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Posted Date: 14 February 2024

doi: 10.20944/preprints202402.0819.v1

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Residents' Travel Choice under Public Health Events and the Optimal Strategies of the Travel Environment for Active Mobility: A Case Study of Harbin, China

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Abstract: During public health events, Active Mobility (walking and cycling) plays an important role in securing residents' travel. To enhance the resilience of urban transportation, this article integrates the travel environment elements for walking and cycling and constructs a travel environment for Active Mobility evaluation index system. This article uses survey data from the main urban area of Harbin in the context of the COVID-19 pandemic in May 2022, and combines the Gradient Boosting Decision Tree (GBDT) and Impact-Asymmetry Analysis (IAA) methods to analyze the satisfaction of the travel environment for Active Mobility. It proposes strategies for optimizing the travel environment for Active Mobility, ensuring residents' travel during public health events, guiding them to adopt Active Mobility, and improving urban transportation resilience. This research shows that Active Mobility can enhance urban transportation resilience. In addition, there are differences in resident demand for walking and cycling environments in the travel environment for Active Mobility. Residents are more concerned about the comfort of the walking environment, while they prioritize the convenience of the cycling environment.

Keywords: Active Mobility; travel environment; satisfaction; gradient boosting decision trees; impact-asymmetry analysis

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1. Introduction

During public health events, public transportation has the highest risk of infection among all modes of transportation [1]. As a result, Active Mobility (AM) of walking and cycling has become the primary choice during public health events [2]. In this regard, the author conducted a survey on the preferred modes of transportation for residents in the main urban area of Harbin during the COVID-19 outbreak. The survey data indicates that the proportion of residents choosing walking is the highest at 25.45%, followed by private car usage at 24.98%, and then cycling (including shared bikes, electric bikes, and private bicycles) at 22.96%. The subsequent proportions, from highest to lowest, are subway at 7.78%, taxis at 7.78%, buses at 7.47%, and other modes of transportation at 3.58%. It is evident that during the pandemic, people primarily choose walking, private cars, and cycling. Both walking and cycling align with the low-carbon urban transportation development strategy, with the combined proportion of Active Mobility of walking and cycling exceeding 48%, which is far higher than public transportation, taxis, and subways. It can be seen that Active Mobility is an important component of urban transportation resilience [3], especially during public health events where the travel environment for Active Mobility is an important space for urban transportation resilience [4].

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Therefore, we need to optimize the travel environment for Active Mobility to enhance urban transportation resilience.

2. Literature Review

In 2020, Li Yuan et al. used an ordered Probit model to analyze questionnaire survey data on pedestrian environment satisfaction, and identified sidewalk connectivity and comfort as important factors influencing residents' perceptions [5]. In 2021, Xu Jun et al. used a Structural Equation Model (SEM) to analyze the relationship between cyclists' satisfaction and various influencing factors, and found that ensuring the safety of cycling was the most important factor affecting cyclists' satisfaction [6]. In 2023, Han et al. used an asymmetric impact analysis method to explore residents' satisfaction with pedestrian environments in both new and old urban areas, and found that the aesthetics of pedestrian environments had a significant impact on overall satisfaction in both areas [7]. In 2023, Yang Linchuan used ordered Probit and gap models to analyze survey data on the satisfaction of elderly people with pedestrian environments, and identified the need for improvement in the availability of seating, pedestrian crossing facilities, and sidewalk width [8]. In 2023, Nikiforiadis et al. analyzed the perceived service quality of infrastructure for pedestrians and cyclists in the city of Thessaloniki, Greece, using a Structural Equation Model (SEM), and found that road surface quality was crucial for both pedestrians and cyclists [9].

In 2016, Zhu Wei et al. utilized a Generalized Mixed Logit Model to analyze the influence of cycling environment on cyclists' route choice. They found that cyclists prioritize safety over comfort when considering the cycling environment [10]. In 2018, Cao Zhejing et al. obtained geographic spatial data of the central urban area of Tianjin, China, and conducted household surveys to gather residents' travel data. They used the Pearson correlation coefficient to analyze the relationship between walking/cycling environment and residents' travel behavior. They found that a good street walking environment encourages residents to choose walking as a mode of transportation [11]. In 2022, Chen Wenqiang et al. conducted a Revealed Preference (RP) survey to collect data on independent travel choices and influencing factors. They utilized a Lasso-logistic regression model to analyze significant indicators affecting mode choice. They found that factors such as travel distance, dedicated bicycle lanes, and cycling skills significantly influence the choice of cycling, while factors such as air quality, traffic conditions, and familiarity with roads significantly influence the choice of walking [12]. In 2023, Zhu Jing et al. used the Daynamica software to collect residents' data on independent travel and street spatial data near residential areas. They employed a binary logistic regression model to analyze the influence of the travel environment for Active Mobility of residential streets on residents' travel behavior. They found that a more comprehensive provision of public service facilities, higher levels of greenery, and better street connectivity increase the adoption rate of Active Mobility among residents [13].

In summary, previous research on the optimization of the travel environment for Active Mobility has mainly focused on resident satisfaction and travel choices, using various methods to independently analyze the walking and cycling environments of Active Mobility, or analyzing their commonalities after merging walking and cycling. However, there has been relatively less analysis of walking and cycling environments from an overall perspective of Active Mobility. In this regard, this paper integrates the commonalities and characteristics of walking and cycling aspects of Active Mobility, constructs an evaluation index system for the travel environment for Active Mobility, and utilizes Impact-Asymmetry Analysis (IAA) methods combined with the Gradient Boosting Decision Tree (GBDT) to explore the asymmetric relationship between the travel environment elements for Active Mobility and resident satisfaction. This aims to identify the priorities for improvement of the travel environment elements for Active Mobility, to increase the level of satisfaction of residents with the travel environment for Active Mobility and to guide them towards the adoption of Active Mobility.

3. Data and Methods

3.1. Indicator System Construction and Questionnaire Survey

3.1.1. A Three-Tier Indicator System of the Travel Environment for Active Mobility

The study integrated the elements of the travel environment for Active Mobility from both walking and cycling perspectives and constructed an evaluation index system of the travel environment for Active Mobility. The construction of the evaluation system was mainly based on the Chinese national standard "Standard for urban pedestrian and bicycle transport system planning" (GB/T 51439-2021) [14], with the principles of safety, convenience, and comfort in mind. Therefore, the three aspects of safety, convenience and comfort of cycling paths are used as the first-level indicators in the evaluation index system of the travel environment for Active Mobility (Table 1).

Table 1. Evaluation index system of the travel environment for Active Mobility.

First Level Indicator	Secondary Indicators	Tertiary Indicators
Safety	Road facilities	Separation facilities for walking and cycling
		Anti-skid surfaces for walking and cycling
		Night lighting of sidewalks
		Barrier-free facilities when walking
	Crowd behavior	Motor vehicle speed
		Non-motorized interference with walking
		Buses occupying cycling lanes while parked
	Social security	Safety hazards when walking
		Feeling safe walking at night
	Vehicle safety	Quality of shared bike bodies
Convenience	Pedestrian network	Alternative routes available
		Convenience of walking across the street
	Accessibility	Walking distance to parks and squares
		Walking distance to bus stops
		Walking distance to convenient service facilities
	Bicycle parking	Convenience of parking spots in the neighborhood
		Parking at public places
		Parking at metro stations and bus stops
		Bicycle maintenance points
		Quantity of shared bicycles
	connectivity	Coherence of cycling paths
		Completeness of cycling road network

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Table 1. Cont.

First Level Indicator	Secondary Indicators	Tertiary Indicators
Comfort	Pavement condition	Path width for walking and cycling
		Timeliness of snow removal on walking and cycling paths
		Encroachment on walking and cycling paths.
		Waterlogging on sidewalks
		Street facilities of sidewalks
		Green light passing time when walking
		The flatness of cycling road surface
		Bicycle-related facilities at intersections
		Color of cycling road surface
	Environmental pollution	Noise while walking and cycling
		Cleanliness of sidewalks
		Odor while walking
		Air pollution while riding
	Road greening	Shade from street trees
	Aesthetics	Building facade
		Landscaping on sidewalks
		Pedestrian behavior
		Recreational activities of residents

3.1.2. Questionnaire Design and Distribution

The questionnaire is divided into two parts: walking environment and cycling environment. Satisfaction with the elements is measured using the Likert 7-point scale, with a score range of 1-7. A score of 1 indicates "very dissatisfied" and 7 indicates "very satisfied." The survey was a questionnaire survey of walking and cycling groups in Harbin City, Heilongjiang Province, in the northeast of China. The survey covers 7 main urban areas of Harbin, including Qunli New District, Haxi New District, Jiangbei District, Nangang District, Daoli District, Daowai District, and Xiangfang District. The survey questionnaire was pre-tested with pedestrians and cyclists, and revisions were made based on their feedback. The questionnaire was then randomly distributed online during the COVID-19 pandemic in May 2022. A total of 1679 questionnaires were distributed, and 1631 valid responses were collected, resulting in an effective response rate of 97.14%. Among these, 896 valid questionnaires were collected for the walking satisfaction survey, and 735 were collected for the cycling satisfaction survey.

3.1.3. Questionnaire Reliability and Validity Tests

To verify the rationality and accuracy of the questionnaire and data, this study conducted reliability and validity analyses on the walking and cycling questionnaires separately using SPSS 26.0. The reliability and validity of both questionnaires were above 0.94 (Table 2). The high reliability and validity of the questionnaires indicate that the content design of the questionnaire is reasonable and the data is reliable. Therefore, the questionnaire data can be further analyzed.

Table 2. Questionnaire Reliability and Validity Test.

	Reliability	Validity
walking	0.949	0.964
cycling	0.965	0.976

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3.2. Research Method

This study employs the method of Impact-Asymmetry Analysis (IAA), which is based on the Three-Factor Theory [15]. According to the Three-Factor Theory, factors can be categorized into three types: basic factor, performance factor and exciting factor [16]. The impact of the basic factor and exciting factor on overall satisfaction is nonlinear, while the impact of the performance factor is linear [17]. The Three-Factor Theory suggests that underperforming basic factors should be prioritized for improvement [18]. However, the Three-Factor Theory overlooks the degree of influence of service factors on overall satisfaction. Mikulic and Prebezac optimized this issue by dividing the degree of influence into three categories: low, medium, and high. They proposed the Impact-Asymmetry Analysis (IAA) and argued that if the impact of underperforming performance factors on overall satisfaction is higher than the impact of underperforming basic factors, the improvement sequence should prioritize those performance factors over basic factors [19]. Additionally, IAA further subdivides the three types of factors in the Three-Factor Theory into five categories (Figure 1).

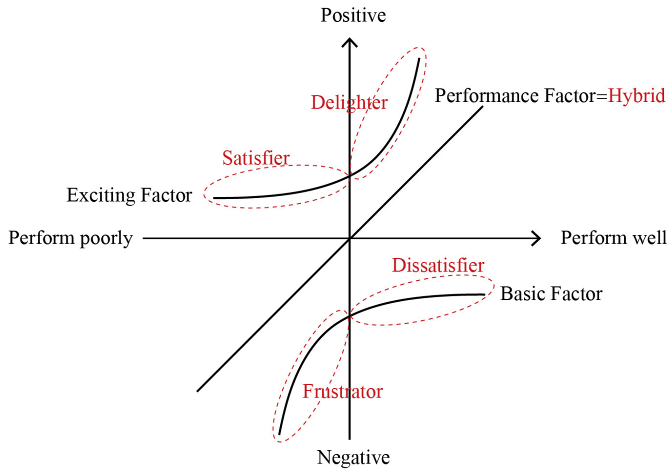

Figure 1. Impact-asymmetric analysis based on three-factor theory.

To conduct Impact-Asymmetry Analysis (IAA), each satisfaction score of service factors needs to be recoded into two groups of dummy variables, and then a Gradient Boosting Decision Tree (GBDT) model is applied for regression analysis. The purpose is to iteratively correct prediction errors multiple times until the loss function reaches the minimum value or remains stable, resulting in a final prediction that is closer to the true value [20]. Additionally, the GBDT method is more reliable for predicting small sample sizes [21]. Based on the regression analysis results for the Reward Index (RI) and Punishment Index (PI), the Range of the Impact on Overall Satisfaction (RIOS) and the Impact-Asymmetry Index (IA index) of service elements can be calculated using the following formulas:

RIOS (Range of the Impact on Overall Satisfaction) = RI + PI;

SGP (Satisfaction-Generating Potential) = RI/RIOS;

DGP (Dissatisfaction-Generating Potential) = PI/RIOS;

IA index (Impact-Asymmetry index) = SGP-DGP.

Using RIOS as the x-axis and IA index as the y-axis, we obtain the IAA grid (Figure 2).

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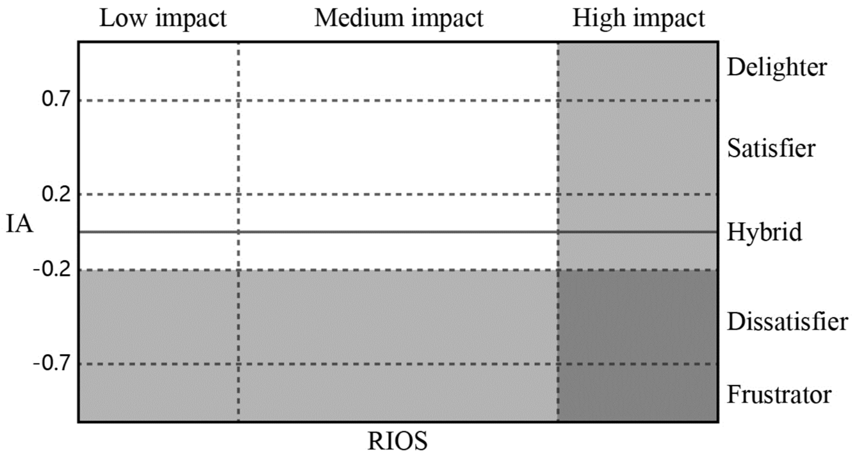

Figure 2. IAA Grid Diagram.

Based on the method of Impact-Asymmetry Analysis, this study integrates two sets of data for walking and cycling and obtains the overall average, maximum, and minimum values of RIOS for travel environmental factors of Active Mobility. Then divide the impact range into high, medium, and low categories according to the following formula:

(1) High impact range: RIOS > (RIOS [average value] + RIOS [maximum value]) /2
(2) Medium impact range: (RIOS [average value] + RIOS [minimum value])/2 ⩽ RIOS ⩽ (RIOS [average value] + RIOS [maximum value])/2
(3) Low impact range: RIOS< (RIOS [average Value] + RIOS [minimum Value])/2

4. Discussion

4.1. Classification of elements

This study employed SPSS 26.0 to conduct a normal distribution analysis of overall satisfaction with walking environments and cycling environments. The results showed that the mean satisfaction scores for both walking environments and cycling environments were 4.37, which falls between 4 and 5. Therefore, satisfaction scores of 4 and 5 were selected as reference variables. Subsequently, the satisfaction scores for 27 walking environment factors and 19 cycling environment factors were re-coded into three values: -1 (representing low performance, including scores 1, 2, and 3), 0 (representing the reference variable, scores 4 and 5), and 1 (representing high performance, including scores 6 and 7) (Figure 3).

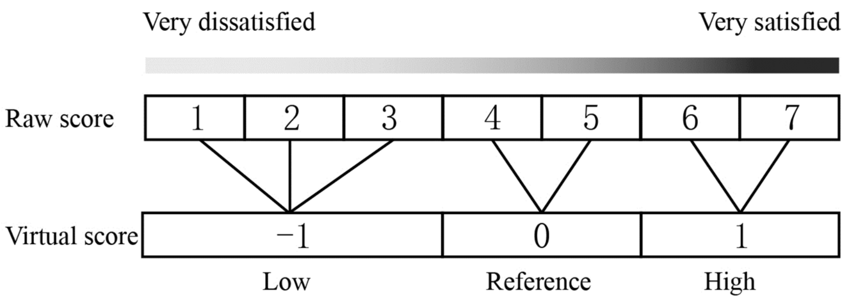

Figure 3. Illustrates the variable transformation diagram.

GBDT models were constructed for walking environments and cycling environments separately using Studio. To improve the accuracy of the models, the walking environment went through 3,581 optimal iterations with a cross-validation error of 0.78, while the cycling environment went through 3,296 optimal iterations with a cross-validation error of 0.85. Then calculate the relative impact values of the 27 and 19 independent variables of satisfaction on their respective overall satisfaction for walking environments and cycling environments. Select 11 elements for walking environments

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(Table 3) and 11 elements for cycling environments (Table 4) with relative impact values of 2% or more for a comparative analysis of rewards and penalties, resulting in low performance (possd), neutral (possn), and high performance (posss).

Table 3. Relative Impact Values of Walking Environment Elements.

Walking Environment Elements	Relative impact value (%)	Relative Impact Value Ranking	POSSD(-1)	POSSN (0)	POSSS (1)
Pedestrian behavior	15.24	1	4.04	4.45	4.87
Landscaping on sidewalks	14.13	2	4.03	4.45	4.79
Building facade	12.02	3	4.07	4.34	4.77
Cleanliness of sidewalks	8.61	4	4.08	4.40	4.58
Street facilities of sidewalks	5.08	5	4.18	4.47	4.49
Safety hazards when walking	4.32	6	4.23	4.41	4.51
Night lighting of sidewalks	3.41	7	4.27	4.37	4.48
Anti-skid surfaces for walking	3.02	8	4.27	4.38	4.52
Barrier-free facilities when walking	2.57	9	4.28	4.39	4.50
Motor vehicle speed	2.50	10	4.28	4.37	4.49
Odor while walking	2.31	11	4.28	4.38	4.48

Table 4. Relative Impact Values for Cycling Environmental Elements.

Cycling Environmental Elements	Relative impact value (%)	Relative Impact Value Ranking	POSSD (-1)	POSSN (0)	POSSS (1)
Completeness of cycling road network	14.33	1	4.07	4.63	4.73
Parking at metro stations and bus stops	12.32	2	4.23	4.33	4.87
Parking at public places	9.59	3	4.29	4.38	4.79
Bicycle-related facilities at intersections	9.25	4	4.24	4.55	4.68
Coherence of cycling paths	8.99	5	4.22	4.52	4.67
Color of cycling road surface	6.78	6	4.28	4.44	4.75
Bicycle maintenance points	6.66	7	4.23	4.53	4.65
Separation facilities for cycling	4.43	8	4.36	4.44	4.61
Quantity of shared bicycles	4.08	9	4.25	4.40	4.88
The flatness of cycling road surface	3.06	10	4.34	4.51	4.62
Anti-skid surfaces for cycling	2.40	11	4.40	4.45	4.55

According to the formula: Reward Index (RI) = posss - possn; Punishment Index (PI) = possn - possd, calculate the Reward Index (RI) and Punishment Index (PI). Then, use the RI and PI values of each factor to calculate the RIOS and IA index. Based on the IA threshold definitions by Lee and Min, the elements are classified into five categories: delighter (IA≥0.7), satisfier (0.2≤IA<0.7), hybrid (-0.2<IA<0.2), dissatisfier (-0.7<IA≤-0.2) and frustrator (IA≤-0.7) [22]. As a result, we obtain the attributes of the travel environment for Active Mobility (Table 5).

Table 5. Attributes of the Travel Environment Elements for Active Mobility.

Travel Environment Elements for Active Mobility		SGP	DGP	RIOS	IA	Classification	Satisfaction Average
Walking Environment Elements	Pedestrian behavior	0.5	0.49	0.83	0.01	hybrid	3.82
	Landscaping on sidewalks	0.45	0.55	0.76	-0.1	hybrid	3.95
	Building facade	0.61	0.38	0.7	0.23	satisfier	4.28
	Cleanliness of sidewalks	0.35	0.65	0.5	-0.3	dissatisfier	4.47
	Street facilities of sidewalks	0.07	0.93	0.31	-0.86	frustrator	4.17
	Safety hazards when walking	0.34	0.66	0.27	-0.32	dissatisfier	4.43
	Night lighting of sidewalks	0.51	0.49	0.21	0.02	hybrid	4.65
	Anti-skid surfaces for walking	0.56	0.43	0.25	0.13	hybrid	4.08
	Barrier-free facilities when walking	0.46	0.53	0.22	-0.07	hybrid	3.91
	Motor vehicle speed	0.58	0.41	0.21	0.17	hybrid	4.15
	Odor while walking	0.48	0.52	0.19	-0.04	hybrid	4.24
Cycling Environment Elements	Completeness of cycling road network	0.14	0.85	0.66	-0.71	frustrator	4.18
	Parking at metro stations and bus stops	0.85	0.15	0.64	0.7	satisfier	4.5
	Parking at public places	0.83	0.16	0.5	0.67	satisfier	4.38
	Bicycle-related facilities at intersections	0.29	0.7	0.44	-0.41	dissatisfier	4.23
	Coherence of cycling paths	0.34	0.66	0.45	-0.32	dissatisfier	4.13
	Color of cycling road surface	0.67	0.32	0.46	0.35	satisfier	4.22
	Bicycle maintenance points	0.28	0.71	0.43	-0.43	dissatisfier	4.12

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Separation facilities for cycling	0.66	0.33	0.24	0.33	satisfier	4.21
Quantity of shared bicycles	0.76	0.23	0.63	0.53	satisfier	4.84
The flatness of cycling road surface	0.37	0.63	0.28	-0.26	dissatisfier	4.21
Anti-skid surfaces for cycling	0.64	0.36	0.14	0.28	satisfier	4.32

Note: The IA value for "Parking at metro stations and bus stops" is 0.69522 with two decimal places of 0.70.

4.2. Impact-Asymmetry Analysis

IAA comprehensively considers the attributes, impact range, and performance level of the service elements. Since both walking and biking datasets have an overall satisfaction average of 4.37, this study uses 4.37 as the criterion to determine whether the satisfaction of the elements meets the expectations of Active Mobility travelers, indicating the performance level of advantages and disadvantages.

As shown in Figure 4, there is a non-linear relationship between over 60% of the travel environment elements for Active Mobility and overall satisfaction. This indicates the rationality of conducting impact-asymmetry analysis on the travel environment for Active Mobility. In particular, completeness of cycling road network and street facilities of sidewalks are classified as frustrator, while bicycle maintenance points, bicycle-related facilities at intersections, coherence of cycling paths, cleanliness of sidewalks, safety hazards when walking and the flatness of cycling road surface are classified as dissatisfier. When frustrator and dissatisfier do not meet the expectations of Active Mobility travelers, it leads to their dissatisfaction. However, when frustrator and dissatisfier meet the expectations of Active Mobility travelers, their impact on overall satisfaction is limited. Satisfaction with cleanliness of sidewalks and safety hazards when walking is higher than the overall satisfaction and meets the expectations of Active Mobility travelers. Therefore, these two factors have limited potential to improve the overall satisfaction of the travel environment for Active Mobility, and thus do not require prioritized improvement. On the contrary, efforts should be directed towards improving the remaining six factors and ensuring that they meet the basic needs of Active Mobility travelers. Pedestrian behavior, landscaping on sidewalks, barrier-free facilities when walking, odor while walking, anti-skid surfaces for walking, motor vehicle speed and night lighting of sidewalks are classified as hybrid. Improvements to any hybrid will enhance overall satisfaction. However, once the expectations of Active Mobility travelers are met, the effect of further improvement on overall satisfaction will diminish. Therefore, to efficiently enhance the satisfaction of Active Mobility travelers, the hybrid of pedestrian behavior, landscaping on sidewalks, barrier-free facilities when walking, odor while walking, anti-skid surfaces for walking and motor vehicle speed should be improved to the level expected by Active Mobility travelers. However, night lighting of sidewalks is already performing well, and can be maintained without prioritizing further improvement. Parking at metro stations and bus stops, parking at public places and quantity of shared bicycles are satisfier and perform well, and they should continue to be maintained. This is because continued improvement is not a significant increase in overall satisfaction. Building facade, color of cycling road surface, anti-skid surfaces for cycling and separation facilities for cycling are satisfier and perform poorly. To significantly improve overall satisfaction, it is necessary to make improvements in these areas that go beyond the expectations of Active Mobility travelers. This can be done when there is sufficient funding available.

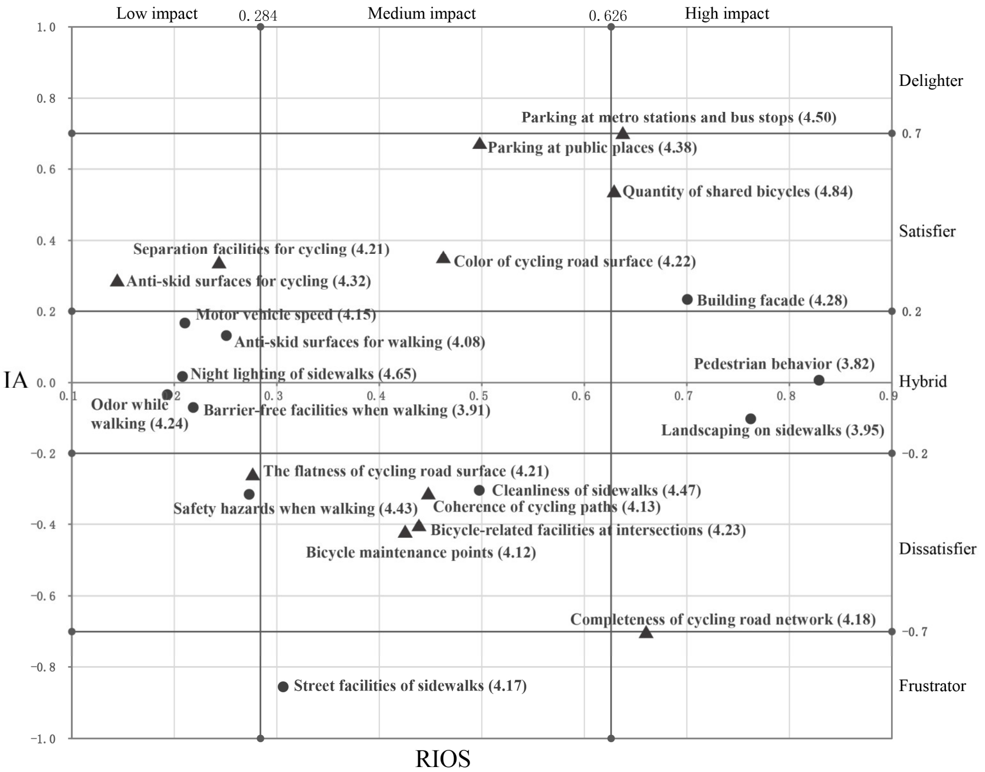

Figure 4. IAA Grid Map of the travel environment elements for Active Mobility. Note: The numbers in parentheses are the mean satisfaction values of the elements. ●: indicates the walking environment element. ▲: indicates the cycling environment element.

These asymmetric impacts also differ in the relative importance of the travel environment elements for Active Mobility. Frustrator and dissatisfier are the most important, and only when meeting the expectations of Active Mobility travelers can they be satisfied. Conversely, delighter and satisfier are of the least importance and will not lead to dissatisfaction among Active Mobility travelers if delighter and satisfier fail to meet their expectations. Frustrator represents the extreme manifestation of dissatisfier, so frustrator should be prioritized when other influencing factors are equal. Given this hierarchy of importance, the further down the IAA grid the more important the element is. The relative importance of the elements of the travel environment for Active Mobility is also related to their degree of influence. The higher the RIOS value, the greater the contribution to the overall satisfaction of the travel environment for Active Mobility. Therefore, the elements on the right side of the IAA grid are more important. Taking into account these two situations, the elements positioned further to the bottom right on the IAA grid are the most important. Therefore, the highest priority for improvement is completeness of cycling road network in the high impact range. On one hand, this is because there is a shortage of parking spaces for motor vehicles, leading to significant encroachment of motor vehicles on bicycle lanes. On the other hand, completeness of cycling road network is a prerequisite for smooth cycling experiences. The next in priority are pedestrian behavior and landscaping on sidewalks in the high impact range. Pedestrian behavior and landscaping on sidewalks are part of the aesthetics of the travel environment for Active Mobility, and people have a strong perception of the aesthetics of the environment. So it is reasonable that pedestrian behavior and landscaping on sidewalks are in the high impact range. The third priority is street facilities of sidewalks in the medium impact range. Bicycle maintenance points, bicycle-related facilities at intersections and coherence of cycling paths are in the same grid in the IAA grid, and their improvement is the fourth in priority. Then, the factors in the low impact range should be improved. The flatness of cycling road surface is the first to improve in the low impact range, followed by barrier-free facilities when walking, odor while walking, anti-skid surfaces for walking and motor

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vehicle speed (Table 6). It is worth noting that only anti-skid surfaces for walking need to be prioritized for improvement in terms of Anti-skid surfaces for walking and riding. Due to the cold winter in Harbin, residents rarely choose cycling as a means of transportation, so the demand for slip resistance on cycling paths is low.

Table 6. Prioritization of travel environment elemental improvements for Active Mobility.

Level of impact	Attributes	Elements	Improved prioritization
High Impact	frustrator	Completeness of cycling road network	1
	hybrid	Pedestrian behavior Landscaping on sidewalks	2
Medium impact	frustrator	Street facilities of sidewalks	3
	dissatisfier	Bicycle maintenance points Bicycle-related facilities at intersections Coherence of cycling paths	4
Low impact	dissatisfier	The flatness of cycling road surface	5
	hybrid	Barrier-free facilities when walking Odor while walking Anti-skid surfaces for walking Motor vehicle speed	6

5. Conclusions

This study investigates residents' travel choices and satisfaction with the travel environment for Active Mobility during public health events. It combines the Gradient Boosting Decision Tree (GBDT) and Impact-Asymmetry Analysis (IAA) methods to analyze the satisfaction with the travel environment for Active Mobility. By considering the attributes, impact range, and performance of the elements, it establishes the priority for improvement. This analysis aims to ensure residents' travel and enhance urban transportation resilience. The study found the following:

First, Active Mobility has played a crucial role in the mobility of Harbin residents during public health events, increasing the resilience of urban transportation. This is because the majority of residents' daily travel consists of short-distance trips of 5 kilometers or less. Specifically, residents' walking trips typically cover a distance of around 2 kilometers, while cycling trips span approximately 5 kilometers.

Second, there are differences in the demands of residents for the elements of walking and cycling environment in the travel environment for Active Mobility. This is due to the different travel speeds of walking and cycling, leading Active Mobility travelers to observe the walking and cycling environments with varying levels of detail. Because the slower pace of walking allows for a more thorough observation of the surrounding environment, residents are more concerned with the comfort of the walking environment. In this regard, aesthetic elements related to comfort should be improved, including pedestrian behavior and landscaping on sidewalks. On the other hand, the greater distance and faster speed of cycling compared to walking leads residents to focus more on the convenience of the cycling environment. Within convenience, connectivity-related elements should be the primary focus for improvement, including completeness of cycling road network and coherence of cycling paths.

Third, all the cycling environment elements have an asymmetric relationship with overall satisfaction. As the primary purposes of residents' cycling are exercise and commuting, once the demand for cycling environment elements is fulfilled, resident satisfaction significantly increases. Among these cycling environment elements, the ones that have a higher overall impact are those related to convenience, as convenience is the most fundamental element for cycling travel. However, the elements that exhibit a symmetrical relationship with overall satisfaction are all walking elements.

These elements are related to the safety and comfort of the walking environment. Since the primary purpose of walking is to stroll, the better the safety and comfort of the walking environment, the more satisfied residents are with it.

Due to the limitations of asymmetric impact analysis applications, there is no unified theoretical guidance for selecting the threshold to distinguish linear and nonlinear relationships in asymmetric impact analysis. Most related studies have adopted 0.2 and -0.2 as the threshold values for differentiation [22,23]. In addition, the scope of the study is limited to Harbin. Harbin is the provincial capital city with the lowest winter temperatures in China. Further research is needed to determine whether the findings apply to other cities. Nevertheless, this paper has constructed an evaluation index system of the travel environment for Active Mobility, providing a theoretical basis for optimizing the travel environment for Active Mobility.

Author Contributions: Conceptualization, D.F. and L.T.; methodology, D.F. and L.T.; validation, L.T. and Y.X.; formal analysis, L.T. and L.Z.; investigation, L.T., D.F., L.Z., Y.X., S.S., J.L. and X.W.; resources, D.F.; writing—original draft preparation, L.T.; writing—review and editing, L.T.; visualization, D.F.; supervision, D.F.; project administration, D.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The basic data are available from the first author upon request.

Acknowledgments: Many thanks to Xinyu Cao at the University of Minnesota for his methodology and guidance on the paper, and to the seniors who helped send out the questionnaires.

Conflicts of Interest: The authors declare no conflict of interest.

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 doi:10.20944/preprints202402.0819.v1

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