calculations are transparent.

5. The literature review is very comprehensive but loosely organized by jumping from one topic to another. Please reorganize it to emphasize on what the research gaps are.

The *Literature Review* has been reorganized and now includes subheadings to differentiate between the topics that are covered in this section. The research gaps are also emphasized.

Minor:

6. In the highlights, you use terms, e.g., "PBSP", "equity stations", as everybody knows about what they are. You also use "equity stations" in the paper too way before it is defined.

The highlights have been revised, and we now define equity stations in the *Introduction*.

Also, what are horizontal and vertical accessibility?

These concepts have been defined on page 5.

7. Page 15, lines 21 and 26, these two equations look the same to me.

Equations (2) and (3) are different due to the exponent on the w.

8. Page 16, the authors say that "we employ a hybrid location-based and person-based approach to calculating accessibility using disaggregated population data". I do not understand.

We have removed this from the manuscript as it was confusing.

9. Section 4.2 does not offer enough information to understand how the data is disaggregated. I could not see how well the disaggregated population fit the original population distribution. Maybe some summary statistics should be provided.

The disaggregated population perfectly fits the original population distribution; this is a property of the pycnophylactic approach employed. Please see:

Tobler, W. R. (1979). Smooth Pycnophylactic Interpolation for Geographical Regions. Journal of the American Statistical Association, 74(367), 519-530.

10. The accessibility scale in figures 6-8 should be unified to allow for a comparison.

As mentioned above, the estimated levels of accessibility change with the chosen thresholds. Our objective is to compare between the conventional system and the system with equity stations. Using a uniform accessibility scale is not very informative and confounds this comparison.

11. The use of bivariate choropleth maps could be confusing.

Bivariate choropleth maps are a standard way of displaying two variables. We have tuned the colour scale which gives more contrast between the various combinations hopefully making things clearer.

Reviewer #2: This is a well-written paper using appropriate methods to address an important question that is a good fit for Transportation Research Part D. I commend the authors on a job well done. I have only a few minor comments and suggestions:

Thank you for your generous assessment of our paper and suggestions for improvements. These are much appreciated.

1) Pages 9-10: The number of stations in the system and when they were added is very confusing: Line 33 of Page 9 says there were initially 115, then line 18 of Page 10 says that 13 equity stations were added, then line 40 of Page 10 says there were 130 stations and line 48 says that 12 of the 130 are equity stations. Can you clarify?

The program launched in 2015 with an initial 115 stations. Since 2015, 3 more "conventional" stations were added. The program then launched an equity initiative in 2018 to add 12 equity stations. The total number of docking stations is now 130. Line 18 on page 19 was removed because it was confusing.

2) Throughout: The maps are evocative, but also hard to follow. A few suggestions here:

a. Can you provide a background layer that indicates where Lake Ontario is, etc?

Figure 1 has been revised. We have labelled Lake Ontario and included an inset map to indicate where Hamilton is located relative to other major cities in Southern Ontario.

b. In the first bunch of figures, the map including the equity stations are the top panel, then in the second bunch, they're the bottom panel. Can you be consistent about which is which?

Thanks for this suggestion. All of the figures now have the equity stations on the bottom panel.

c. Figure 5 is pretty uninformative because so few stations are within a 3 minute walk - can you either zoom into an area where there's meaningful variation or move the figure to an appendix and acknowledge that it's uninformative?

The figure was removed, and we have explained why it was uninformative the manuscript (see page 17).

d. The color palette for Figures 9-12 is not distinct enough - I had a hard time telling what was blue and what was green

The colour palette has been changed. We hope that this gives more contrast between the various combinations of accessibility and median total household income.

3) Page 20: The number of accessibility doesn't make sense - given 130 racks total, there's no way there are 25.2 racks per person the way I'd conventionally interpret that number. Can you clarify the interpretation of the accessibility metric using the FCA method?

According to our analysis using the BFCA method, this translates to a total level of service of 25.2 racks per person with a walking threshold of 15 minutes. This number is then allocated to the population to obtain their accessibility levels. In other words, the accessibility of any one location will be less than 25.2

racks per person, and the sum of all accessibility in the system will be exactly 25.2 racks per person. The preservation of the population and level of service across the system is the key advantage of the BFCA method.

4) Page 22: Numbers for accessibility within 15 minutes look wrong - I wouldn't expect there would be fewer racks per person for a longer walking distance

The numbers for accessibility within 15 minutes are correct. There are fewer racks per person for a higher threshold because the population that can reach the stations increases, thus increasing competition for the resource (i.e., leads to higher demand), which reduces the level of service and the accessibility.

Reviewer #3: This manuscript demonstrates a method for evaluating proximity to public bike share stations in Hamilton, Ontario. I recommend major revisions.

The literature review should be edited for clarity. It currently has multiple issues.

Consider using subheadings to better organize the material. It feels imbalanced that section 3 is split into so many different subsections while section 2 is not.

The literature review (section 2) has been reorganized and now includes subheadings to differentiate between the topics that are covered in this section.

The discussion of different types of equity beginning at the bottom of p. 4 is confusing. Beginning on l. 42, the authors introduce horizontal and vertical equity—both of which are referred to in terms of spatial distributions of stations but then the discussion of Qian and Jaller (2020) transitions to questions of use. These are not the same and should be properly differentiated (spatial distribution/access versus use/outcomes).

The definitions of these different types of equity have been clarified on page 5.

The Philadelphia study by Caspi and Noland (2019) showed fewer trips from low-income block groups, but is this definitive evidence of inequity?

This is a good point. Fewer trips may not be definitive evidence of inequity. However, Caspi and Noland note that specific efforts in Philadelphia to increase bike share trips from low-income block groups were not sufficient. This leaves the question as to whether their efforts were effective in addressing inequity, or whether there are other factors that can better explain fewer trips.

Section 3.5 should be folded into the literature review and used to motivate the piece. Also review section 4.1 and pull relevant literature review into section 2. The methods and data section should not include novel discussion of the literature. If your contribution is methodological, the reader should know this once they have completed reading the literature review.

Thank you for this suggestion. We have made these changes in the manuscript.

The way that accessibility is employed in this paper—as access to a bike share facility—is different from how it is commonly conceptualized in the academic literature. The literature typically examines access to opportunities by linking travel impedance with some notion of a destination's desirability (e.g., total jobs, presence of a grocery store, etc.). Here, the metric you propose is capturing proximity to infrastructure. This is an important distinction to make, as completing a fuller accessibility assessment would require data on cycling infrastructure that is likely to be difficult to obtain and parse.

Thank you for the opportunity to clarify this point.

Bike share stations can be considered as destinations since they offer a service. If a person wants to use the bike share program, they need to access a station. The maximum quantity of bicycle racks at each station (e.g., potential supply) reflects the destination's desirability. For instance, a bike share user would be more likely to travel to a station where they have a reasonably high chance of getting a bicycle (i.e., represented by the total number of bicycle racks) instead of travelling to a station with few racks

where their chances of getting a bicycle are smaller. The travel impedance is the walking times to bike share stations.

See section 2.3 for this clarification.

Figure 1 is not helpful – latitude/longitude are not needed on the x and y axes. (Figure 4 redundantly labels the X and Y axes as well.) Provide an inset map showing the broader context, a scale bar, and north arrow. You might consider adding other contextual features—major roads, surrounding cities, etc. These comments apply to all of the map-based figures in the manuscript.

Figure 1 has been revised as per your suggestion. We have also labelled Lake Ontario and included an inset map to indicate where Hamilton is located relative to other major cities in Southern Ontario. The rest of the figures also feature a scale bar and north arrow. Adding major roads and surrounding cities to all of the figures made them look too busy.

Figure 2 should show the blue/green meaning in the legend. Overlapping circles and very subtle differences in size make the figure hard to interpret.

The legend on Figure 2 has been revised.

Figure 3 and 4 and Table 1 are not necessary and should be omitted or moved to supplementary material. If needed, population density could be included in Figure 2.

We added population density to Figure 2, but the resultant figure was too busy. As a compromise, we have omitted Figure 3 but kept Figure 4. Table 1 has been moved to supplementary material.

Figures 5-8 would be easier to interpret if a discrete, rather than continuous, scale was used. Think through whether a quantile plot, natural breaks, or some other discrete categorization scheme would be more appropriate for elucidating differences in accessibility. A map that shows differences between the two scenarios would be more illuminating than the current map where changes are almost impossible to discern. Why do the units of accessibility shift so dramatically in magnitude and can the units be labeled?

The accessibility units are racks/person. The units change so dramatically because of congestion. At smaller walking thresholds, so few people can access the stations which means that there is less crowding or competition. As walking thresholds increase, more people can access the stations which increases demand and congestion.

As a reminder, the code and data are open, so the reviewer is welcome to verify the calculations.

Figures 9-12 are very difficult to interpret. Further, they do not give a sense of how many people experience each accessibility level. Table 2 contains much more information than the figures and should be retained while the figures could be moved to supplementary material. This income-based analysis raises questions about that presented in section 5.1. Exactly how does that analysis and its results provide equity-related insights?

These figures tell us the level of accessibility by level of total median household income, and reveal the spatial differences in accessibility and income. The table tells us how many people by each income level

can access a bike share station at a certain walking threshold and what the levels of accessibility are. The figures reveal that inequities persisted as evidenced by differences in accessibility according to income quintile. We have used the log distribution for colour scale to enhance the differences in the figures.

See page 30-33 for specific policy and planning implications based on the findings.

The discussion at the bottom of p. 31 and top of p. 32 is confusing. These are not recommendations that come from your study and it's not clear how the "gaps in coverage" relate to the findings you present.

The figures indicate areas in Hamilton where accessibility levels are low for groups with low total median household income. These "gaps in coverage" have been revealed by the BFCA method, which takes demand and supply into account unlike other accessibility models. The "gaps in coverage" are potential locations for future equity stations.

Overall, the paper feels too long. Streamlining the analysis and exposition should allow you to cut 1-2 thousand words.

After making all revisions requested by the reviewers, the manuscript is 1 page shorter than the original submission.

Minor comments

= Horizontal equity is not served merely by "growing the population served irrespective of the walking threshold" (p. 29, l. 23). Rather, it requires equalizing accessibility across groups considered equal in ability or need. If you define the entire population as a group, then horizontal equity quickly loses meaning because we would need to provide service/racks where demand would be very low in order to achieve it. Reconsider whether horizontal equity is an appropriate concept for use in this context.

We have significantly revised the *Discussion* section and clarified this part of the manuscript.

= The idea of "absorption of disparities" has been articulated elsewhere in the transportation/EJ literature (e.g., Forkenbrock & Sheeley, 2004; Rowangould et al., 2016).

We have included these references in the manuscript.

= Using the word "recent" to describe prior work will quickly date the paper. Use different terms. This is an issue at a number of locations in the paper. For example, on p. 7, ll. 35-39 the word "recent" is used to refer to a 15-year-old publication.

"Recent" has been removed from that sentence.

= All equations should be numbered and referred to explicitly.

Equations are now numbered.

= p. 6, l. 55: Use a more neutral phrase instead of “able-bodied.” See https://ncdj.org/style-guide/.

We have now used the phrase “an adult who does not have a disability”.

= p. 19, l. 13: I think you mean “network travel times” instead of “of travel times.”

We have corrected this in the manuscript.

References

Forkenbrock, D. J., & Sheeley, J. (2004). Effective Methods for Environmental Justice Assessment. National Cooperative Highway Research Program.

Rowangould, D., Karner, A., & London, J. (2016). Identifying environmental justice communities for transportation analysis. Transportation Research Part A: Policy and Practice, 88, 151–162.