Revolutionizing Cycling Infrastructure:
A New Approach to Enhancing Safety and Management of New York City's Cycling Network

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Policy Brief

Considering the massive worldwide increase in the use of cycling infrastructure, understanding cycling network infrastructure quality is a key factor in meeting the needs of cyclists. This report synthesizes methods used from around the world, current infrastructure maintenance procedures and current crash data to inform New York City on new practices to reduce crashes and improve cycling infrastructure.

Key Findings

- Despite promoting the expansion of cycling networks, most cities lack proactive measures to assess and maintain the quality of their cycling infrastructure.
- Research indicates a strong correlation between the quality of the cycling infrastructure and perceived user safety.
- Well-maintained, protected cycling lanes with clear separation from vehicular traffic significantly increase perceived safety; however, crashes and injuries in New York City have not significantly decreased and, in fact, have seen record numbers.
- Other cities engage the community to obtain public feedback that inform infrastructure improvements and use data from cyclist counters and prioritized maintenance efforts.
- Despite the attempts to engage with communities, results are limited due to budgeting constraints and staffing issues.

While inspection services currently evaluate the physical conditions of vehicular infrastructure on a scale from 1 to 10 across New York City, inspectors neglect cycling infrastructure as most cycling crashes occur along roads that have been evaluated to be in good condition (above 7). Incorporating methods into New York City that other cities already use to investigate the quality and maintenance of their cycling infrastructure, such as crowdsourcing and sensor-based systems, offer promising solutions for real-time data collection and issue reporting. Thus, the results from this study reveal that learning from and incorporating successes from research and other cities is key to reducing cycling crash rates in New York City.

Policy Recommendations

- Develop a bikeability index that incorporates infrastructure quality, safety, connectivity, and cyclists' preferences. This index will guide investment decisions and focus improvements in areas with the greatest need.
- Establish a proactive maintenance program that prioritizes cycling infrastructure on par with current vehicular infrastructure procedures.
- Prioritize the expansion of protected bicycle lanes and intersections, particularly on high-traffic corridors, roadways rated low in pavement quality, and intersections in areas with high crash rates.
- Utilize community feedback further, develop a user-friendly application that allows cyclists and municipalities to report and obtain cycling infrastructure issues in real-time.

Acknowledgments

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Introduction

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Defining Terms

For purposes of this paper, the terms cycling, cyclist, bicyclist, bicycle lane, and bike network, will be used as blanket terms to encompass all modes of travel that legally operate on current bicycle networks, which include but are not limited to:

Trontinettes, skateboards, rollerblades, electric scooters, electric bicycles, and pedal assist bicycles. It is with some broad understanding that other modes of transportation utilize the micromobility network, though frowned upon by many. This includes mopeds, larger scooters, assisted movement wheelchairs, hoverboards, e-skateboards, and one wheels.

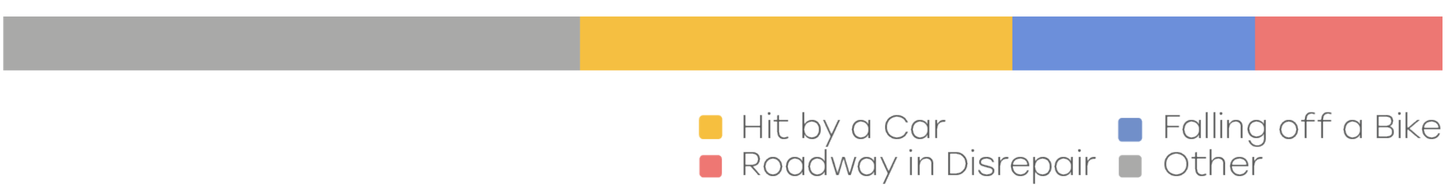
Use of active modes of transport for commuting and recreational purposes has increased tenfold over the past decade considering the economic, health, and environmental benefits it offers [1, 2]. Since COVID-19, there has been a worldwide active transportation boom and the number of cyclists in particular has increased by 5% between 2022 and 2023, while the number of e-bicycle users increased by an astonishing 23% [3]. This stark increase in cycling post-covid has now surpassed vehicular travel in Paris for the first time ever, [4] while London has witnessed the saturation of its cycling network which has now become a 'victim of its own success' [5]. Cities now struggle to adapt their cycling network to meet ever-increasing annual mileage and growth standards [2].

Which attributes affect your perception of the bikeability of the area you currently live in? Studies suggest that an active user is more likely to use a micromobility mode depending on the number of stores, their access to work, the prevalence of green pathways, and access to public facilities [6]. Some argue that it is based on rider comfort, the location of these lanes and their separation from vehicular travel lanes, [7, 8] as well as the types of use on the network and attractiveness [9].

Some studies demonstrate that bikeability is based on the current infrastructure materials used as a whole to support the use and functionality of the cycling network [10]. To support this theory, agencies around the world are looking into a scientific understanding of their networks more in terms of different typologies that currently exist [11], such as the roughness of roads [12]. This approach focuses on development and automating a condition assessment standard of the infrastructure currently available [13, 14]. Currently, municipalities use a worldwide standard of roadway ratings that focus only on the vehicular tire paths, utilizing a condition scale called the Pavement Condition Index (PCI). This index employs various condition types and assigns a rating to each roadbed –Table 1; Appendix 1.

While some municipalities create algorithms to predict vehicular pavement deterioration along the wheel path and the budget required for resurfacing projects, the worldwide standard of rating utilized does not take bicycle lanes into consideration unless they are on a shared road. User comfort and safety within the network should remain a priority, however, there is a focus on vehicular roadway distress across data aggregators. As it stands, road safety does not currently benefit from the modal shift from vehicular use to active transport [7]. According to the National Highway Traffic Safety Administration (NHTSA), "bicyclists are especially vulnerable to crashes in a collision with a motor vehicle. The most effective means of protecting cyclists is to eliminate conflict with motor vehicles to avoid rises in crashes". While the NHTSA recommends various countermeasures to reduce crashes from the increased use of cycling or other modes of micromobility within cities such as helmet laws and increased driver training [15], the number of reported crashes continues to rise. An example of a common worldwide effort to reduce these crashes is Vision Zero - an initiative introduced in Sweden in 1997 that was developed to maintain that "life and health cannot be exchanged for other benefits within society, and no one should be killed or seriously injured when moving within the road traffic system" [16]. Cities launched efforts to understand and interpret crashes that occur within cycling networks, but these attempts offer nothing more than political approval ratings [17]. Additionally, the crash data that is collected, if at all, "is extremely limited considering the registration of crashes involving cyclists or pedestrians in

Top Three Causes of a Crash (US) 2023



official road crash statistics is not complete and a large proportion of these (non-registered) crashes are single vehicle bicycle crashes, for which the safety by numbers effect does not apply" [15, 18].

This paper investigates the correlation between current roadway quality and documented cyclist crashes to determine whether municipalities can adopt a methodology to inclusively rate their roadways, while addressing user needs in the most feasible and efficient way possible.

No.	Distress Type
1	Alligator Cracking
2	Bleeding
3	Block Cracking
4	Bumps and Sags
5	Corrugations
6	Depressions
7	Edge Cracking
8	Joint Reflections
9	Lane/Shoulder Drop-Off
10	Longitudinal Cracking
11	Low Ride Quality
12	Patching and Utility Cuts
13	Polished Aggregate
14	Potholes
15	Rutting
16	Shoving
17	Slippage cracking
18	Swelling
19	Weathering and raveling

PCI range	Class
85-100	Good
70-85	Satisfactory
55-70	Fair
40-55	Poor
25-40	Very Poor
10-25	Serious
0-10	Failed

Table 1 - Distress Types + Pavement Condition Index Range

Methodology

Methodology

To investigate the relationship between cycling infrastructure quality and safety, this study will utilize a mixed-methods approach incorporating expert interviews, news articles, academic literature, and government documents. To identify current areas that cycling infrastructure can improve, this paper focuses on a case study of New York City (NYC) and aims to answer the following questions:

Is there a correlation between the quality of the cycling lane's infrastructure and crashes?

Can insights from other cities' practices enhance the methodologies used to assess and improve NYC's cycling lane infrastructure quality?

How can the development of a crowdsource rating system assess the condition, both perceived and physical, of cycling lanes that is separate from conventional roadway rating systems?

How can this user feedback be leveraged to reduce municipal strain and gather real time insights for a user-centric enhancement of bicycle lanes?

Case Study: NYC

As of 2024, NYC has reached the tenth anniversary of its Vision Zero initiative, the results of the initiative have been much less than stellar with a record number of crashes involving cyclists occurring in the year's first quarter, numbers shown in Table 2 [17]. NYC passed an additional milestone - reaching a record number of network miles of cycling infrastructure but covering only 1.72% of the city. To the best of my knowledge and at the time of this writing, no qualitative or quantitative model has been developed to successfully estimate factors that can influence a user's decision to use cycling networks. Primarily focusing on NYC with its record-breaking cyclist crashes and unmet infrastructure needs, this paper will attempt to address the following: if NYC can learn from various city's lessons and success stores, how current methods utilized could be successfully enhanced within the cyclist network, and if methods could be combined to assist existing networks beyond the scope of NYC.

Can Insights from Other Cities Assist NYC?

While NYC is considered one of the top cycling cities in the world, it can use improvements. To understand methods in which NYC can reduce and one day eliminate their high cycling crash numbers, I have contacted 65 cities and asked the following questions to gain deeper knowledge from municipal planners, engineers, and project managers:

How do you monitor and maintain bicycle lane conditions?

What measures do you take for bicycle lane users' safety and satisfaction?

Can you share successful community engagement examples in bicycle lane improvements?

Do you use any new technologies or data analysis in managing bicycle lanes?

This paper will deep dive into the results from the various municipalities that have responded, as well as review the data that currently exists in NYC to further understand if alternate reasoning exists for the record-breaking crash numbers.

Recommendations for NYC

A set of recommendations will be issued to NYC on how it could best leverage the massive number of cyclists that use the network daily to create a process to upload desired data in real-time. As a result, planners and leaders will have up-to-date information to define areas, both established and new, requiring resources to implement upgrades.

Year	Crash Count	Actual Count*
2016	5937	29685
2017	6397	31985
2018	6147	30735
2019	5962	29810
2020	5224	26120
2021	5081	25405
2022	5348	26740
2023	5391	26955
2024	493	2465

Table 2 - Cyclist Crash Totals in NYC
*Actual Count is if all crash incidences were reported. according to the NHTSA

Literature Review

Literature Review

Part 1
Benefits of Active Transportation

The World Health Organization (WHO) emphasizes the health benefits of cycling, going beyond its role as a mode of transportation. Along with walking, these activities significantly reduce the incidence of non-communicable diseases, such as heart disease or cancer. Cycling also contributes to environmental sustainability by reducing air pollution and traffic congestion through decreased vehicular emissions. [2]. The WHO's comprehensive review titled Walking and Cycling: Latest Evidence to Support Policymaking and Practice released in 2022 highlights these modes as beneficial and necessary for the future of urban planning and public health strategies. Additionally, the economic impacts of creating and improving active transportation and pedestrian infrastructure on local businesses have been significantly increased as the addition of the cycling network generally has positive or non-significant economic effects on retail and food service businesses [1].

Part 2
The Critical Role of Infrastructure in User Safety

Urban mobility leaders have increasingly recognized active transportation such as cycling as a sustainable and efficient mode of transportation. The growing emphasis on cycling infrastructure reflects an awareness of its benefits in reducing congestion, promoting public health, and minimizing environmental impacts.

While the WHO highlights these benefits, the safety and effectiveness of cycling networks rely on the quality of infrastructure provided by municipalities. The relationship between the built environment and micromobility injury proves that proper infrastructure design will reduce crash rates and increase safety. Findings suggest that implementation of improved lane network designs through traffic calming measures, such as neckdowns, buffers, daylighting, and segregated lanes as shown in Figure 1 [19] , assist in decreasing the risk of accidents and injuries on the network [7].

In addition to the traffic calming measures mentioned, studies show that full-width measurements should be considered. The maintenance of the network must be held to good conditions to provide wide enough paths to not only adhere to ideal municipality standards, but also avoid increased accidents and maintain increased network usage. With bicycle lane usage on the rise and meeting saturation, municipalities must be sure to maintain these standards with standardized checks on what is currently available and if upgrades should be made that will lead to increased space for the growing number of cyclists, especially in urban areas [13]. A method to address this is creating a demand-driven design of the network infrastructure that can lead to improved bikeability, as with increasing the widths of the network where needed. Demand-driven design of the infrastructure will lead to a better understanding of cyclists' needs and the demand that exists, especially within urban areas [8]. As shown in Figure 2, this can be done through manual counts, cyclist counter systems as well as tracker applications that read user routes to estimate the total number of users on a cyclist network at any given time [8]. Steinacker promotes the idea of adapting new network infrastructure based on the current and past usage patterns and community feedback that exists. Widening lanes allows for more freedom for the cyclist, especially with the staggering increase of e-bikes and bike couriers in dense cities.

Figure 1 - NACTO Urban Street Design Guide: Neckdown, Chicane, Buffer [19]

Figure 2 - Cyclist Counter [19]

Part 3 Urban Bikeability Index (BI)

The development of an urban bikeability index (BI) that includes criteria such as safety, connectivity, and infrastructure quality is a good step in the right direction [9] – infrastructure in some cases specifically includes the availability of biking facilities such as repair shops [6]. Such an index would help city planners and policymakers prioritize investments in infrastructure improvements, focusing on areas that yield the greatest benefits in terms of safety and usability.

However, this would be done in-house by municipalities that have strained their financial budgets and staffing restraints, as discussed in Theme 1 – Findings from Experts Around the World. Defining what infrastructure is and why it is important for this research is noted to be crucial when focusing on creating new methods. "The quality of service for complementing modes of transport, such as walking or public transport, is stated to interact with cycling levels … and the surface quality [of roads are] crucial" [6].

Bike crash data is the most popular crash record keeping procedure in micromobility and investigations into single-bicycle crashes reveal that the infrastructure involved in roadway maintenance, not only facilities, but plays a crucial role in crash severity [6, 20]. Studies highlight how poorly maintained road sections significantly increase the risk of severe injuries in crashes, as also proven by being the third highest cause of crashes in the US [15]. Enhancing the maintenance of bicycle lanes and roads with a BI will dramatically improve safety outcomes for cyclists [6, 20].

Part 4 Perceived Safety and Comfort from Rider Surveys

Perceived safety and comfort are additional factors that are crucial in influencing cyclists' willingness to use cycling networks that are available to them [21]. For instance, studies by Niska and Sjögren in Malmö and Linköping, Sweden [21] found that cyclists' assessments of various surfaces indicated that smoother surfaces, like [new] asphalt, were perceived as more comfortable compared to surfaces with small concrete slabs, which were deemed unpleasant by a majority of cyclists – seen in Figure 3. Niska and Sjögren's studies, utilizing smartphone accelerometers to measure cycling path roughness, have demonstrated a correlation between higher acceleration values and increased cyclist discomfort. Acceleration values defined as the amount of energy it takes to start your bike after a stop [21].

These studies suggest that to assume the perceived comfort of a micromobility surface, setting limit values for different roughness levels is necessary to classify surfaces accurately in different buckets [21]. While the results using the accelerometers lined up quite a bit with a sample size of subjective surveys using the same paths ways to understand comparisons, there began to be a difference in the data when it came to perceived comfort as the accelerometer assumed that a route of gravel would be more uncomfortable while the riders noted it was more comfortable than the aforementioned concrete joints [21]. These concrete joints can be compared to when a roadway has many cracks or potholes – as seen in Appendix 1. The surveys conducted by Niska and Sjögren revealed that the presence of unevenness on cycling paths, such as warping also greatly impacted rider's experience [21] – this can be commonly found along bus stops due to conventional asphalt pavement being flexible as shown in Figure 4. This defect allows the asphalt pavement to be moved by the force and heat generated by braking buses and trucks, leading to wave-shaped hills or warps along the length of a bus stop. This issue is most pronounced at high-volume stops along curbs in municipalities where idling buses further heat the roadway surface, as well as near-side stops in mixed-traffic lanes where trucks may be adding to the wear [22].

Figure 3 - Concrete Flags with Joints

Figure 4 - Pavement Warping

Part 5
Importance of Roughness Indexes

The two types of distresses are proven to be uncomfortable; however, there are more to the scale of the physical roughness of cycling paths. One of the most concise organization of data found for the methodology that cities use when rating their roadways was found in the study entitled “Transition from Manual to Automated Pavement Distress Data Collection and Performance Modeling in the Pavement Management System”. Within the document, the terms for measurements of road surface roughness along the vehicular lanes are as follows: Distress Manifestation Index (DMI), the International Roughness Index (IRI), and the Pavement Condition Index (PCI). The PCI is defined as being composed of two sub-indices: the IRI and DMI [23]. The IRI is defined as being a representation of the overall pavement roughness similarly described in Niska’s 2014 study [21], and the DMI is defined as a representation of the distress which is usually an overall subjective rating created by the inspection teams within municipalities which many are still using today, such as NYC. These two indices, when combined under certain formulations defined by the municipalities, provide a PCI value for a defined range, usually a subgroup of corridors to represent that corridor’s condition. PCI formulas are unique for different corridor types. An example of distress types typically used in pavement ratings can be seen in Appendix 1.

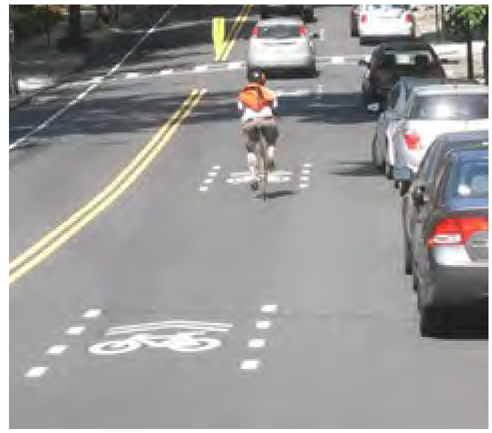
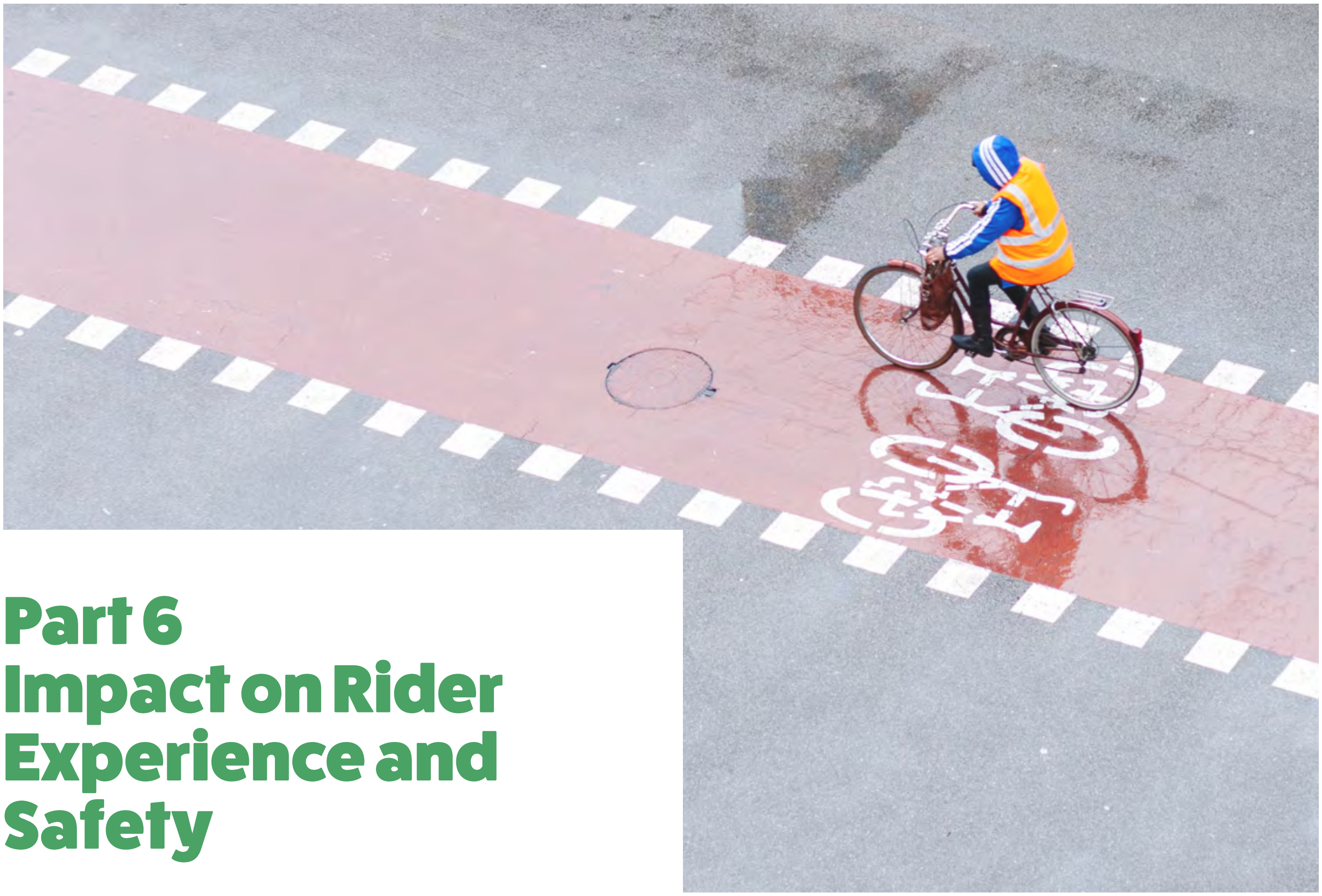


Figure 5 - Bicycle Facility Type: Sharrow

While this rating system is effective for vehicular assessments, the IRI's focus on the wheel lane does not fully capture the specific comfort needs of cyclists. The only instance a vehicular lane rating will benefit a bicycle lane is if the bicycle lane is shared with the vehicular lane in the form of a sharrow, as shown in Figure 5. For cyclists, roughness metrics like megatexture to microtexture values are more indicative of the actual experience [12]. Additionally, IRI and PCI do not incorporate factors that cyclists may come across that are specific to cycling networks such as roots breaking through the asphalt or causing a concrete flag to rise above the neighboring flags. More defects that are neglected are under-maintained greenery that covers the lanes, and potentially dangerous infrastructure designs such as manhole covers which can have openings that are wide enough to fit a wheel. A list of these potential additions to a cycling IRI distress types can be found in Appendix 2.



Part 6
Impact on Rider Experience and Safety

As shown, the impact of infrastructure quality on cycling perceived safety is important. Inadequate or poorly maintained cycling paths can lead to increased instances of roughness and a reduction in comfortability within the cycling network. Smoother cycling paths with fewer irregularities result in lower accident rates and improved safety for cyclists [7]. This data has highlighted that intersections and paths with better maintenance and clear separation from vehicular traffic significantly reduce the likelihood of crashes and near misses.

The relationship between perceived safety and actual safety is evident. Cyclists often report higher levels of comfort and willingness to use cycling networks when they perceive the infrastructure to be safe and well-maintained [24]. This perception is critical for promoting cycling as a viable mode of transportation, as it directly influences ridership and overall [25].

Synthesizing these studies into the NYC realm forms a case for understanding where the needs are. As cities continue to expand and adapt their cycling networks, the focus must not only be on increasing the number of bicycle lanes but also on enhancing the current stock's quality and maintenance. The following section will explore strategies employed by cities worldwide to enhance roadway quality, emphasizing the benefits of proactive maintenance and community-engaged infrastructure development.

Results

Theme 1 Findings from Experts Around the World

65 cities

Studies on cycling infrastructure are heavily influenced by the populations under study meaning that cycling facilities and user preference differ according to the past experiences and other personal traits of the cyclist such as physical capabilities, and preferred routes [26]. To inform NYC's strategies for reducing cyclist crashes and enhancing urban mobility, I initiated a comprehensive outreach to cities around the world in early 2024. My approach involved reaching out to a diverse range of cities from areas with well over one million residents to small cities with fewer than 50,000 residents. The variation in population sizes was driven by the hypothesis that smaller cities might offer more innovative approaches to cyclist safety and improved infrastructure, given their more manageable population sizes and potentially different urban dynamics. To assess the potential influence of weather on bicycle lane inspection practices, I ensured the selected cities experienced diverse climates to best compare to NYC's seasonality.

Furthermore, to compile a robust list of cities, I focused on identifying cities with high mileage of cycling infrastructure and high rates of cyclist riders. The search criteria centered on "bicycle usage" metrics, enabling me to pinpoint cities that have significant engagement with cycling as a mode of transport.

Figure 6 - Map of Expert Outreach

Out of the 65 cities contacted, 17 have responded to the below questions as of the production of this paper and the results have been grouped into themes of: Monitoring and Maintenance of Bicycle Lane Conditions, Safety and Satisfaction Measures, Community Engagement in Bicycle Lane Improvements, Use of Technologies and Data Analysis, Locations Lacking Staff or Specific Programs.

How do you monitor and maintain bicycle lane conditions?

What measures do you take for bicycle lane users' safety and satisfaction?

Can you share successful community engagement examples in bicycle lane improvements?

Do you use any new technologies or data analysis in managing bicycle lanes?

City	Estimated Population 2024	Bike Lane (mi)	Avg High (C)	Avg Low (C)	Avg Rain (mm)	Avg Snow (mm)
New York City, New York	7,931,147	1,375	29	-2	95	154
Melbourne, Australia	5,316,000	621	25	6	55	0
Los Angeles, California	3,748,640	1,200	29	9	85	0
Vancouver, Canada	2,683,000	249	22	2	252	51
Vienna, Austria	1,990,000	870	21	-3	60	61
Stockholm, Sweden	1,720,000	472	22	-5	56	81
Phoenix, Arizona	1,676,481	1,000	41	8	29	0
Edmonton, Alberta	1,568,000	149	23	-14	68	78
Helsinki, Finland	1,347,000	746	21	-8	56	149
Amsterdam, Netherlands	1,182,000	477	21	1	44	20
Oslo, Norway	1,101,000	112	21	-7	85	224
Jacksonville, Florida	990,931	800	32	8	128	0
Denver, Colorado	708,948	196	31	-5	47	61
Portland, Oregon	616,840	385	28	2	226	61
London, Ontario	447,255	311	26	-8	61	114
Freiburg, Germany	230,241	249	25	-1	86	41
St. John's, Newfoundland and Labrador	112,165	31	20	-7	108	486

Table 3 - List of Respondents

Common themes that were found through each respondent were through minimal monitoring and maintenance, attempts to successfully utilize community engagement, tests using technologies, and issues regarding staffing and budgets to successfully do any type of bicycle lane maintenance.

1. Monitoring and Maintenance of Bicycle lane Conditions			
a. Regular Inspections and Damage Repair			
Conduct regular inspections of bicycle lanes and address reported damages or deficiencies either through visual inspections or electronic recording methods like video and sensors on a seasonal basis.	Freiburg	Edmonton	Helsinki
b. Public Reporting Systems			
Have systems in place for the public to report issues directly, such as damage or debris in bicycle lanes, which helps in prompt maintenance.	Oslo	Jacksonville	Freiburg
2. Safety and Satisfaction Measures			
a. Maintenance Standards			
Maintaining Priority 1 and 2 bicycle lanes to high standards, ensuring safety during winter with timely snow and ice removal.	Edmonton		
b. Infrastructure Improvements			
Focus on creating bicycle lanes that provide low stress for cyclists and use green pavement markings for better visibility and safety.	Jacksonville		
3. Community Engagement in Bicycle lane Improvements			
a. Public Input and Engagement			
Involve the community through surveys and public meetings to gather input on bicycle lane projects, leading to more tailored and accepted improvements.	Edmonton NYC	Phoenix Freiburg	Vancouver
b. Digital Platforms for Engagement			
Online platform for reporting issues (such as NYC's 311)	Oslo	NYC	Portland
Moved to virtual public meetings to increase community engagement.	Phoenix		
4. Use of Technologies and Data Analysis			
a. GPS and Data Tracking			
Uses GPS units on maintenance vehicles to track completed tasks and manage the bicycle lane network efficiently	Oslo		
b. Data-Driven Decisions			
Utilizes data from various sources like Eco Counters and bike counts to understand usage patterns and plan network improvements.	Edmonton	NYC	Phoenix
5. Locations Lacking Staff or Specific Programs			
a. Understaffed and unable to provide specific details on bicycle lane management	Vienna Helsinki St Johns	Denver Los Angeles London	Portland

Table 4 - List of Respondents

Comparative Analysis of Bicycle Lane Management and Safety in Cities

It was with great surprise that a medium sized city, Freiburg, Germany, already implements a somewhat in-house inspection of the bikeways. Their focus is on maintaining the extensive cycling network through regular inspections and public engagement. Freiburg employs visual inspections and plans for electronic surface checks soon though no solid date yet. The city also currently relies heavily on public surveys to identify issues, as with other cities that have responded. This supports the claim that "public engagement is crucial for maintaining the cycling network, as it helps identify areas needing attention that may not be apparent through visual inspections alone"[21]. Freiburg combines regular inspections with electronic recording and continuous improvements based on public feedback and statistical data from accidents and traffic surveys.

On the other side, Vienna, Austria; Amsterdam, Netherlands; Helsinki, Finland; Los Angeles, California; and Denver, Colorado along with St. Johns & Newfoundland and London, Ontario all responded that due to being understaffed, could not provide detailed information requested. Locations that did not respond raise concerns, as the growth of cycling infrastructure continues, budget constraints or staffing shortages could lead to continued neglect of existing infrastructure. The lack of any response at all from other municipalities may also be attributed to similar constraints, highlighting a potential systemic issue. Portland, Oregon was also understaffed but made a point to mention that there are methods for communities to report conditions such as 823-SAFE and a website which is down at the time of this writing.

Vancouver, Canada, provided some information and responded that it currently uses - as found within many municipal sites and NYC - the Pavement Condition Index (PCI) and International Roughness Index (IRI) only for shared bikeways, allowing for a response to public service requests for needed maintenance – though no timeline was provided from ratings to correction.

Stockholm, Sweden, meanwhile, is looking to updated methods for rating streets, including bicycle lanes, reflecting a newer approach to cycling infrastructure assessment compared to other cities on the list above. These updated methods support Niska and Sjogren's understanding that municipalities should be exploring different methods for rating streets, including bicycle lanes, to show a commitment to proactively maintaining, updating, and improving upon the current stock of infrastructure quality that is currently available [21]. Oslo, Norway, also stands out with its broad system for public reporting of issues via an online platform (bymelding.no). This public type of recording was noted to be anything from litter and excessive gravel after snow melts, to potholes and poor mobility due to snow and ice. This system is also used by their parking officers to report potential issues they come across on their daily routes. The recorded registrations of issues in their system that are noted to be able to be carried out immediately without the need for more intense treatment are sent directly to Oslo's contractors and executed within a short period of time – again, no timeline provided. This semi-real time data stream is apparently then set with a high standard of maintenance, particularly for prioritized bicycle lanes, and allows for the data to be incorporated from public feedback to more major planning processes. A potential issue in Oslo's methods comes with budget limitations in ability to sweep only 111 mi and plow only 75 mi per year, so prioritization is important.

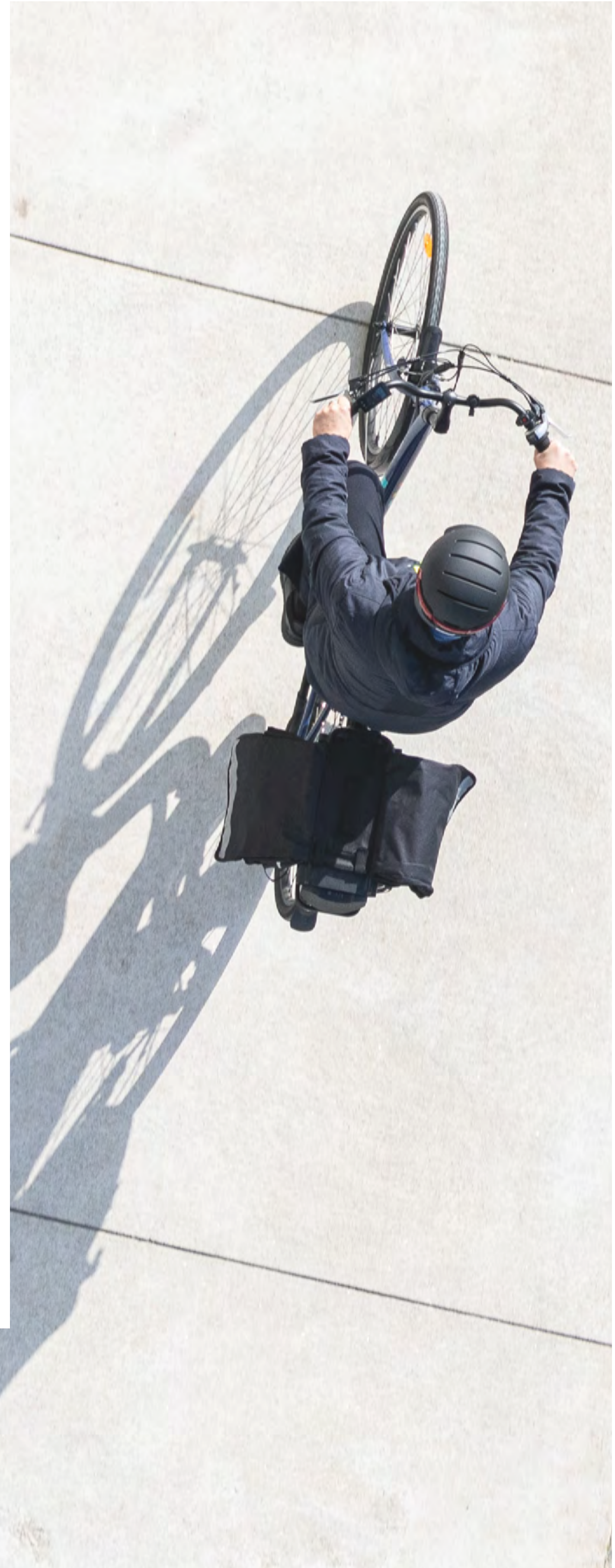
Phoenix, Arizona, mentioned that it has a more focused sense of community engagement and maintenance; however, it has no need to respond to or rate sections for up to a two-year cycle, allowing for quite a bit of time to surpass between creation and deterioration. As mentioned previously, using vehicular indices like PCI and IRI allows for a systematic evaluation of pavement conditions, facilitating targeted maintenance interventions but may miss cycle infrastructure specific needs seen in Appendix 2. Phoenix also has increased public engagement through virtual meetings advertised though mailers to residents within a half-mile radius of a planned project and outreach techniques such as providing a public facing email and the creation of the Phoenix Connected Active Neighborhoods Program (PhxCAN). All these efforts are aimed at using information to expand its bicycle lane network by over 1800 miles by 2050, or 31 new miles per year.

Like Oslo and Phoenix, Jacksonville, Florida, integrates public reporting and vehicular lane ratings with its MyJax service, allowing residents to flag pressing issues like debris and missing signage along bicycle lanes. However, Jacksonville prioritizes projects that minimize traffic stress for cyclists of all ages and abilities, favoring shared-use paths and protected bicycle lanes whenever feasible. When constraints exist such as funding, or the various distress types, efforts are made to make the new bicycle lanes as wide as possible and with green pavement markings or striped buffers. It is unclear whether these enhancements are integrated into existing roadbeds or implemented exclusively during major reconstruction projects. Jacksonville has begun to use some technological advancement in a means to manage bicycle lanes in addition to its roadways with annual aerials and site visits. They are actively looking into obtaining a mini street sweeper to clear protected bicycle lanes, acknowledging the need as their linear mileage of protected bicycle lanes increases though may come across some roadblocks as the cost of this new maintenance vehicle costs a lot which may require government or other internal funding down the line.

Edmonton, Canada, combines winter and summer maintenance programs with public engagement in its planning, utilizing data from Eco Counters and Miovision bike counts to inform infrastructure improvements for what they note to be priority bicycle lanes. Through public engagement, Edmonton utilizes the neighborhood level knowledge to reimagine transportation infrastructure that meets the needs of the neighborhood for the next 30-50 years. Project teams work with various stakeholders to identify areas of concern, including concerns of missing infrastructure. This is proved by the recent successful approval of the Terwillegar Drive bike way, which is slated to begin in 2024. Additionally, the bicycle lanes are split in categories: Priority 1 are cleared of snow and ice down to bare ground pavement within 24 hours of a snowfall. This is completed using a variety of equipment such as brooms, plows, and traction materials through dispatched crews during as well as after a snowfall has ended. There are also noted to be Priority 2 bicycle lanes that receive the same service but are completed within 72 hours of the end of a snow fall. During the summer, the city does not perform any preventative maintenance activities. As with NYC, inspections are also conducted on the cycle infrastructure but on a notification basis through the 311-notification process with the target to have the location inspected within 5 days – no note on follow ups. Following an assessment, the location is placed in queue for repair and timelines can differ greatly between repair methods.

In cities like Melbourne, Australia, community feedback and innovative reporting methods also play a role. A 2030 transportation strategy endorsed in 2019 was the result of extensive community consultation to further improve their networks. Melbourne maintains bicycle lanes as part of routine city maintenance, engaging the community through the Participate Melbourne platform and collecting data to monitor performance and plan new routes such as the recently completed Grattan Street bicycle lanes. In terms of specifically collecting data, Melbourne has external and internal data that is collected to monitor how the bicycle lanes are performing such as volumes, speeds and time flow.

This multi municipality analysis reveals that successful bicycle lane management in cities of all sizes involves a blend of regular maintenance, community engagement, and data-driven decision-making that cities can benefit from. These insights provide potential lessons for NYC as well as reflect their current procedures. Much like Edmonton, Pheonix, Oslo, Melbourne, and Jacksonville, NYC currently obtains complaints from its residents about its current cycling infrastructure through public engagement events ran by community districts within each borough as well as a public facing portal called 311 where residents can call, text, message, and upload complaints through a portal. Much like Phoenix, NYC roadways are required by the city to reach a roadway rating at least once every two years and use a team of inspectors and an in-house application process that allows the inspectors to rate the roadways based on a matrix of criteria that combines IRI and PCI distress percentages leading to an overall rating of Good, Fair or Poor as noted in Table 1. And much like the other cities that responded, NYC currently only rates bicycle lanes that are within the roadway or shared lanes. All in all, with Freiburg, Osla and Stockholm currently leading the best direction, the need for a comprehensive, data-informed, and community-engaged approach to enhancing its cycling infrastructure and reducing cyclist crashes is important. To get there, it is important to understand the current procedures that NYC takes to create their networks, and investigate the data.



New York City

Theme 2 NYC's Methods, Findings and Data

493 bike crashes

As of Feb 2024

Importance of Safety in NYC Cycling Infrastructure

Focusing on NYC it's politicians and leaders emphasize the importance of safety in cycling infra-structure development and maintenance; however, enhancements often only prioritize vehicular roadways. Over the past decade, NYC has implemented numerous measures under the Vision Zero initiative which was introduced in 2014. These measures such as increased traffic light cameras were and are currently aimed at eliminating traffic deaths and serious injuries. Despite these efforts, the city continues to grapple with high rates of not only pedestrian incidences, but cyclist fatalities and injuries, pointing out the need for a radical shift to understand how to implement safety interventions and continued infrastructure improvements. How does NYC under-stand their cycling network and where to implement or improve new locations?

How NYC Creates Their Cycling Infrastructure

Upon reaching out to NYC's Department of Transportation, they provided and in-depth analysis on the processes that are currently used when dealing with their cycling infrastructure. NYC under-stands the specific criteria and decision-making processes that guide the selection of new bicycle lane locations within NYC's expanding network and the DOT understands that this selection process is crucial. NYC's network expansion is determined with the primary goal being to ensure every New Yorker has access to both a local network of conventional bicycle lanes and a core protected cycling route that is connected to the larger citywide network [27]. As seen in their DOT Priority Investment Areas document [28] to help prioritize where to expand next, the DOT looks at broad safety data to address areas where they are seeing high injuries. This ensures that previously underserved neighborhoods have equal access to the bike network and allows for upgrades to existing lanes to meet demand and create new lanes where the ridership is growing. Finally, there is an ongoing development for a citywide greenway plan to enhance waterfront access across the five boroughs of NYC (Brooklyn, Manhattan, Queens, The Bronx and Staten Island)for both recreational and commuting purposes [29]. The city-wide Greenway plan is a huge undertaking and is a much slower process since it involves off-street capital projects (major roadway re-construction projects), but the plan serves as a guide and is a goal for where the DOT can prioritize work.

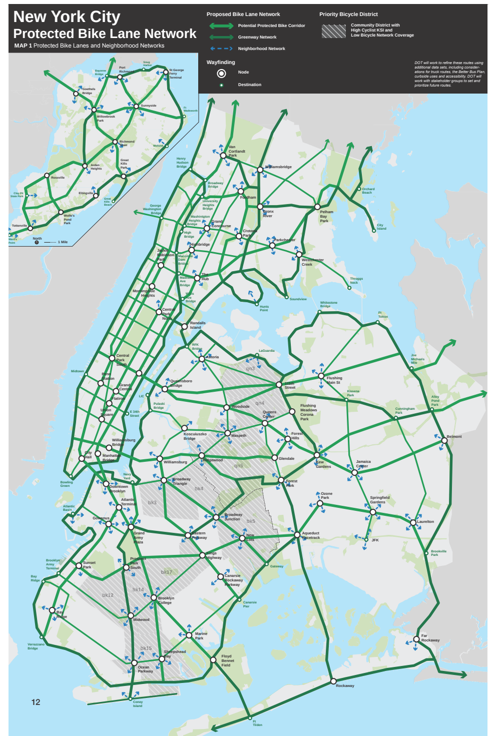


Figure 7 - NYC's Proposed Protected Bicycle Lane Network

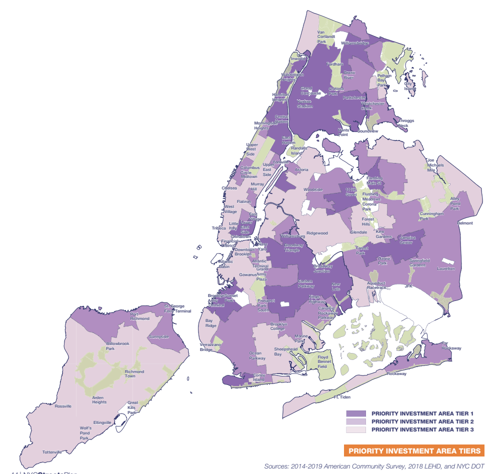


Figure 8 - NYC StreetPlan Priority Areas

Protection and Safety Standards

The factors that determine whether a bicycle lane is implemented as fully protected, partially protected, or unprotected are also under a strict process and NYC's decisions try to align with overall safety and usage patterns observed in the city. According to NYCDOT, protected bicycle lanes are generally implemented on streets that form their core network such as the streets that see many cyclists, streets that may have high vehicle volumes or a heavy mix of trucks in overall volumes. In some cases, they will partially protect a lane at intersection approaches where cyclists are at greatest risk but where vehicle incursion into the lane mid-block is not likely. As for unprotected lanes, they are specific to local neighborhood streets or as mentioned, connectors between protected lanes. NYCDOT noted to have found that adding unprotected lanes to the network provides a level of safety since they designate clear space for cyclists to travel and en-courage more cyclists to use a particular route adding to safety in numbers effect.

Infrastructure Upgrading Requirements

Given that generally, many newly implemented bicycle lanes receive only painted markings to delineate pathways, crosswalks, bicycle lanes, and buffered zones, it is crucial to determine whether upgrades consistently involve full resurfacing or if approaches vary based on lane condition, usage amounts and safety impacts involved with the upgrades. NYCDOT indicates that lane upgrades can be triggered by routine maintenance or the need to align facilities with current or improved standards of design and construction. As streets with bicycle lanes get resurfaced, engineers will revisit marking drawings to ensure what is re-installed meets current design standards or needs a full update to meet current standards. NYCDOT follows a similar process when a street is scheduled for markings refresh and not a full resurfacing, a markings refresh happens more frequently than resurfacing. Additionally, several lanes a year are selected for upgrades outside of routine maintenance including some of the city's older lanes that need an upgrade or lanes where volumes have increased, or lanes where safety concerns have developed. Upgrades include many of the factors that the literature review noted and are imperative to having a safe network for cyclists from: adding barriers, better intersection design, widening lanes to account for increased capacity and speed differentials between traditional cycle and other micromobility devices, and/or the addition of cycle corrals or pedestrian islands.

Impact of Community Feedback

Community feedback has been seen to be a crucial component in understanding the needs of cyclists and identifying areas for improvement. NYC is no stranger to this as it uses community feedback as a key to ensure a design meets localized needs. This type of feedback informs NYC planners on the best lane placements, design details, and localized needs. Additionally, the city seeks input on local desire lines and loading needs to ensure businesses retain necessary access. As with other municipalities, some crowdsourcing and various other data sources including timelapse cameras, regular manual counts, and on-demand computer visualization software also help inform where NYC planners should focus their work both in developing new lanes and upgrading existing networks.

Results from Vision Zero Efforts*

Looking at the various methods cities use to reduce crash incidences, like Vision Zero, for NYC there does not seem to be a current solution that works. The city of Hoboken, New Jersey, just minutes from NYC; however, has seen zero fatalities over the past seven years. NYC has not been successful, according to a report by Transportation Alternatives (TA) released April 2024 [17], traffic fatalities in NYC decreased initially after the launch of Vision Zero in 2014 but began to rise again in recent years. The report notes that traffic fatalities were 16% lower in the past decade compared to the decade preceding Vision Zero, translating to over 400 lives saved; however, this progress has not been consistent across all road users over the years. Pedestrian fatalities declined by 29% from 2014 to 2023, while driver fatalities rose by more than 11%, mainly in predominantly Black and Latino neighborhoods which is another issue. Cyclist fatalities have since fluctuated, with 2023 marking the deadliest year for cyclists this century.

1.72% of NYC's streets are protected

bike lanes as of Feb 2024

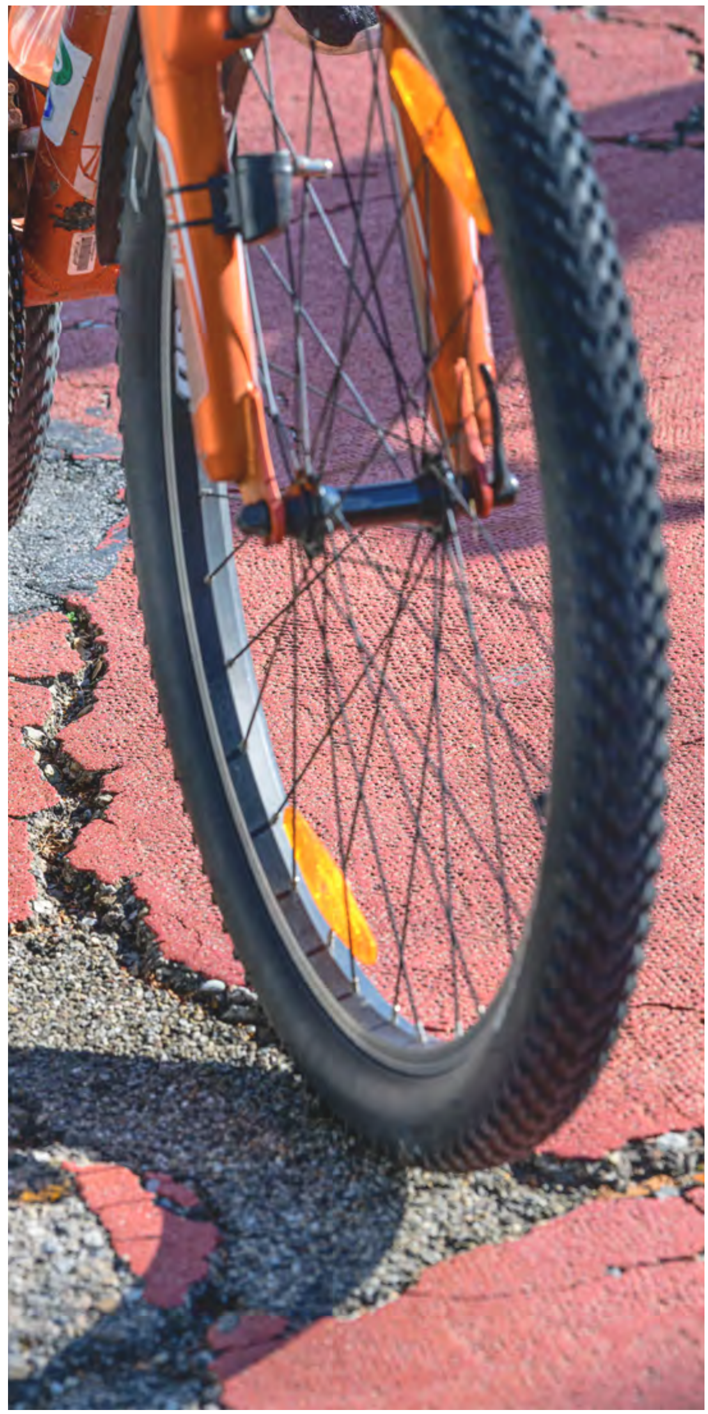
*ChatGPT 4 assisted with the structure of this section.

One of the most important findings from TA's analysis report, and the purpose of this research, is that safety interventions need to be implemented system wide rather than in a piecemeal fashion. The report shows that areas with comprehensive measures, such as speed limit reductions and automated speed safety cameras, have seen significant declines in speeding and related crashes. The report shows that overall speeding decreased at 92% of the speed camera locations throughout the city, leading to a 35% drop in average speeding tickets and up to a 99% reduction at some sites [17]. This increase in the implementation of automated speed safety cameras is a major indication that when a city incorporates consistent and widespread safety measures, there is a more effective change in driver behavior and improved road safety compared to "testing" enhancements in parts of the city as a pilot.

Despite increased use of cycling networks worldwide, NYC's infrastructure has been noted to not keep pace with these changing dynamics of road use. The number of vehicle miles traveled (VMT) has risen by 16% since 2014, reaching a record high, while the number of cycling trips has nearly doubled. Despite this surge in cycling, the city has only marginally increased its protected bicycle lane infrastructure, covering just 1.72% of the city's streets since the implementation of its Vision Zero initiative 10 years ago. This lack of adequate infrastructure has contributed to a rise in cyclist fatalities and injuries.

Addressing Overall Issues from NYC

To address these issues, it is crucial to To address these issues, it is crucial that NYC develops a comprehensive rating system for the cycling network that incorporates both perceived and actual safety data. Surveys of rider perceptions can reveal that safety and comfort are of top concern for cyclists and if tracked appropriately, NYC can better understand the corridors where most improvement, enhancement, and new builds are required. Roughness indexes and the condition of bicycle lanes directly influence the reduction of accidents and increase the overall cycling experience. By integrating crash data, rider surveys, and engineering assessments into a unified rating system, NYC will better prioritize and implement infrastructure improvements that enhance safety for all cyclists. To do this we must find similarities between the current method DOT uses of inspection ratings of NYC's streets and compare them to their adjacent bicycle lanes.



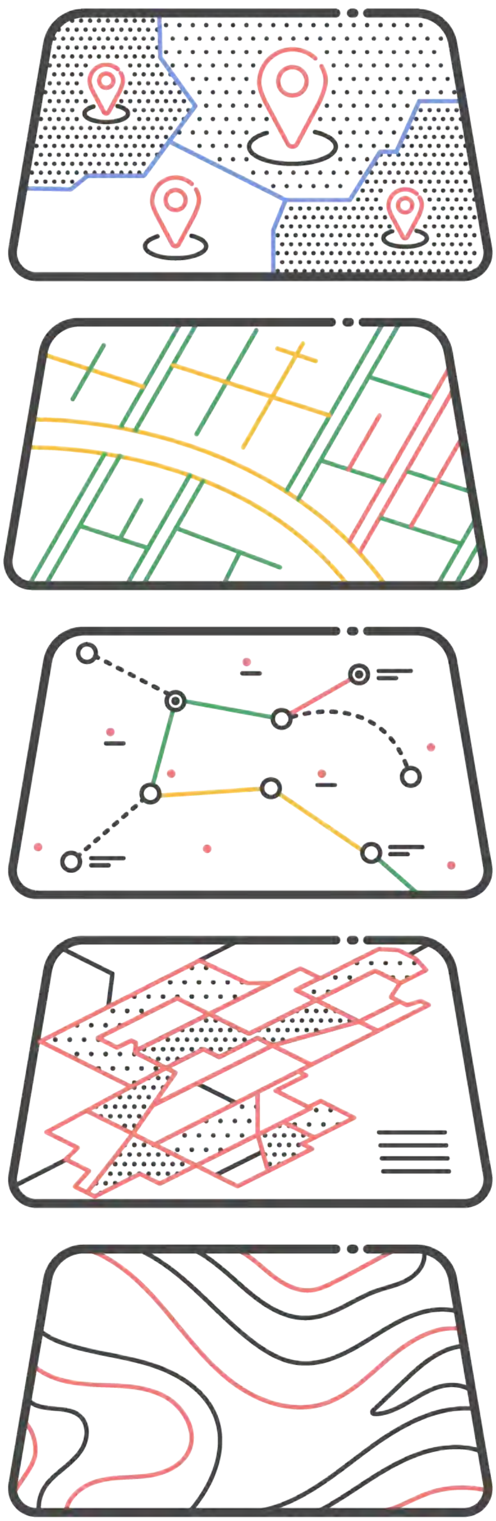
10+ million lines of data

Correlation Between Infrastructure and Crashes in NYC

NYC has thousands of available datasets that can be found within their portal, NYC Open Data. Obtaining the data is crucial to understanding the relationship between the current infrastructure and the bicycle lanes across the city. The datasets collected as of April 2024 are the New York City Department of Transportation Street Assessment (DOTSA) Ratings, New York City Police Department Crash (NYPD) Data, New York City Department of Transportation (DOT) Bike Network Lines, New York City Department of City Planning (DCP) Neighborhood Boundaries (NTA), and New York City 311 Complaints.

DOTSA Ratings	• The street ratings that use a PCI score were highly repetitive due to its use of grandfathered in street naming information, and the need to retain historical data, a clean up was done to remove any duplicate corridors that contained the same On / From / To and Segment Identification Number. • Historic data was removed by filtering the most recent rating for each street segment
NYPD Crash Data	• Cash data contained GPS coordinates to allow for positioning along the network of rated roadways. • A spatial join was created by creating a 40-foot (12-meter) buffer around the rated roadway to encompass entire street widths where a crash may have taken place. A crash point was counted only once and to the closest street segment feature. • Remember: Cyclist crash or injury data is never accurately collected as 20% of crashes involving vehicles are not reported [15], example of the full set of crash data in Table 2. • Remember: Even though roadway distress is the third highest cause of a crash in the US, NYPD does not have a recording input option of roadway distress as a cause of crash.
DOT Bike Network	• Bicycle lanes in NYC are not rated unless they are on the vehicular roadway. A spatial join was established with updated street rating data based on the spatial proximity of the bicycle lane to the closest roadway that has the rating, counted only once. • Types of facilities that exist within the bike network can be found in Table 6 - Facility Type with Rating Percentage
DCP NTA Boundaries 2024	• Crash data that occurred within the bike network was spatially joined to each NTA to visualize the intensity of bike crashes within each neighborhood; Table 5
NYC 311 Complaints	• Dataset was found to be too large to functionally run. A smaller data set was found with 100 thousand complaints on blocked bicycle lanes alone; however, did would not support the efforts of this study.

NYC collects so much data. The datasets contain over 10+ million records, from early 2000 to real-time.



Geoprocessed Data

DCP NTA

DOTSA + DOT Bike Routes

NYPD Crash Data + Bike Routes

DOTSA Ratings

The Agency performs ongoing assessment of NYC streets. Ratings are based on a scale from 1 to 10 grouped in the following categories: Good (%) - ratings of 8 to 10, Fair (%) - ratings of 4 to 7, and Poor (%) - ratings of 1 to 3.

Base Information Layers

DOT Bike Network

NYPD Crash Point Data

NYC DCP NTA Layer

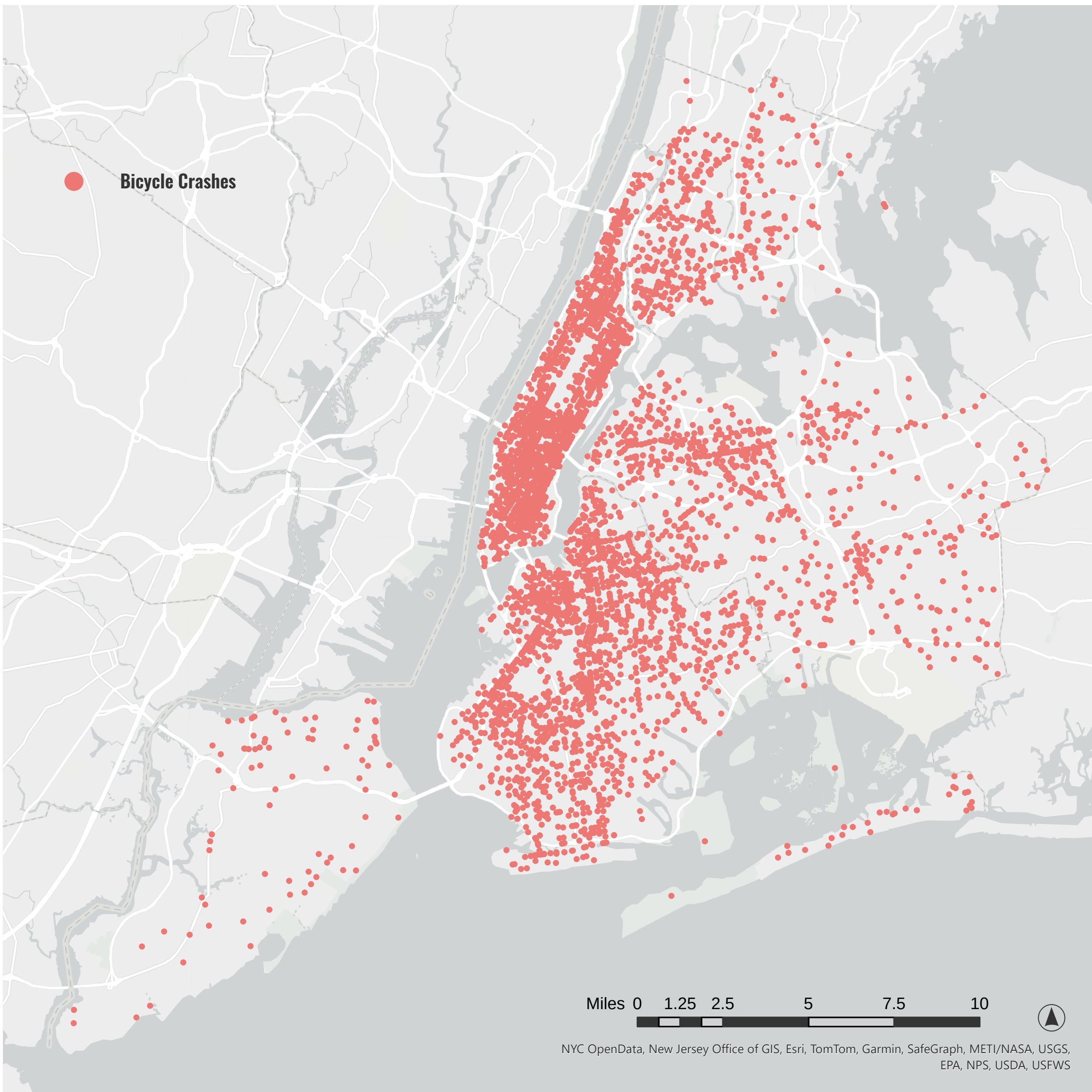
NTAs are approximations of NYC neighborhoods created for the purpose of reporting Decennial Census and American Community Survey (ACS) data. NTAs are aggregations of census tracts and nest within Community Districts.

Basemap Vector

The NSW Basemap Dark Grey provided by ESRI, provides a dark background with minimal labeling and features key roads.

Figure 9 - Geoprocessed Data Flow

Between February 2023 and February 2024, NYC's 22,607 bicycle lane segments had an astonishing 5,073 bicycles involved in a crash.

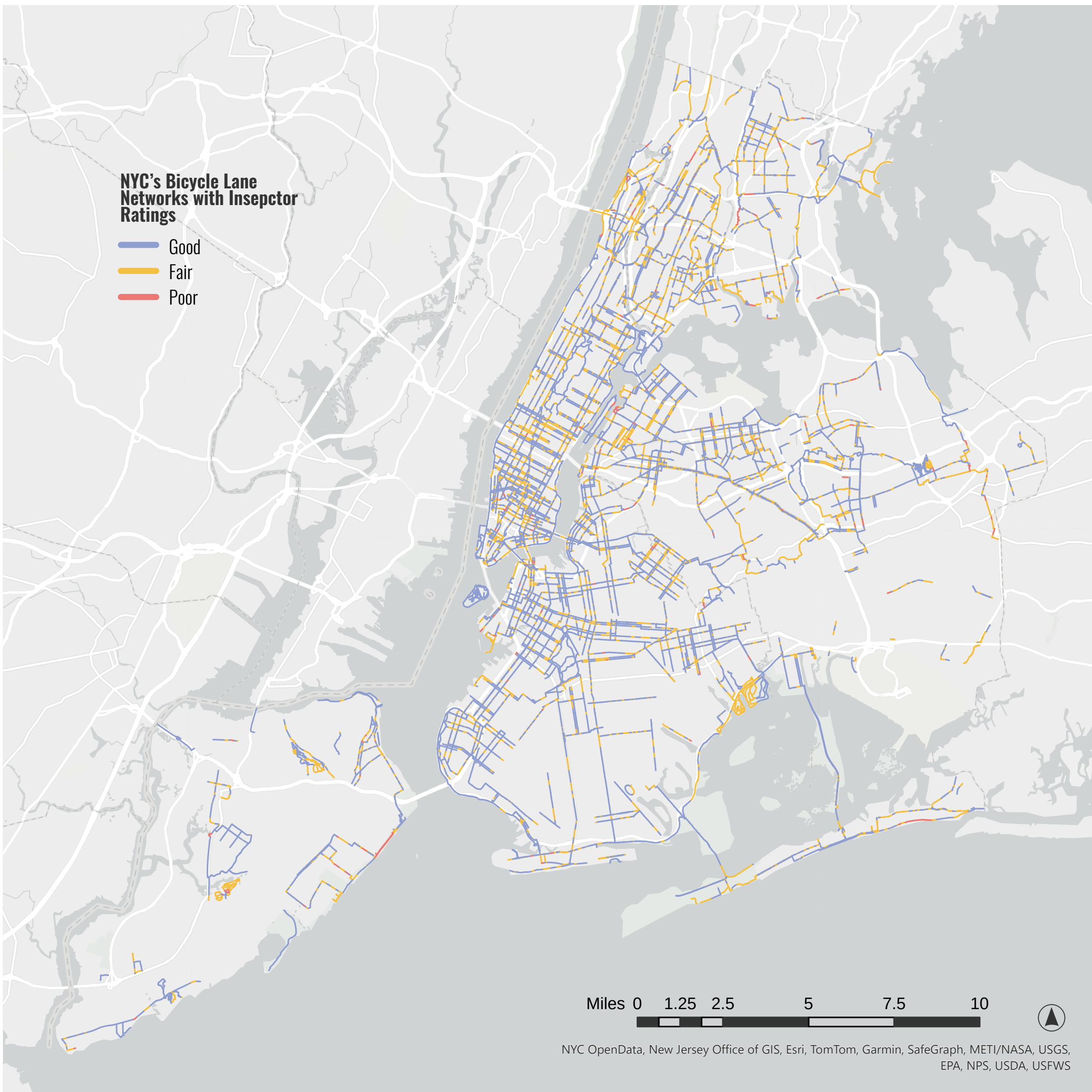


Map 1 - Total Bike Crashes from February 2023 - February 2024

2,624 of those crashes occurred within or adjacent to an official bicycle lane facility.

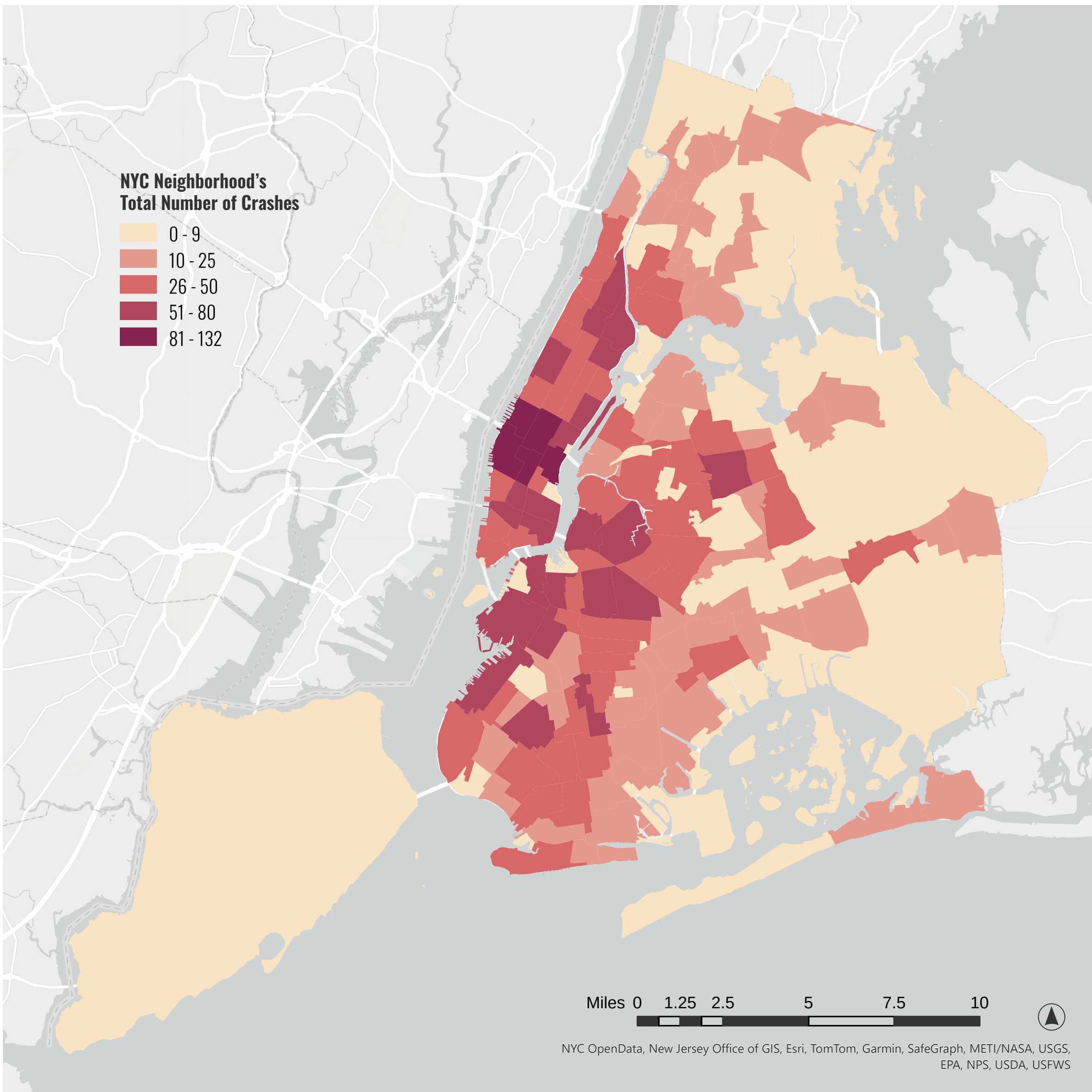
Map 2 - Total Bike Crashes Within or Near the Bicycle Network

NYC's 22,607 bicycle lane segments have an inspector rating of 53% good, 45% fair and 2% poor



Map 3 - NYC's Bicycle Lane Network with Inspector Rating

The top 3 neighborhoods in NYC with the highest crashes - 334 - are in Midtown-Times Square, Flatiron-Union Sq and Chelsea-Hudson Yards.



Map 4 - Density of Bike Crashes by Neighborhood

Neighborhood Crash Data, Bike Lane Ratings and Percentage of Good, Fair, or Poor in Each; Top 50

Crash data from February 2023 - February 2024

Neighborhood	Crash	Poor	Fair	Good
Midtown-Times Square	132	1	99	87
Midtown South-Flatiron-Union Sq	104	0	66	65
Chelsea-Hudson Yards	98	0	80	139
Murray Hill-Kips Bay	94	0	47	91
Hell's Kitchen	92	0	49	75
Bedford-Stuyvesant (West)	80	1	47	131
Harlem (South)	79	0	46	74
Williamsburg	79	0	87	197
East Harlem (North)	78	2	147	207
Borough Park	78	1	14	23
East Village	75	0	69	209
Greenwich Village	73	0	66	79
Park Slope	73	0	33	125
Lower East Side	68	6	158	191
Harlem (North)	65	0	48	141
Flatbush	65	0	15	30
Fort Greene	65	0	49	148
East Midtown-Turtle Bay	64	1	48	39
SoHo-Little Italy-Hudson Sq	64	2	70	61
Sunset Park (West)	63	4	61	153
Dtown Brooklyn-DUMBO-Boerum Hill	62	4	165	151
East Harlem (South)	60	0	85	103
Upper West Side (Central)	60	0	89	117
Elmhurst	60	0	103	131
Bedford-Stuyvesant (East)	59	0	13	28

% Good, Fair, Poor in Neighborhood

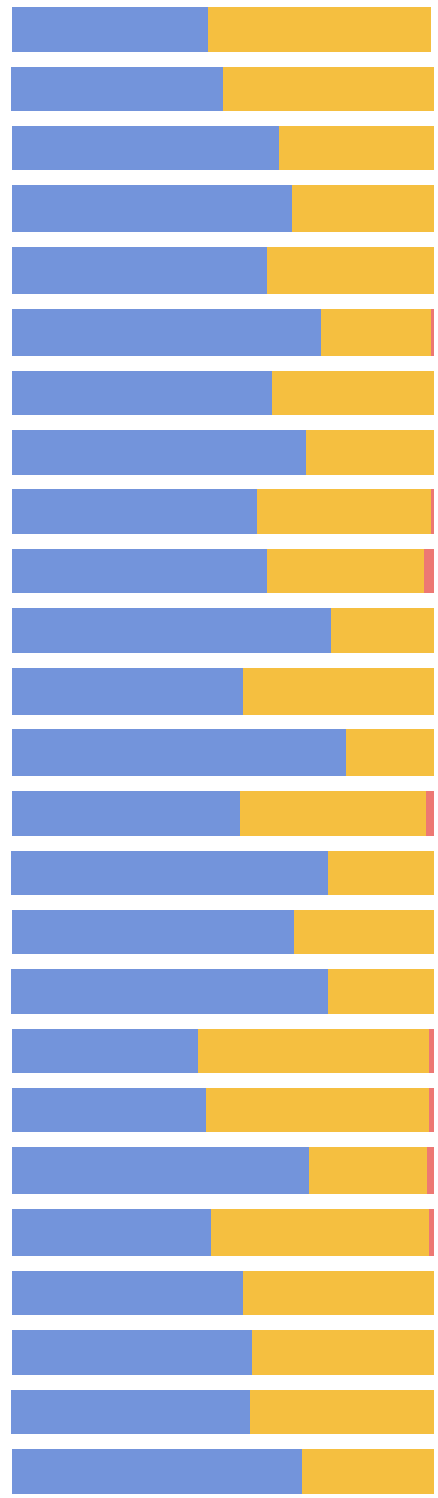


Table 5.1 - NYC Bike Crashes and Ratings by Neighborhood

Neighborhood	Crash	Poor	Fair	Good
Carroll Gardens-Cobble Hill-Gowanus-Red Hook	59	8	117	319
East Williamsburg	55	8	63	119
Upper East Side-Lenox Hill-Roosevelt Island	54	5	84	159
Bushwick (West)	50	2	42	76
Crown Heights (North)	49	0	59	151
Upper East Side-Carnegie Hill	48	0	13	44
Upper East Side-Yorkville	48	0	34	58
Bensonhurst	48	0	3	1
Central Park	47	0	70	224
Washington Heights (South)	44	2	86	83
Morningside Heights	43	0	25	33
Jackson Heights	43	2	83	122
Bushwick (East)	42	0	58	100
Clinton Hill	42	0	20	53
Gramercy	41	0	18	61
Mott Haven-Port Morris	41	4	175	130
Prospect Heights	41	0	25	43
Upper West Side-Lincoln Square	40	0	47	31
Chinatown-Two Bridges	39	0	139	152
Sunset Park (Central)	39	1	28	59
Jamaica	38	0	22	21
Woodside	38	0	78	115
Tribeca-Civic Center	37	2	56	66
Gravesend (East)-Homecrest	37	0	10	15
Sunnyside	37	1	130	192

% Good, Fair, Poor in Neighborhood

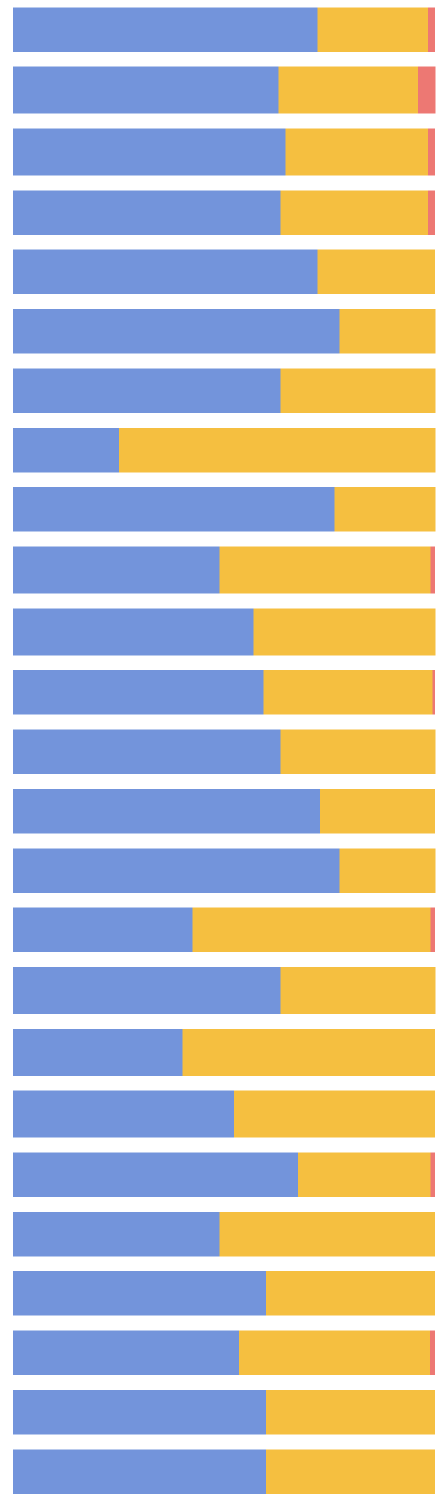
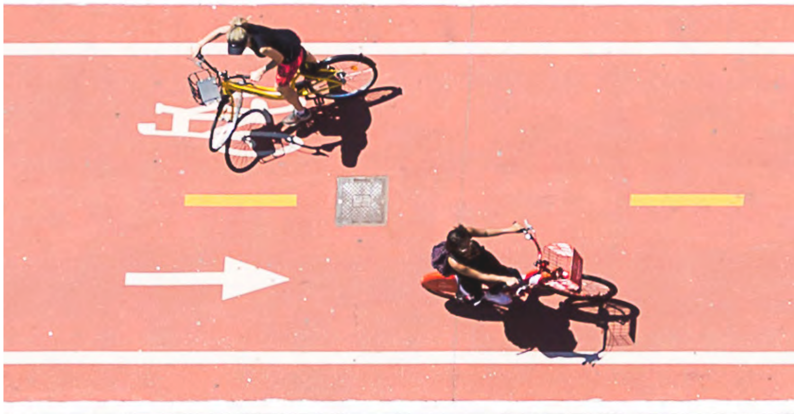


Table 5.2 - NYC Bike Crashes and Ratings by Neighborhood

Results

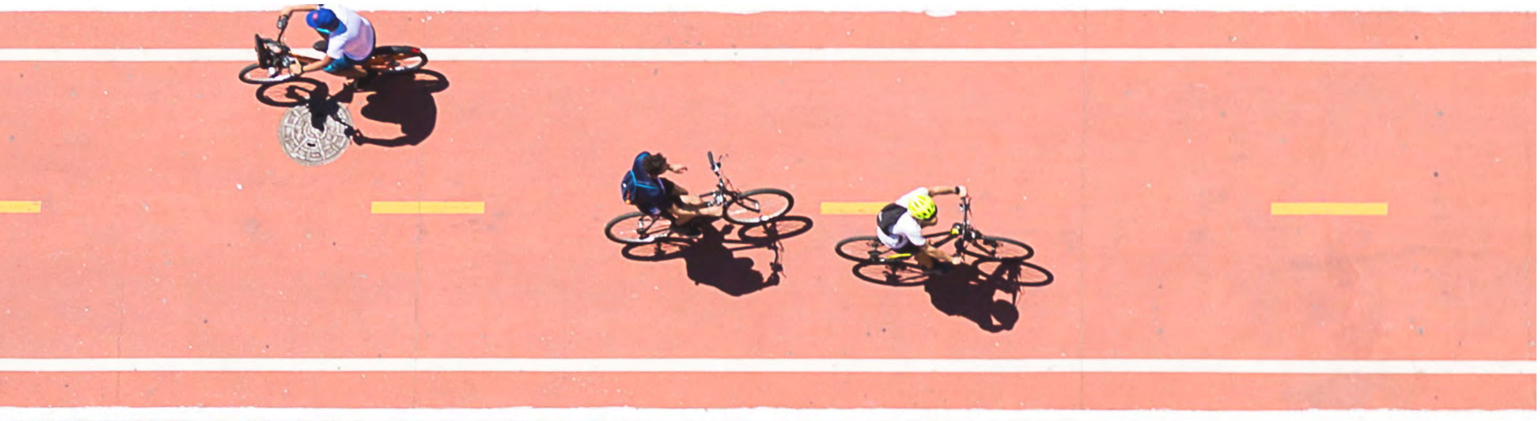
The analysis of the data described above reveals that between February 2023 and February 2024, NYC's 22,607 official bicycle lane segments had an astonishing 5,073 recorded instances of a bicycle involved in a crash. NYC neighborhoods with highest total number of crashes in the past year can be seen in Map 4. When comparing NYCDOT's data in Figure 8 to Map 4, NYCDOT's findings on areas that are considered priority in reducing crashes do not line up on where the crashes have been occurring between 2023 and 2024 and where the priority areas are along the cycling infrastructure. Building on this, Table 5 further demonstrates the top 50 neighborhoods in NYC with the highest bike crash incidences along the bike network. At the time of this writing, this study reveals NYC's overall vehicular infrastructure has been rated by its inspectors as 60% good, 38.8% fair, and 0.6% poor. Compared to the cycling infrastructure and the NYC inspector's ratings they have been paired with, it has been found that the cycling infrastructure has ratings of 53% good, 45% fair, and 2% poor.

It is also revealed in Map 3, that pairing crash data with bicycle lane facility type show a more distributed variation in inspector rating-except for the boardwalk facility type. Bicycle lane facility types that are standard and are a sharrow have some of the highest percentages of overall bike crashes between 2023 and 2024 at 38% and 15% respectfully. Interestingly, 37% of reported crashes were revealed to be within or near a protected bicycle lane. To understand this, reported NYPD crash data reveals that 33% of the reasons for crashes in or near a protected bicycle lane were due to "Driver Inattention/ Distraction". No further detail is provided with this crash data; however, with 33% of NYC crashes occurring within an intersection [31] we can assume the buffered crash points absorbed these instances. It is worthy to note that NYC does not rate their intersections at the time of this writing.



Facility Type	Crash Total	%	Good	Fair	Poor
Standard	988	38%	57	42	1
Protected Path	963	37%	56	43	1
Sharrows	401	15%	56	42	2
Curbside	99	4%	62	37	1
Bike-Friendly Parking	77	3%	58	42	0
Signed Route	36	1%	58	41	1
Greenway	30	1%	66	32	2
Sidewalk	12	0%	57	43	0
Buffered	10	0%	58	41	1
Link	6	0%	72	26	2
Ped Plaza	2	0%	60	40	0
Boardwalk	0	0%	48	39	13
Dirt Path	0	0%	50	48	1
Other	0	0%	56	44	0
Velodrome	0	0%	100	0	0

Table 6 - Facility Type with Rating Percentage



Inspector Rated Cycling Infrastructure Rating Percentages

Analyzing the Data

Obtaining the cycling infrastructure ratings from the most recent vehicular roadway ratings suggest that even though a roadway or bicycle lane was rated as good by NYCDOT inspectors, there are still high rates of bicycle crashes still occurring. With most of NYC's bicycle infrastructure being of Fair to Good quality, joining the most recent vehicular roadway rating with NYC's cycling network infrastructure alone does not fully explain the extent of cyclist crashes in NYC. NYPD's crash data is also very limited, the data only accounts for a bicycle crash when there is another vehicle involved and only accounts for a bicyclist, not other modes of micromobility. Additional factors must be considered to develop effective measures for understanding the roadways that are used by the most vulnerable users, reducing crashes and improving cyclists' safety.

Community Feedback and User Experience in NYC

As mentioned, NYC does utilize community feedback from community meetings and complaint portals as do several other cities. The reporting system that NYC uses for complaints, 311, is a powerhouse complaint portal accounting for tens of millions of complaints a year. A sample size of bicycle lanes complaints from June 2010 through May 2024 complied by an external community organization exported over 100 thousand complaints, specifically complaints on blocked bicycle lanes. At the time of this writing there were no other organized types of data sets regarding bicycle lanes from NYC and this data set was organized by a community member group and not NYC directly. This data has been useful, in 2023 NYC introduced a new effort to get people to report issues they see on the street called the Loading Zone Feedback Portal [32]. This new portal is limited to issues blocking bicycle, bus and vehicular moving lanes. With cyclist injury and death on record highs, how can we leverage the rising numbers of cyclists to report issues on their routes. Much like the new Loading Zone Feedback Portal, technology is the answer to creating a similar real time application that is all inclusive and will provide municipal leaders information specific to and for micromobility users.

Recommendations

Theme 3 Recommendations for NYC

Implementing a Comprehensive Bikeability Index

Understanding the most recent NYC Plans such as the NYC StreetsPlan which is advertised as a "five-year transportation plan to improve the safety, accessibility, and quality of the City's streets for all New Yorkers," [28] led to the realization that there are no plans to implement a method to eliminate cycling crashes.. The synthesis of studies, notably those by Arellana, Hardinghaus and Calvey, emphasize the importance of a demand-driven approach to cycling infrastructure design and maintenance [6, 14]. NYC can borrow these insights as well as what has been collected from several other cities to implement a Bikeability Index (BI) [6, 9] which is tailored to an urban landscape. This index will account for factors such as poor infrastructure quality that pertain to both the vehicular lane and the cyclist path, cyclist safety, and overall user preference such as use. In the studies conducted in Germany, Denmark and the Netherlands, it was found that most respondents were likely or very likely to choose to cycle on off-street paths (71%–85% of respondents); physically separated routes next to major roads (71%); and residential routes (48%–65%) [26]. This user defined data allowed for cyclists to speak to their preferences and can help NYC understand where they can best add to the bicycle network to best serve the users.

Adopting a Demand-Driven Design Approach

Arellana and Hardinghaus' studies focus on the significance of constructing a BI that includes cyclist preferences and safety concerns. The methodology involved factors like directness, comfort, traffic safety, and security, assigning weights to these factors based on user feedback. When Arellana's study was conducted in Barranquilla, Colombia, their results revealed that primary roads, despite having lower BI values due to higher accident rates, were preferred more by cyclists [2]. This finding allows NYC to prioritize enhancing safety on high-demand routes to cater to actual cycling patterns. With that, further research must be completed to enhance street ratings and further understand crash data to understand the weight of importance each road has on its users. "The mode choice model shows a strong positive effect of a high bikeability along the route on choosing the bike as the preferred mode" [6], reinforcing the need for a comprehensive and well-implemented bikeability index in NYC.

Addressing Safety Concerns Through Infrastructure Condition Assessment Enhancements

As seen in much of the paper so far, the need for regular maintenance and quality assessment of cycling infrastructure is important [14]. Current roadway inspection efforts done by NYCDOT inspectors do not identify issues that directly affect cyclists and bike lanes such as uneven surfaces, inadequate drainage, and insufficient signage, as depicted in Appendix 2. These factors significantly impact cyclists' safety and comfort, which leads to crashes. The study by Calvey recommends establishing regular maintenance schedules and promptly addressing issues like cracks, potholes, and faded markings. NYC must adopt a similar approach towards its bicycle lanes, ensuring that bike lanes are frequently maintained and remain safe for use throughout the year. This new type of inspection can immediately begin and occur within the cycling infrastructure that is within vehicular paths such as sharrows. This will allow for the NYCDOT inspectors to rate the shared lane along with the roadway providing a bicycle lane rating for the first time. At the time of this writing, NYCDOT can easily adapt their current vehicular infrastructure rating application to include all the recommended bicycle lane defects shown in Appendix 2 and be the first in the world in being proactive in the safety of its cyclists.

NYC must utilize a BI and Demand Driven Design while continually using community feedback to be revolutionary and lead the design and implementation of a cyclist infrastructure inspections. NYC can help cyclists by using cyclists through an application extension, plug-in or a standalone application that gives the users of the cities infrastructure the opportunity to become a roadway inspector and rate their own network that they use frequently. Combining the foundations of applications such as Yelp! or Google Maps reviews with fitness tracker applications such as Strava or AllTrails along with already successful crowdsourced transportation mapping applications such as Waze or Transit, can allow the users to rate the current network, as well as regular roads, provide a real-time update on issues that may exist allowing for municipal planners or engineers to readily understand needs that exist immediately.

Application	Core Functionality	How It Can Be Used	How Users Rate Their Experiences	Benefits to Others
yelp	Business reviews and recommendations	Find reviews and ratings for local businesses	Generally positive, with some criticism for fake reviews	Helps businesses improve services based on feedback
Google Maps	Navigation and location-based services	Get directions, find places, and explore maps	Highly rated for accuracy and ease of use	Provides real-time traffic updates and location sharing
STRAVA	Activity tracking for running and cycling	Track workouts, analyze performance, join challenges	Very popular among athletes for its detailed analytics	Encourages a healthy lifestyle and community engagement
AllTrails	Hiking and outdoor activity guides	Discover and navigate trails with user reviews	Well-regarded for comprehensive trail information	Promotes outdoor activities and environmental awareness
waze	Community-driven navigation and traffic alerts	Navigate with real-time traffic updates from other users	Praised for real-time accuracy but can be overwhelming	Reduces traffic congestion through user-shared data
transit	Public transit navigation and scheduling	Plan trips, get real-time updates, and find routes	Positive for its accurate and timely information	Enhances public transit use, reducing reliance on cars

Table 7FTable - Current Relevant Applications

Real-time data can benefit both cyclists and municipal planners. Cyclists will receive immediate alerts about hazards, while planners will be alerted about those same hazards to promptly dispatch maintenance crews to address issues like potholes, root protrusions, or overgrown vegetation. When used like Waze or Transit App, the cyclist can report an issue as they occur. There can be an immediate alert or signal when there is a cyclist crash, emergency construction or parade taking place, marking the map for all other users to see the issue that is occurring in real-time. The application can be coded to alert emergency services where they are needed in case of a crash or emergency and additionally if accelerometer access is provided, the tactical feedback can send automated alerts to emergency services alerting of a crash – much as cell phones do now for vehicular crashes. *

*ChatGPT 4 assisted with the structure of this section.

Next Steps + Conclusions

Crowdsourcing Bikeability

Application Concept

The proposed application for NYC – and beyond - would allow cyclists to rate and report issues along the cycling network in real-time. This crowdsourcing approach would provide valuable data for urban planners and improve the cycling experience for users.

Key Features:

1. User Ratings and Reviews:

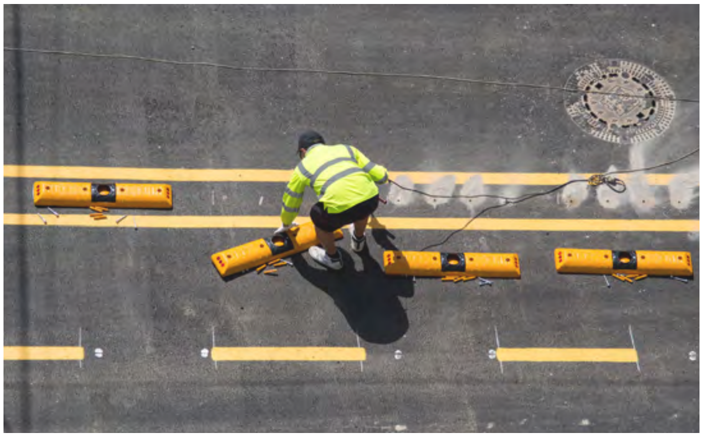
- Cyclists can rate micromobility paths based on the distress types noted within their networks.
- Users can submit reviews and multimedia documentation of specific issues.

2. Real-Time Issue Reporting:

- The app would enable cyclists to report problems such as potholes, obstructions, and safety hazards immediately.
- Integration with GPS and mapping services would enable precise geolocation of reported issues.

3. Integration with Emergency Services:

- The app could alert emergency services in case of emergencies.
- Using accelerometers and other sensors, the app could detect crashes and automatically notify authorities.



4. Data for Municipal Planners:

- The collected data would be accessible to city planners and maintenance crews through open data portals, helping them prioritize repairs and improvements.
- Regular updates on infrastructure conditions would facilitate better planning and resource allocation.

5. Community Engagement:

- The app would foster a sense of community among cyclists, encouraging them to contribute to the maintenance and improvement of the cycling network.
- Gamification elements, such as badges and rewards for reporting issues, could increase user engagement.

Conclusion

Takeaways

In conclusion, the urgency to enhance cyclist safety in NYC is there. The city's Vision Zero initiative, while initially promising, has not shown consistent results for a decade, especially for cyclists. Rising number of cyclist fatalities and injuries, along with the increasing popularity of active transportation, requires a shift in how the city approaches cycling infrastructure in both creation and maintenance. This includes more robust reporting into the type of crash that occurs to differentiate the type of micromobility device used. By learning from the successes and challenges of other cities worldwide, NYC can adopt a more comprehensive, data-driven, and user-centric approach to infrastructure development and maintenance.

The implementation of a Bikeability Index with a crowdsourced reporting app are not just minor technological advancements but they represent the needed shift towards empowering the user, cyclists, and involving them in the decision-making process. These tools can provide very useful real-time data, enabling the city to understand and prioritize repairs, identify high-risk areas as they change through the seasons, and tailor infrastructure enhancements to the specific needs of cyclists. By investing in these solutions, NYC can create a revolutionary enhanced cycling network that is not only safer but also more efficient, enjoyable, and equitable for all users. This, in turn, will lend a hand to a more sustainable and livable city, where cycling is not just a mode of transportation but a continued way of life.

Limitations and Continued Learning

While the data presented in this paper was robust, there could be more efforts made by municipal employees to understand what they are collecting much better. NYC is one of the densest and most populated cities on the planet and with that comes avalanches of data collection that becomes lost or inaccessible. At the time of this writing, my device is unable to work through the over 20 million lines of data for 311 reporting to figure out if there are any correlations between cyclists' needs, or crash information and the location of which they took place. This data could have provided me with more instances of crash information to join with the rated streets to gain a clearer understanding. Additionally, the equal amount of data that exists for street ratings prevented a year-by-year analysis of the crash data compared to the roadway's ratings. With that we could see if there is a direct correlation between improvements of roadways and crashes over the past decade along with a deterioration record of the roadways.

Additionally, while NYC has master plans to build out their network of cycling infrastructure, it should develop plans, or at the very least mention a plan to track the long-term impacts of any improvements to understand the evolving nature of cyclist behavior and crash rates. Further research should also be made into the equability and accessibility of the cycling network within NYC. NYC DOT noted that it is aware of high severity crash corridors that impact black and brown residents more, but there should be increased strategies on how to best meet their needs to ensure level safety all around.

And finally, if provided more time and an increased budget, the comparative analysis could include more cities worldwide – for example, Japan and South Korea were promising due to the appeal of their cycle infrastructure; however, the language barrier prevented further contact to gain deeper knowledge on the procedural efforts that are used to assist in enhancing NYC's current methods.

Appendix

1. PCI Distress Types

Alligator Cracking

Bleeding

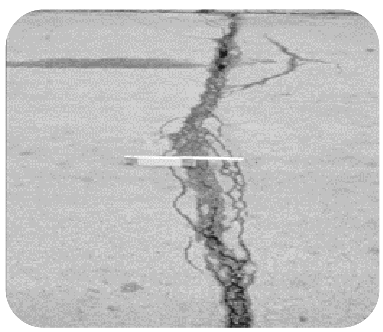
Block Cracking

Bumps

Corrugations

Depressions

Edge Cracking



Joint Reflections

Lane Drop Off

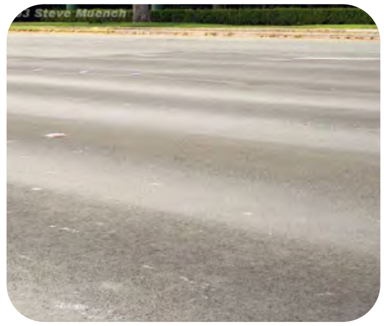
Longitudinal Cracking

Patching

Polished Aggregate

1. PCI Distress Types

Potholes



Rutting

Shoving

Slippage Cracking

Swelling

Raveling

2. Cycling Infrastructure Distress Types

Ponding

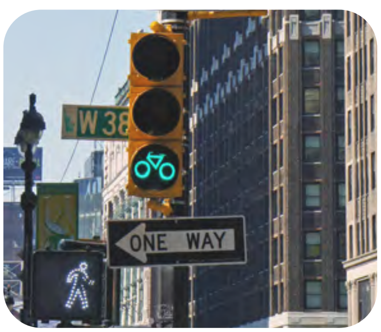
Poor Construction
Right of Way

Faded Markings

Double Parked Car

Bollard Issue

Signage Issue



Traffic Light Issue

Unkempt Landscape

Utility Bump

Abrupt End

Width Issue

Aggressive Joints

2. Cycling Infrastructure Distress Types

Protruding Roots

Track Spacing

Dangerous Intersection

Concrete Spillage

Utility Hazard

Poor Replacement

Obstruction

Debris/Snow

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Thank You.

Revolutionizing Cycling Infrastructure:
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and Management of
New York City's Cycling Network

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