Keep 'em Separated

A Desire Lines Analysis of Bidirectional Cycle Tracks in Montreal

Supervised Research Project Report
Submitted in partial fulfillment of the Masters of Urban Planning degree

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ABSTRACT

As cities worldwide aim to increase the presence of the bicycle as a legitimate mode of urban transportation, the perception of danger plays a significant role in deterring new potential users. In Montreal, Canada bicycle users claim to perceive intersections with bidirectional cycle tracks twice as negatively as similar protected facilities mid-block or intersections with painted bicycle lanes. This study aims to understand this negative perception through a fine-grained analysis and observation of the interplay between the built environment and bicycle user behaviour at these intersections. Using The Desire Lines Analysis tool pioneered by Copenhagenize Design Company, this paper offers recommendations and design interventions for two intersections with bidirectional facilities in the City of Montreal. Results demonstrate a predominant number of users following the prescribed routes of the built environment through each intersection, but also shine a light on over a quarter of users who do not. The trajectories of bicycle users that are questionably legal result in observed conflicts at both bidirectional intersections. Conflicts were grouped into three major observed themes – counter-flow interactions, priority confusion and directional awareness. Recommendations in this paper aim to address each one of these observed themes with appropriate designs that are choreographic, prioritized and predictable for all road users. Planners, engineers and urban designers can gain significant insight into best practice bicycle infrastructure through techniques such as The Desire Lines Analysis that observe behaviour and design accordingly.

RESUME

Alors que les villes à travers le monde tendent de plus en plus à légitimer la présence du vélo en tant que moyen de transport urbain, la perception du danger joue un rôle dissuasif marquant auprès des nouveaux utilisateurs potentiels. À Montréal, les cyclistes affirment percevoir les intersections munies de pistes cyclables bidirectionnelles en bordure de rue de manière deux fois plus négative que les autres installations similaires, protégées au milieu de la rue ou aux intersections, avec des bandes cyclables. Cette étude vise à permettre la compréhension de cette perception négative à l'aide d'une analyse précise et d'observations de la réciprocité entre l'environnement bâti et le comportement du cycliste dans de telles intersections. En utilisant l'outil « Desire Lines Analysis » introduit par Copenhagenize Design Company, le présent document présente des recommandations et des interventions de conception pour deux intersections de la Ville de Montréal dotées d'installations bidirectionnelles. Les résultats démontrent un nombre prédominant d'usagers suivant les voies prescrites par l'environnement bâti, mais attirent également l'attention sur plus du quart des cyclistes qui ne les respectent pas. Les trajectoires légalement discutables de ces cyclistes résultent en des conflits observables aux intersections bidirectionnelles. Ces conflits ont été regroupés en trois grands thèmes : les interactions à contre-courant, la confusion en matière de priorités et la conscience directionnelle. Les recommandations incluses dans le présent document visent à répondre à chacun de ces thèmes observés avec des designs appropriés, lesquels sont chorégraphiques, priorisés et prévisibles pour tous les utilisateurs de la route. Les planificateurs, ingénieurs et urbanistes peuvent accéder à un aperçu des pratiques exemplaires en termes d'infrastructures cyclables grâce à des techniques telles la « Desire Lines Analysis » qui observe le comportement et la conception en conséquence.

INTRODUCTION

As interest and discourse surrounding urban cycling has become more present across the globe in the last decade, North American cities have been actively involved in this transportation shift. Although generally lagging behind their European counterparts, major cities in Canada and the US have expanded their urban cycling facilities and have seen a significant increase in cycling modal share and government investment since the early 2000s (Pucher, Buehler & Seinen, 2011). More recently, interest by North American cities for cycle tracks (protected on-street bicycle facilities) has gained considerable attention – inspired by the success of cities like Copenhagen, Amsterdam and Groningen who have some of the highest modal shares and most extensive on-street bicycle networks. Studies in both Europe and North America point to cycle tracks as having the lowest injury risk factor of all types of bicycle facilities as well as contributing to an increase in bicycle traffic and accompanying decrease in motor vehicle traffic (Teschke et al., 2012; Pucher, Dill & Handy, 2010). Following Jacobsen's 2003 findings of "Safety in Numbers", cycle tracks also arguably offer a promising opportunity for cities to increase their ridership numbers (and thus bicycle and pedestrian safety) through lowering the barrier to entry – namely the perceived danger of urban cycling (Jacobsen, 2003). Negative perception has been shown to be an important deterring factor for potential bicycle users, while cycle tracks have been rated as some of the most preferred or positively perceived bicycle infrastructure in surveys from Vancouver to Copenhagen (Hull & O'Holleran 2014; Teschke et al., 2012; Pucher, Dill & Handy, 2010).

With the oldest and most extensive network of cycle tracks in North America, Montreal, Canada presently has 82km of protected on-street bicycle facilities, within its overall bicycle network of 748km encompassing recreational trails, painted lanes and designated shared streets (Vélo Québec, 2015). Although the city has announced the creation of a new 6km segment of unidirectional cycle tracks, the entirety of Montreal's existing protected network is made up of bidirectional paths located on one side of the street, separated from motor vehicle traffic by either concrete barriers or plastic bollards adjacent to a row of parking (Ville de Montréal, 2016). In a local 2013 survey conducted by the Transportation Research at McGill (TRAM) group, respondents were asked to rate their feeling of safety for different types of bicycle facilities in the city of Montreal – at both mid-block and intersection locations. Results showed that bicycle users felt safer using cycle tracks mid-block than painted lanes or no infrastructure – but when located at intersections, bidirectional cycle tracks were perceived twice as dangerous (responses of 'bad' and 'very bad') – even more dangerous than painted lanes (see table 1).

<u>**TABLE 1: Perception of infrastructure types by Montreal bicycle users**</u>

TYPE OF BICYCLE FACILITY	Negative Perception Mid-Block	Negative Perception at Intersection
Arterial without Facility	57%	46%
Painted Bicycle Lanes	26%	20%
Bidirectional Cycle Tracks	17%	33%
Calm Residential Street	9%	9%

Data from 2013 TRAM Montreal Cycling Behaviour Survey

Given that the perception of danger acts as an important deterring factor to new bicycle users, it is important to understand why existing users may perceive bidirectional cycle tracks negatively at intersections and offer some improvement strategies to decrease this negative perception. This paper uses The Desire Lines Analysis tool to perform a fine-grained analysis of bicycle user behaviour through bidirectional intersections in Montreal in order to bring to light some of the reasons that may influence its negative perception. It begins with a brief review of observational analysis methodologies used in the field of urban and mobility planning, and subsequently presents the methodology by which data was collected, treated and analyzed for this study. The final sections examine the conflicts that arise in these intersections, providing design intervention recommendations and conclusions.

BACKGROUND

Observational analysis has been discussed and used as an effective tool for studying street life and human behaviour in urban planning for several decades now (Gehl & Svarre, 2013). This discourse of observing patterns and habits at the street level was launched into the American mainstream with the writings of Jane Jacobs in the late 50s and early 60s – critiquing and rebelling against top-down, theory-based city planning:

> *"You've got to get out and walk. Walk, and you will see that many of the assumptions on which the projects depend are visibly wrong … It is the premise of this article that the best way to plan for downtown is to see how people use it today; to look for its strengths and to exploit and reinforce them."* (Jacobs, 1958)

In 1970, William H Whyte formed a research group while working with the New York City Planning Commission – The Street Life Project, where he directly observed and documented people using public space in the city. This method of direct observation had previously been employed primarily in anthropological and ethnographic studies, but Whyte's work was seminal in bringing this form of analysis into the city space. In his work The Social Life of Small Urban Spaces, Whyte discusses the mandate by which his research group was originally formed – to study urban crowding, when in fact they often found through observation the opposite to be true – many public spaces suffered from vast emptiness (Whyte, 1980). His research often also featured the placing of a camera for several hours at a high vantage point and recording time-lapse photography of public space in order to map the locations and patterns of people. This early use of city observation enabled researchers to challenge long-held assumptions about how we design our urban space.

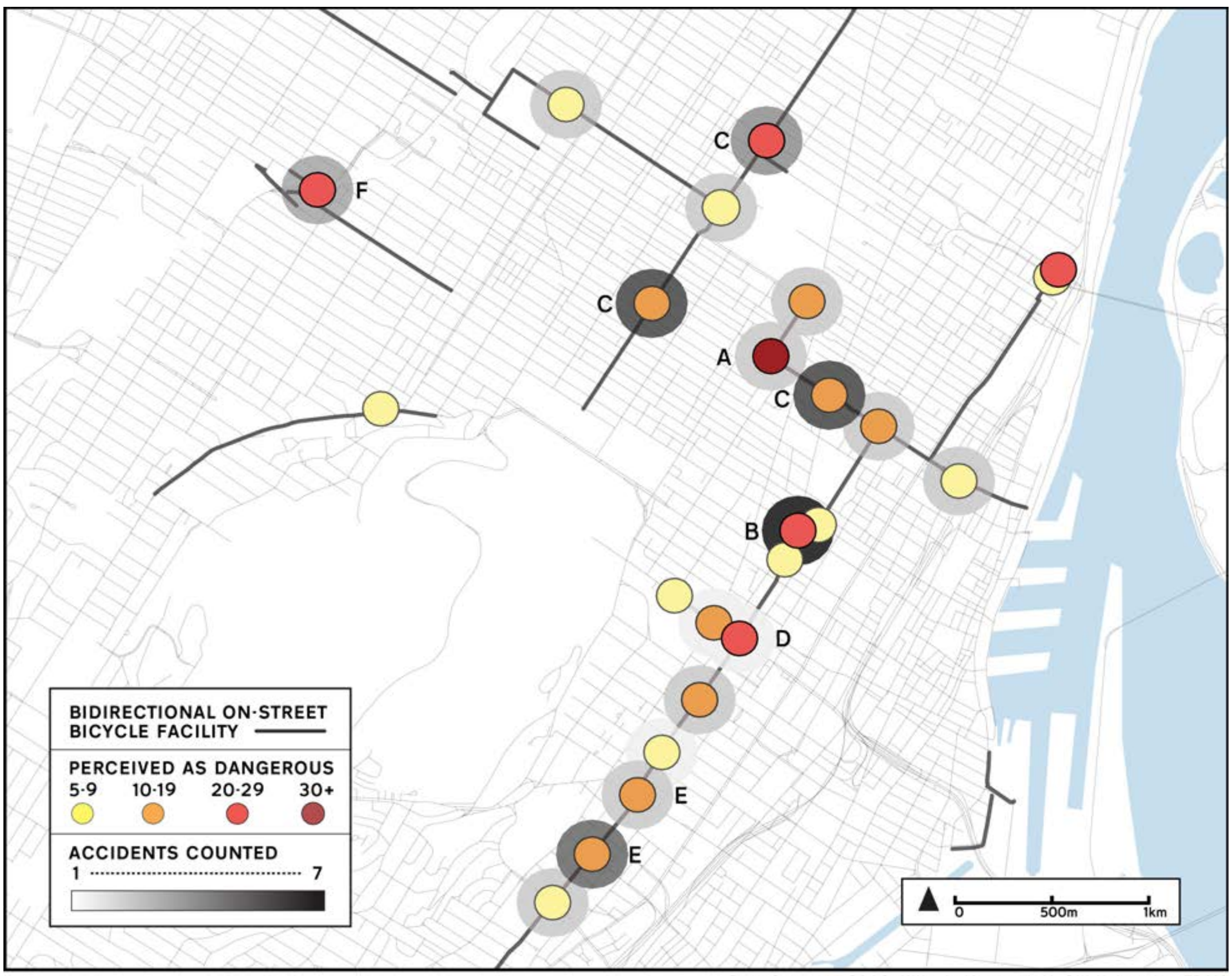
Since the 70s, the work of Danish urban planner Jan Gehl has continued to formalize and canonize methods for observation in city spaces. His 2013 book How to Study Public Life lays out various methodologies to understand context-specific issues in the parks, streets, playgrounds and unidentified spaces of our cities – to a greater specificity than was described in Whyte's earlier work (Gehl & Svarre, 2013). Gehl's writing and speaking has popularized both quantitative and qualitative methods of analysis in cities, such as pedestrian counts, pedestrian mapping and documenting patterns of behaviour. Operationally, many of the study methods used and discussed by Gehl have played an important role in the work of the traffic department in his hometown of Copenhagen, Denmark. Pedestrian counts performed by the city in 1985 led to the redevelopment of the Strøget walking street in the city centre (City of Copenhagen, 2012). A thorough methodology of observational techniques applied to bicycles has also allowed the city to study and develop arguably one of the world's most comprehensive urban bicycle networks with nearly 400 kilometres of on-street cycle tracks (City of Copenhagen, 2015).

Many North American and European cities today have installed automated bicycle and pedestrian counters and employ some methodology of manual counting – to varying degrees of success. The City of Montreal currently uses data from 21 automated bicycle counters (generally magnetic loop counters in the pavement) to understand overall bicycle flows and citywide displacements of bicycle users. Researchers have been able to use this macro-level data to articulate patterns at the urban scale – from temporal trends to impacts of weather on cycling (Miranda-Moreno & Nosal, 2011). However beyond this high-level analysis, there has been a lack of understanding into how bicycle users interact on the ground with the design of infrastructure – particularly at intersections, which have been found to be the most collision-prone element of a road network (Morency & Cloutier, 2005). Bicycle urbanism consultancy – Copenhagenize Design Company began testing out a new observational analysis tool dubbed The Desire Lines Analysis in 2012, to begin building a new body of knowledge on bicycle user behaviour. As a fine-grained analysis, this method of observation traces the movements of bicycle users through an intersection, much like

Jan Gehl's pedestrian tracing techniques employed in studying public space (Gehl & Svarre, 2013). The resulting 'Desire Lines' show where bicycle users choose to ride, both where they are legally permitted to, and where they are not, therefore offering new insights into the potential disjoint between the built environment and behaviour of bicycle users. Since 2012, The Desire Lines Analysis has been performed at numerous intersections in Copenhagen and in Amsterdam, with an ongoing strategy to continue this work in a global study and compare the interaction of bicycle user behaviour with infrastructure types across the world. This study in Montreal serves as the first investigation of on-street bidirectional cycle tracks (Colville-Andersen et al., 2012; Axinte et al., 2014; Imbert & te Brömmelstoet, 2014).

METHODOLOGY

In order to identify candidate intersections to study in the city of Montreal, the 748 kilometres of bicycle facilities on the island were segmented into their component elements: 271 kilometres of recreational or off-street paths, 214 kilometres of painted on-street bicycle lanes, 181 kilometres of shared or marked streets, and 82 kilometres of protected on-street cycle tracks (Vélo Québec, 2015). These final 82 kilometres of bicycle facilities were plotted out spatially and given 50 metre buffers at each intersection point. These buffers served as catchment areas for the responses of surveyed cyclists in which they were asked to place a pin on the intersection in Montreal they felt was most in need of improvements. Of the 1280 recorded points of concern from respondents, the intersections touching or near (10 metres away) a protected on-street bicycle facility with 5 or more dropped pins were logged and recorded. These results were then overlaid with geo-located 2013 and 2014 bicycle accident data from the *Société de l'assurance automobile du Québec*, recording the number of accidents to fall within each of the previously logged 50-metre intersection buffers. The results of this intersection selection process can be seen in figure 1 with studied intersections A and B identified.



Data Sources · SAAQ, Ville de Montreal, McGill University, TRAM
Coordinate System · NAD83(CSRS) / MTM zone 8
Date · August 1, 2016

FIGURE 1: Bidirectional cycle track intersection selection in Montreal

Among the final selection of intersections, types of road configurations were grouped together (i.e. Two intersecting one-way streets, with one bidirectional cycle track), to further identify subtleties in the built environment between each intersection that might influence the behaviour of bicycle users. The two final intersections selected for this study each respectively held the highest score for perception of danger by bicycle users and highest bicycle accident count for intersections with protected bidirectional facilities. Figures 2-4 shows the details of these intersections and the vantage points from which they were recorded. Each intersection also has a unique road configuration for intersections with bidirectional cycle tracks, allowing an analysis of these cycle tracks within different physical contexts. A schematic of these different road configuration types can be found in the appendix of this paper.

TABLE 2: Candidate intersections ranked in Montreal

INTERSECTIONS OF INTEREST	Perception of Danger	Accident Count	Type
Berri & Cherrier	●●●●●	●●	A
St. Urbain & de Maisonneuve	●●●●	●●●●●●●	B
Rachel & Papineau	●●●●	●●●●	C
Rachel & St. Denis	●●●	●●●●●●	C
Berri & Ontario	●●●	●●●●●●	C
University & de Maisonneuve	●●●●	●	D
du Fort & de Maisonneuve	●●●	●●●●●	E
Guy & de Maisonneuve	●●●	●●	E
St. Laurent & Van Horne	●●●●	●●●	F

The first intersection is Berri and Cherrier Streets, which had the highest negative perception for bidirectional cycle tracks in the city. It is a type A road configuration, which consists of two intersecting two-way streets and two intersecting cycle tracks. There are painted bicycle lanes on the north side of Berri Street (shown in red), as well as two bicycle signals in the north-south direction, which allow bicycles to cross in both north and south directions when motor vehicles are given a straight green arrow. The cycle tracks meet on the northwest corner of the intersection in a painted waiting box protected by plastic bollards – next to which there is a BIXI (Montreal bike share) station. There are bicycle-crossing marks in both directions, but are mostly faded out on the pavement. Lastly, on the south side of Berri, the road dips down into an underpass and the cycle track follows

The second intersection is Saint Urbain Street and de Maisonneuve Boulevard, which saw seven official bicycle accidents between 2013 and 2014 – the highest for intersections with bidirectional cycle tracks in the city. It is a type B road configuration with two intersecting one-way streets and only one bidirectional cycle track along de Maisonneuve. There is a painted southbound bicycle lane on Saint Urbain Street with a green bicycle box that also functions as a bus stop and faded bicycle crossing markers on the pavement. This intersection has the extra complication of another street bisecting Saint Urbain that is two-way at Ontario, and then switches to one-way, as it becomes President Kennedy Avenue on the west side. There are no bicycle signals here presently and bicycle users are required to use the straight green arrow and motorists are meant to yield.

Aerial photos for both of these intersections can be found in the appendix.

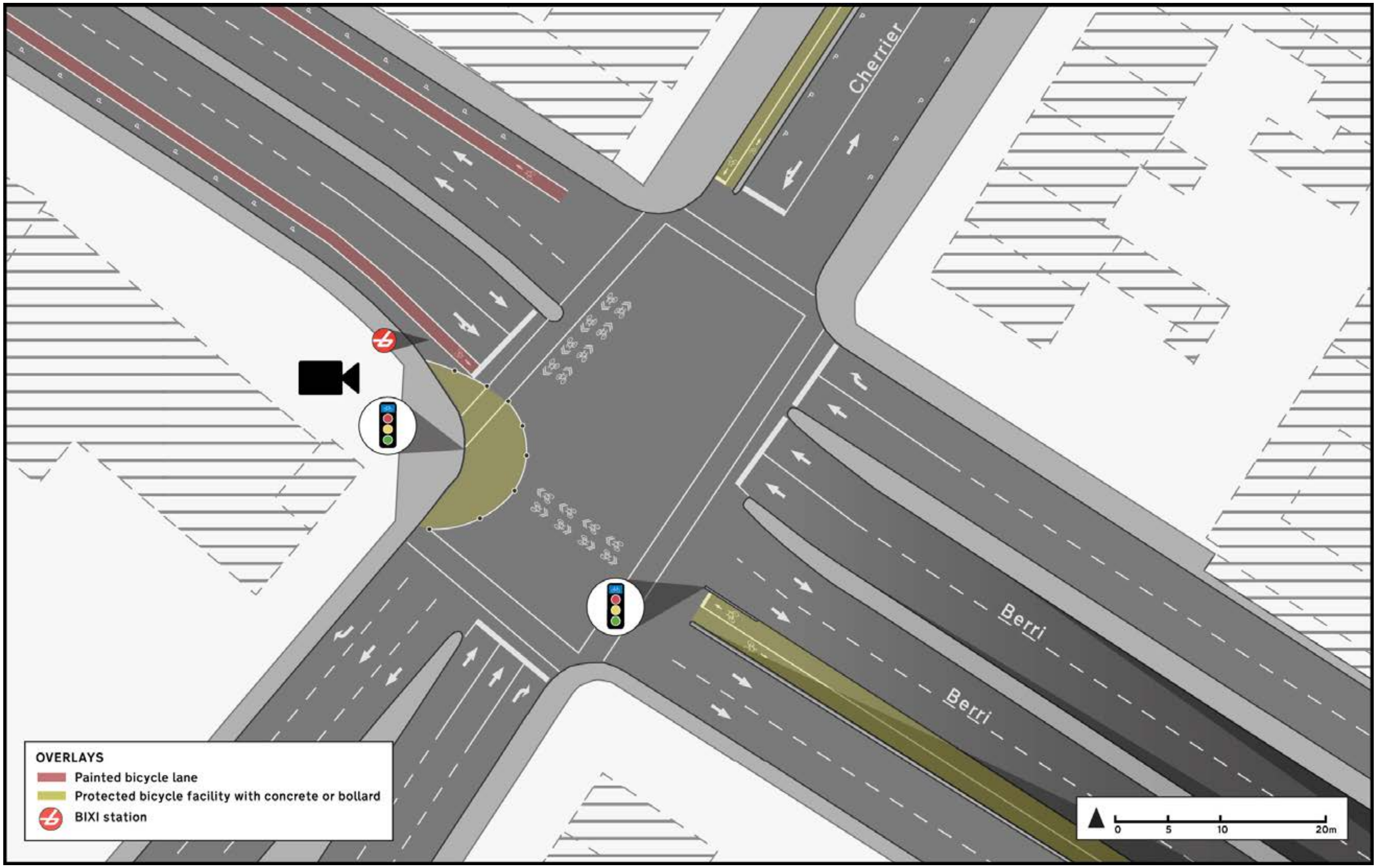


FIGURE 2: Intersection selection A – Berri & Cherrier Streets

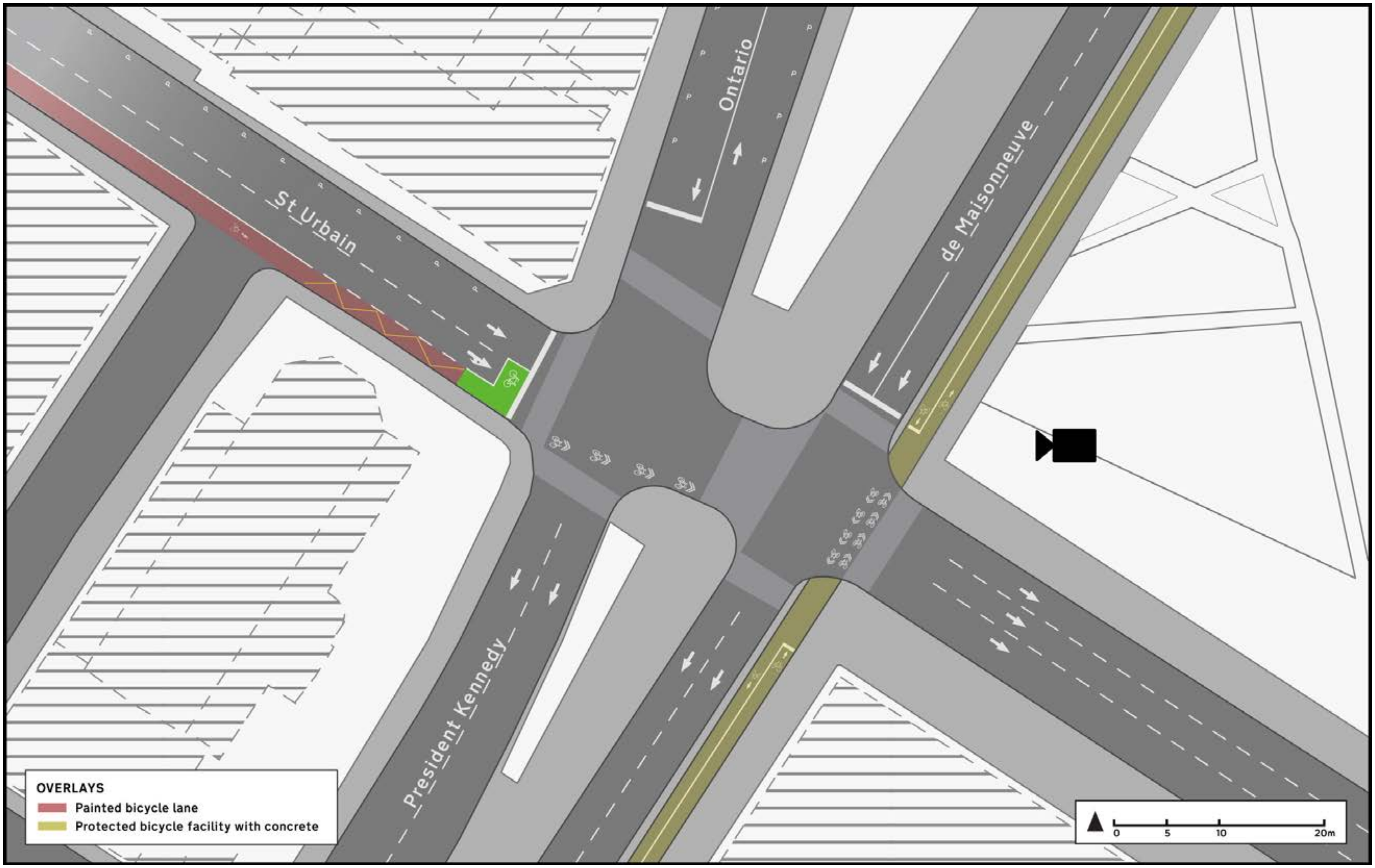


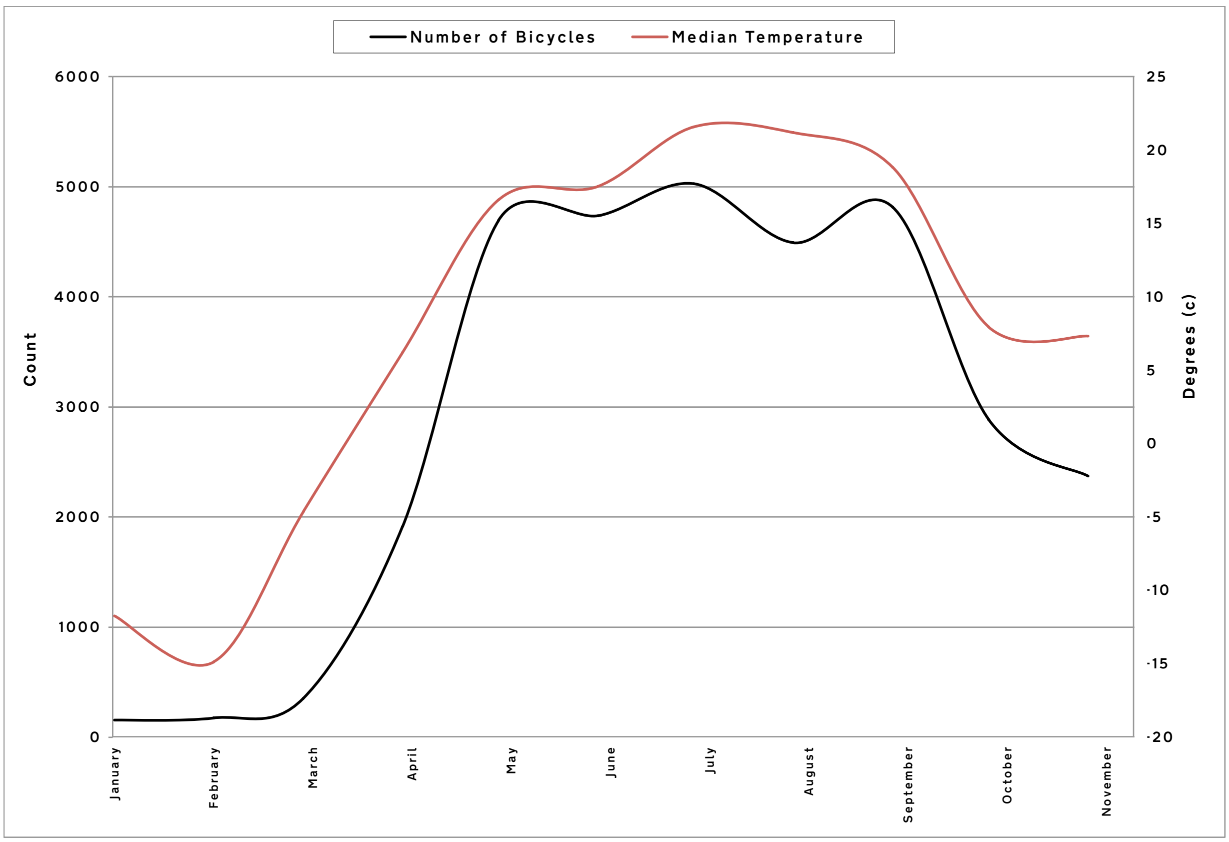
FIGURE 3: Intersection selection B – Saint Urbain Street & de Maisonneuve Boulevard

DATA COLLECTION

Each intersection was filmed from one vantage point (as can be seen in figure 4) on Tuesday, May 24 and Wednesday, May 25, 2016. In figure 5, the 2015 average monthly bicycle counts on Berri Street recorded by an automatic counter for the City of Montreal are plotted against the local median temperature of the same year, demonstrating that the month of May can be seen as the start of the significant biking season in Montreal. Yearly counting profiles of other major streets in the city follow a similar profile – with significant numbers of bicycle users beginning to peak in May.

FIGURE 4: Vantage points to film at each intersection

On each weekday of filming, video cameras recorded six hours of footage: morning rush hour (7:30am – 9:30am), midday (2:00pm – 4:00pm), and evening rush hour (4:30pm – 6:30pm). Both days saw warm summer weather in the range of 20 degrees Celsius (with 10 minutes of rain in the evening of May 25). The results and subsequent analysis portray the observed movements, flows, conflicts and indicators from these two intersections.



Data Sources: Ville de Montréal, Environment Canada

FIGURE 5: 2015 monthly bicycle counts on Berri/Montreal weather profile

RESULTS

In total, 12 hours of footage were analyzed, recording the following observations:

- *Desire Lines*: the paths taken by bicycle users
- Bicycle conflicts: collisions, near-misses, bunching, awkward manoeuvres, confusion
- Gender split
- Children on bicycle alone or with parents
- Presence of helmets
- Presence of personal versus public bicycles (BIXIs)
- Red lights run by bicycle users

The resulting desire lines for Berri and Cherrier streets can be seen in figures 6, 7 and 8.

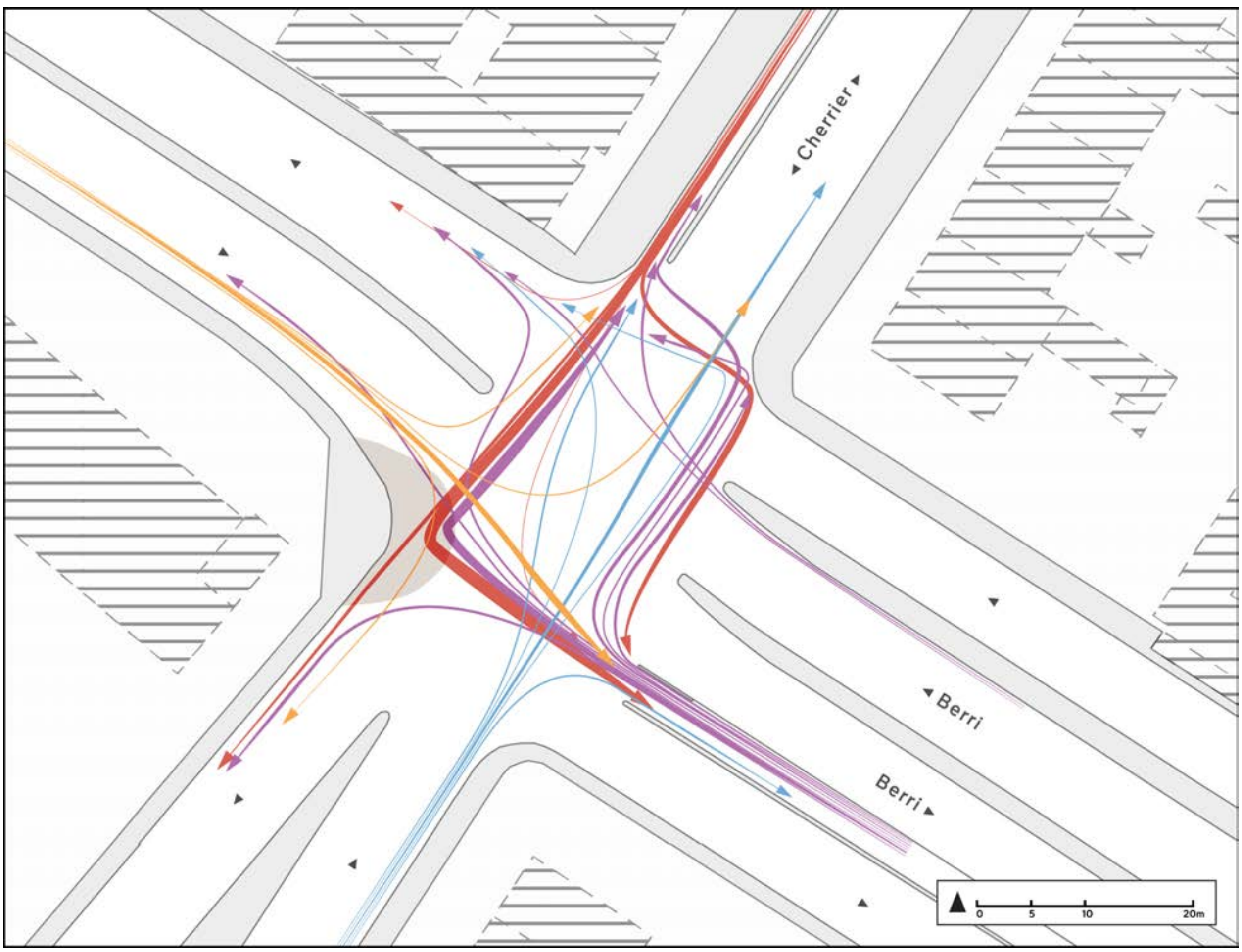


FIGURE 6: All Desire Lines observed at Berri & Cherrier

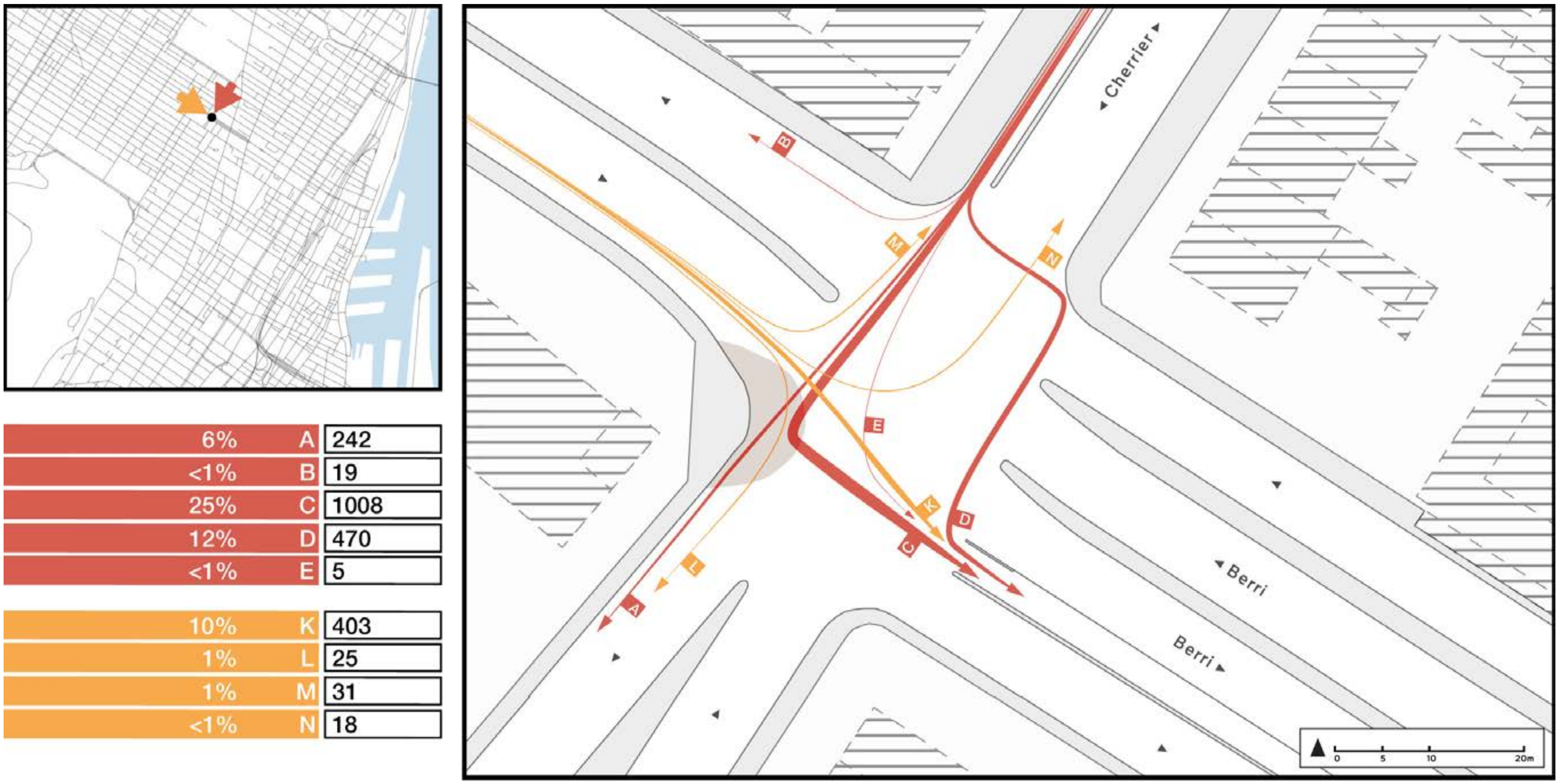


FIGURE 7: Desire Lines observed at Berri & Cherrier – Southbound & Westbound

4%	F	172
1%	G	53
1%	H	51
<1%	I	7
<1%	J	15
2%	O	70
3%	P/P2	68 / 45
6%	Q/Q2	177 / 67
7%	R/R2	262 / 29
17%	S	687
4%	T	156

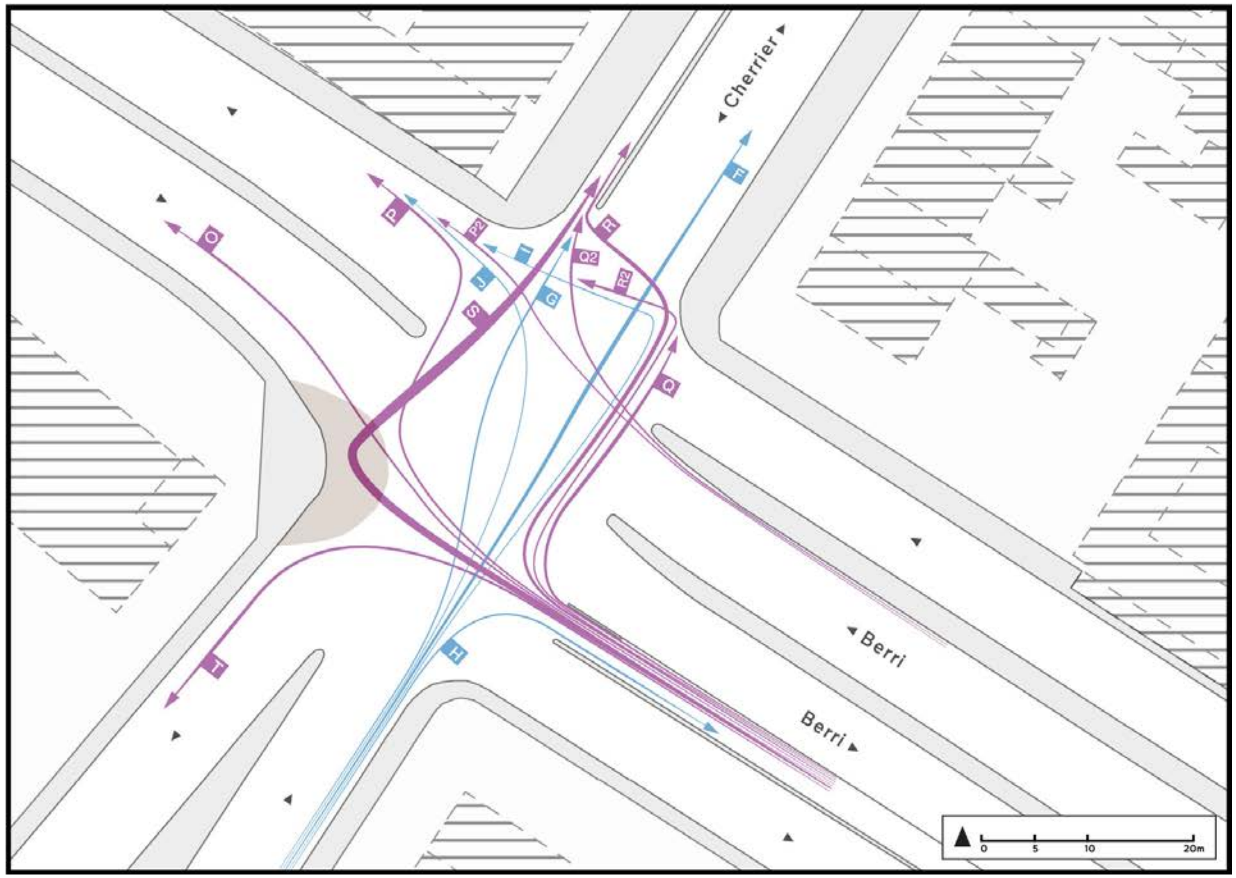


FIGURE 8: Desire Lines observed at Berri & Cherrier – Northbound & Eastbound

All in all, 4080 bicycle users were observed passing through the intersection of Berri and Cherrier, 60% of which were male and 40% female, while 18% of bicycles observed were BIXIs and 60% of users wore helmets. The most prominent path taken was desire line C – accounting for 25% of the total bicycle movement as users come from the east to take the Berri Street cycle track southbound – one of the few north-south protected bicycle routes in the city. The second most prominent movement, desire line S – is the inverse of desire line C, with 17% of users taking this path heading northbound on Berri and turning right in the waiting box eastbound towards the Cherrier cycle track. Observing these two movements in high volume is not surprising as the design of the intersection leads users this way. Interestingly is that when following the movements of desire lines D, Q and R, it can be seen that together another 25% of users opt for questionably legal paths to avoid the box turn prescribed by the current design. Only 4% of all bicycle users at this intersection or 149 bicycles directly broke the law by running red lights, but it is rather these questionably legal non-conforming desire lines that will serve as interesting and important to understand how conflicts arise in the following section of this paper. As referenced in previous desire lines from Copenhagenize Design Company, the presence of many different desire line trajectories can be seen as an indication that the existing infrastructure design does not conform to the wishes of bicycle users – namely, good design should be intuitive (Colville-Andersen et al., 2012; Axinte et al., 2014; Imbert & te Brömmelstoet, 2014).

Next, the resulting display of desire lines for Saint Urbain Street and de Maisonneuve Boulevard can be seen in figures 9, 10 and 11.

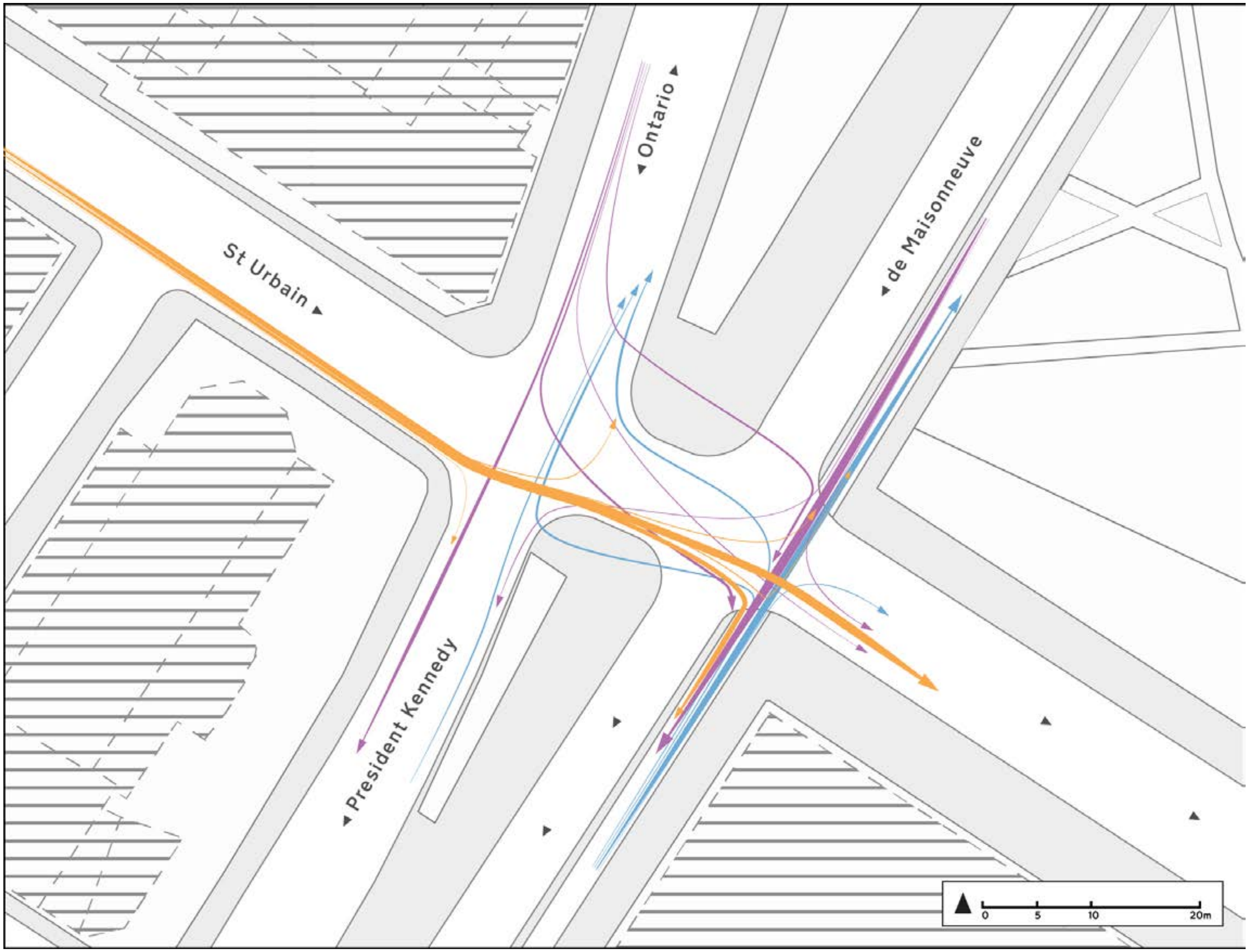


FIGURE 9: All Desire Lines observed at Saint Urbain & de Maisonneuve

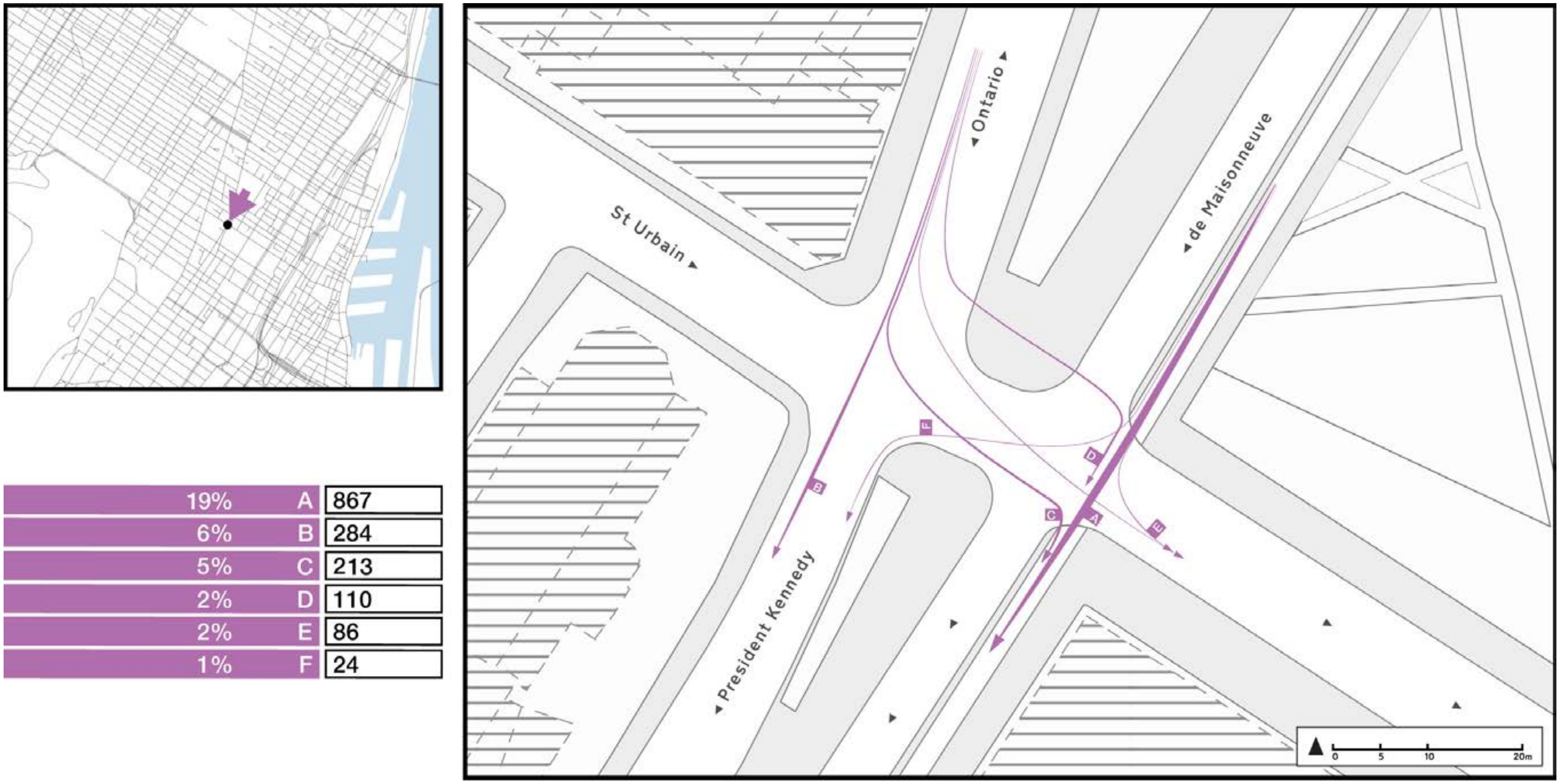


FIGURE 10: Desire Lines observed at Saint Urbain & de Maisonneuve – Westbound

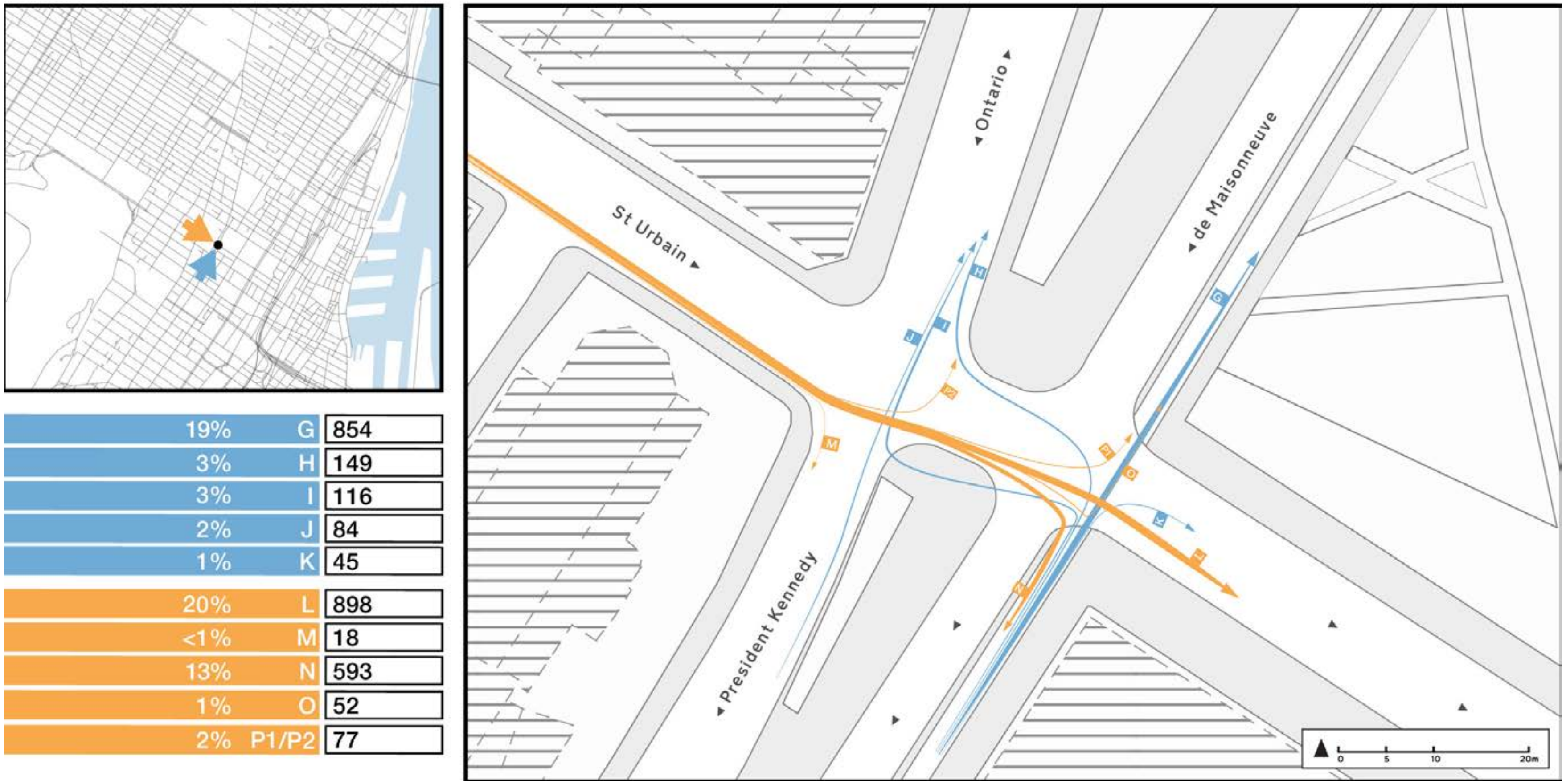


FIGURE 11: Desire Lines observed at Saint Urbain & de Maisonneuve – South & Eastbound

At this intersection, 4470 bicycle users were observed passing through Saint Urbain Street and de Maisonneuve Boulevard, 59% of which were male and 41% were female, while 23% of bicycles observed were BIXIs and 55% of users wore helmets. The three most prominent desire lines A, G and L each account for 19-20% of the total bicycle movement here. These three desire lines are all straight-through movements south, east and westbound. Apart from desire line N, which accounted for 13% of movements, the remaining 13 desire lines together (each under 6%) represent 1258 users – the remaining 28%. Some of these movements fall in a legal "gray-zone", where users did not explicitly break the law, but end up using the intersection in a way other than the design was intended. Only 90 users or 2% were observed explicitly running red lights. The following section presents the conflicts observed in both intersections with a discussion of what might have caused them, followed by design recommendations and conclusions.

CONFLICT ANALYSIS

Along with a series of observed indicators explained in the previous section, bicycle conflicts were observed at both intersections as desire lines converge at various points. To reiterate, for this study a bicycle conflict was defined as an observed bicycle collision, near miss, bunching, awkward manoeuvre or confusion with another bicycle, pedestrian or motor vehicle. Figure 12 demonstrates one example of north south bunching that was observed with the convergence of various desire lines: C, E, K, O, P, S and T.

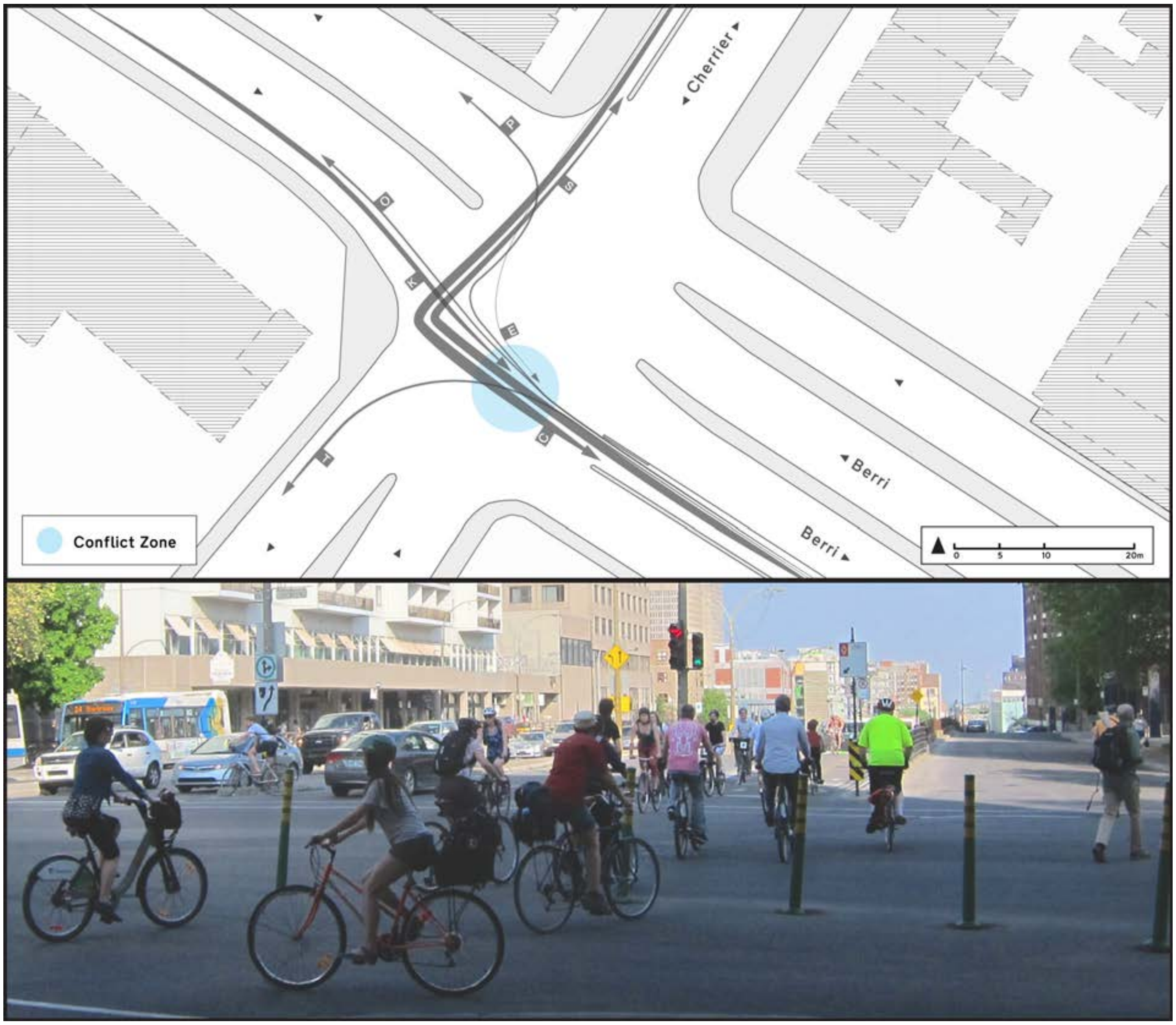
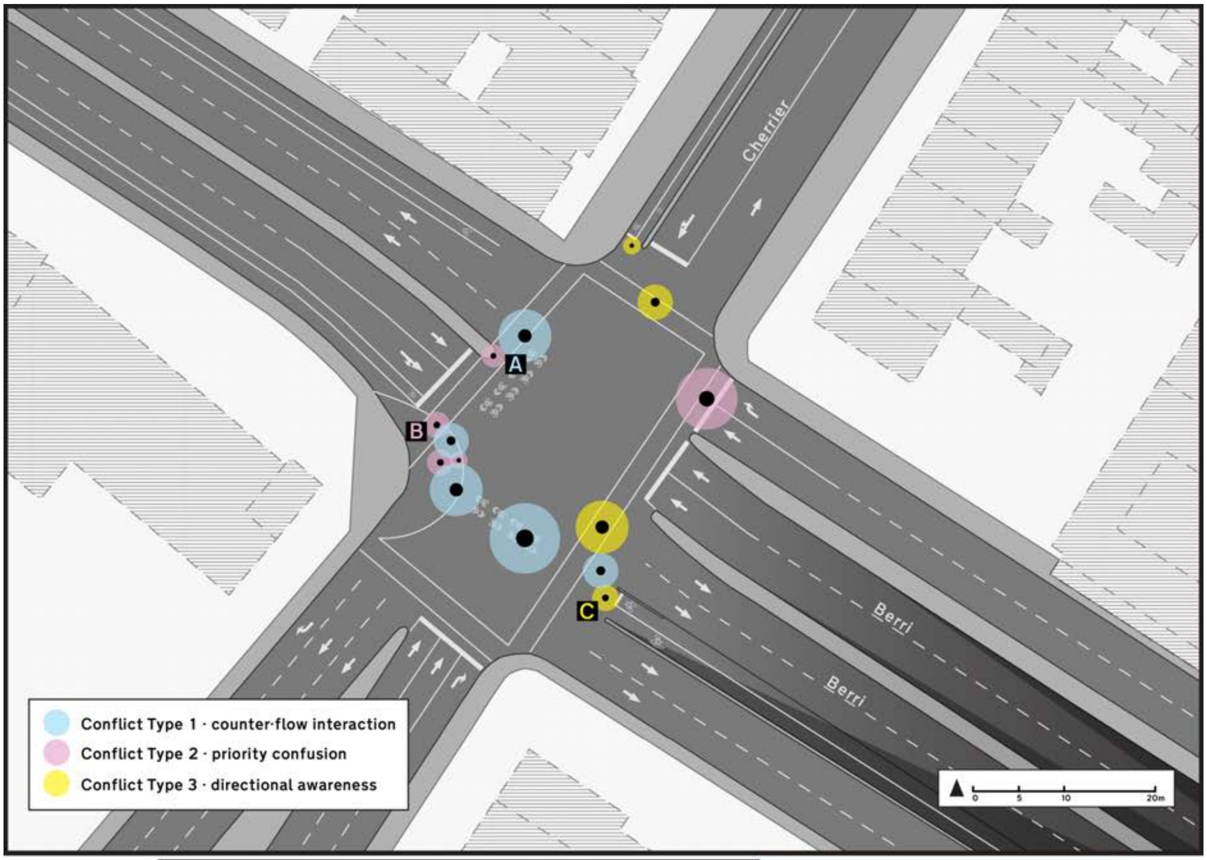


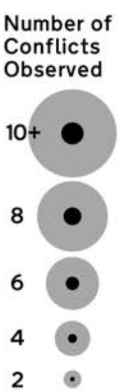
FIGURE 12: An example of Desire Lines converging and generating conflict

In this example, northbound and southbound bicycle users are forced to slow down and awkwardly manoeuvre between each other due to the significant number of other bicycles trying to get through this pinch point. Some northbound users are pushed to their right, putting them in a dangerous place near the path of southbound motor vehicle traffic. Observations like this were compiled and logged with all subsequent observed conflicts to produce a typology of conflict for each intersection that would serve to better explain how bicycle users interact with the built environment.

Overall, three types of scenarios were identified that generate conflict: counter-flow interactions, priority confusion, and directional awareness. The example in figure 12 falls into the first category of counter-flow interactions, where the design of the intersection guides two counter-directional flows together at certain points where conflict is generated. The second type of scenario – priority confusion – can be observed when bicycle users and pedestrians do not have a clear understanding of where each one must wait at the corner of the intersection, leading to bunching, blocking and potential for collision. The third type of scenario – directional awareness – concerns the desire lines that take legally questionable routes and surprise bicycle users, pedestrians and motorists from directions they were not anticipating – leading to conflict.

The observed conflicts at both intersections can be seen separately in figures 13 and 14, each segmented into their type and frequency – as well as an example of each for the sake of clarity.





Example A · counter-flow interaction

As bicycle users cross the north side of Cherrier east and west, the interaction between large groups of bicycles in two directions generates bunching, awkward manoeuvres and near collisions. between bicycles and pedestrians. This scenario was observed 6 times.

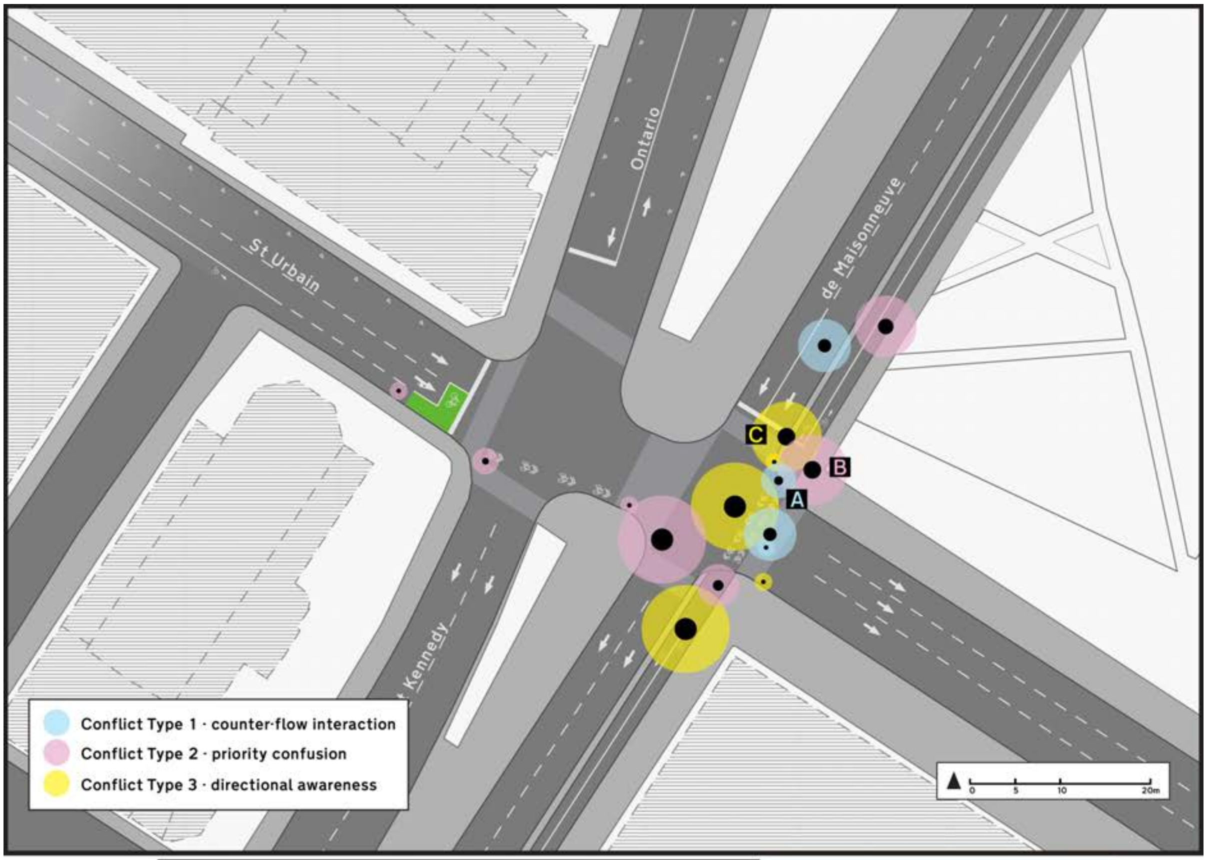
Example B · priority confusion

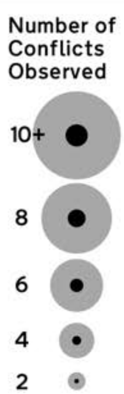
While pedestrians and bicycle users wait their turn to cross the intersection, it is often unclear where each user is expected to stand. In this example bicycles are stopped in various locations, blocking the path of pedestrians and oncoming westbound bicycle users alike. Conflict in this scenario was observed 3 times.

Example C · directional awareness

A substantial number of bicycle users took a less-than-legal route from the east to get to the southbound cycle track on Berri Street. Northbound users waiting for the light to change can be seen here surprised by bicycles approaching from their right, the east - where they do not anticipate it. This scenario was observed 3 times as well as several encounters with pedestrians and motorists.

FIGURE 13: Conflict typology/examples at Berri & Cherrier





Example A · counter-flow interaction

As the protected cycle track here is bidirectional, instances of bunching and near hits occur between opposing directions of bicycle users. Here, an eastbound user is trying to pass another while entering the alloted space for westbound users. This scenario was observed 4 times at this corner and 6 times at mid-intersection locations.

Example B · priority confusion

It was frequently observed that bicycle users moving east and west did not use the marked stop line, but rather advanced further into the intersection. This created scenarios where pedestrians were often blocked from moving or had to circumvent bicycles. Pedestrians and bicycle users alike seemed constantly unaware of where they were expected to wait. This scenario occurred on this corner 8 times.

Example C · directional awareness

With the bidirectional cycle track being placed to one side of the road, bicycle users who desire to get to the far side will cut corners at both the east and west corners of the intersection. Here a user making a less-than-legal movement surprises a westbound user who also happens to be ahead of the stop line. This scenario occurred at the east corner 8 times and 12 times on the west side.

FIGURE 14: Conflict typology/examples at Saint Urbain & de Maisonneuve

A full list of observed conflicts for both intersections presented in the figures 13 and 14 can be found in the appendix of this paper.

DISCUSSION

The development of a conflict typology in the previous section sheds light on the common themes observed while examining bicycle user behaviour at both intersections in this study with bidirectional cycle tracks. In order to understand why bicycle users in Montreal feel negatively about intersections with bidirectional cycle tracks and negatively about these two intersections in particular, it is important to put emphasis on these observed themes and offer recommendations of what may need improvement in the built environment. To reiterate, the conflict types identified were as follows: counter-flow interaction, priority confusion, and directional awareness. If each of these describes an issue that generates conflict in the intersection, then it might be fruitful to offer recommendations and design interventions that address each particular issue.

First off, counter-flow interaction conflicts were observed as issues largely of capacity – bicycle users were forced to travel in two directions within the confines of one cycle track. Often times, there was excessive bunching or awkward manoeuvres created because of too many users attempting to move past one another in two directions. It would stand to reason that separating these two directions into their own respective spaces and ensuring sufficient east-west and north-south routes within an urban area would spread out users and ease these conflicts. From these observed conflicts, it is recommended that the construction of protected cycle tracks follow a choreographic design, where opposing directions of traffic are given their own protected space, with observed desire line trajectories influencing their interaction.

Secondly, priority confusion conflicts seemed to arise from either a lack of clarity in the built environment of how each transport mode should move or from a disjoint between the built environment and the mobility desires of users. When bicycle users, pedestrians and motorists did not have a common understanding of where to wait for signal changes, they would accidentally block one another, causing bunching, near collisions and confusion. Design interventions for this type of conflict should seek to physically and temporally separate transport modes at complex intersections, offering priority and safety to the more vulnerable road users – namely pedestrians and bicycles. Designs may also be employed that create incentives and promote behavioural change with timing, spacing and sight lines.

Lastly, directional awareness conflicts were observed in scenarios where road users were surprised by the arrival of a bicycle from an unanticipated direction. These surprising encounters seem to be some of the most dangerous as they tend to be observed when users are already in motion – turning a corner or in a blind-spot. Recommendations to avoid these conflicts would be to keep all faster-moving transport modes following the same directional logic – i.e. If motorists travel on the right side of the street and subsequently turn right, so should bicycle users. Observing desire lines brings awareness to the conflicts generated by unanticipated movements and suggests that intersections should follow a design that is predictable for all users.

RECOMMENDATIONS

Figures 15 and 16 offer design recommendations for both of the intersections in this study, aiming for a reduction in the number of conflicts and an improvement in the perception of these junctions. The suggested interventions follow the previously made assertions in this discussion and aim to design intersections that are choreographic, prioritized and predictable. It should be made aware that these figures are conceptual– they seek to address observed conflict through adjustments in the built environment, and showcase how that might manifest itself on the ground. These designs also represent best-practice infrastructural adjustments, which may have to be approached more incrementally in reality with more thorough network-scale considerations.

Choreographic Design

The first design intervention recommended here is the separation of cycle tracks into unidirectional facilities on each side of the road. As all intersecting roads here are two-way, with motor vehicles on the right side, so too are the cycle tracks. Conflicts observed with bunching can be avoided as cycle track capacity has doubled here, with different directional flows of traffic being separated on different sides of the street. Cycle tracks should be wide enough (Copenhagen minimum is 2.2 metres) so that slower users may stay to the right and faster users may comfortably pass. This way all streams of movement can interact as smoothly as possible. An additional recommendation would be to increase the number of nearby protected east-west and north-south protected bicycle corridors to alleviate any further capacity issues.

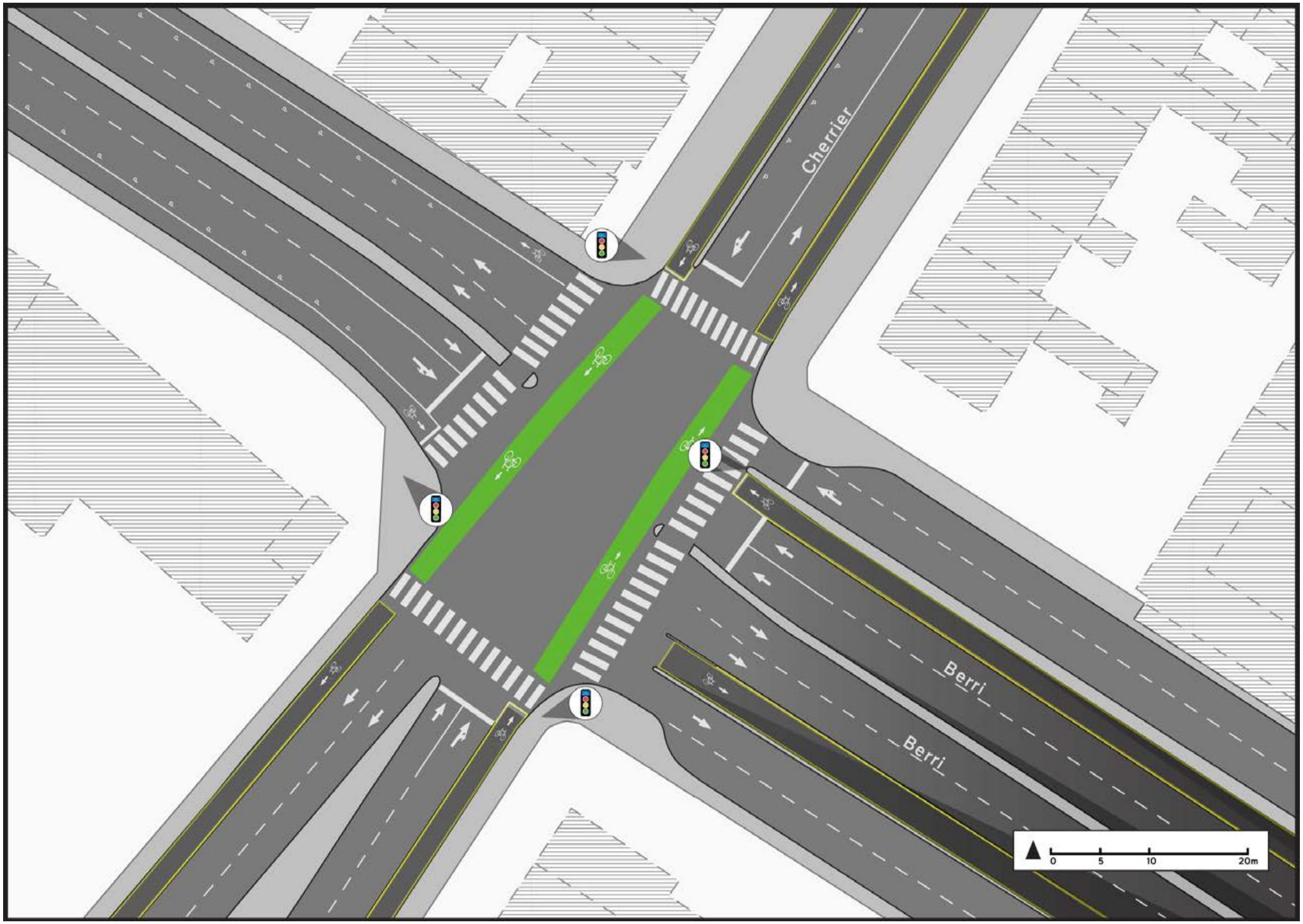


FIGURE 15: Design recommendations for Berri & Cherrier

Prioritized Design

One of the most noticeable elements of this new design is the increased presence of bold markings and signals. As one of the major observed conflicts here was the blocking and bunching between bicycle users and pedestrians, highly visible pedestrian and bicycle crossing markers clearly demarcate where each transport mode shall move. As previously mentioned, issues of bunching are improved due to the presence of unidirectional cycle tracks, but the placement of stop lines and crossing markers ensures clarity for users waiting at each corner. For example, since this intersection will continue to see heavy southbound flows from the east (see desire line C – eastbound left turn), pedestrian crossings and southbound stop lines were both pulled back, to create sufficient waiting space for these left box-turning bicycle users. Additionally, all motor vehicle stop lines are pulled back from the bicycle stop lines to ensure that vulnerable users are visible and given priority – as well as the implementation of bicycle signals with prioritized phases at all four bicycle stop lines. By placing both bicycle and vehicular signals on the approaching side of an intersection, users are required to remain at their stop line in order to see their respective signals and before proceeding into the intersection.

Predictable Design

These design interventions eliminate the possibility of observing desire lines D, Q and R as bicycle users heading northbound on Berri Street will be approaching on the far right side of the underpass – on a protected unidirectional cycle track. These identified desire lines created nearly all of the lack of directional awareness in this study of this intersection. As users stay to the right side of the road northbound, their right turns eastbound and straight-through movement northbound are both simplified – ensuring all users follow the same directional logic. Any remaining potential dangers of motor vehicles turning into straight-through bicycle traffic can be managed with bicycle signal phasing, giving each transport mode time differentials and permissions. For example, southbound bicycles would be given a green bicycle signal for 5 seconds before motor vehicles are given a green signal. Often times a straight arrow for motor vehicles is not respected, so this ensures that bicycle movement begins before vehicle movement, placing bicycle users ahead and within a visible line of sight mid-intersection. At the end of the signal phase, bicycles are given a red bicycle signal while motorists have 5 seconds of green to complete right turns safely.

The following design interventions and recommendations have been developed for the intersection of Saint Urbain Street and de Maisonneuve Boulevard as seen in figure 16.

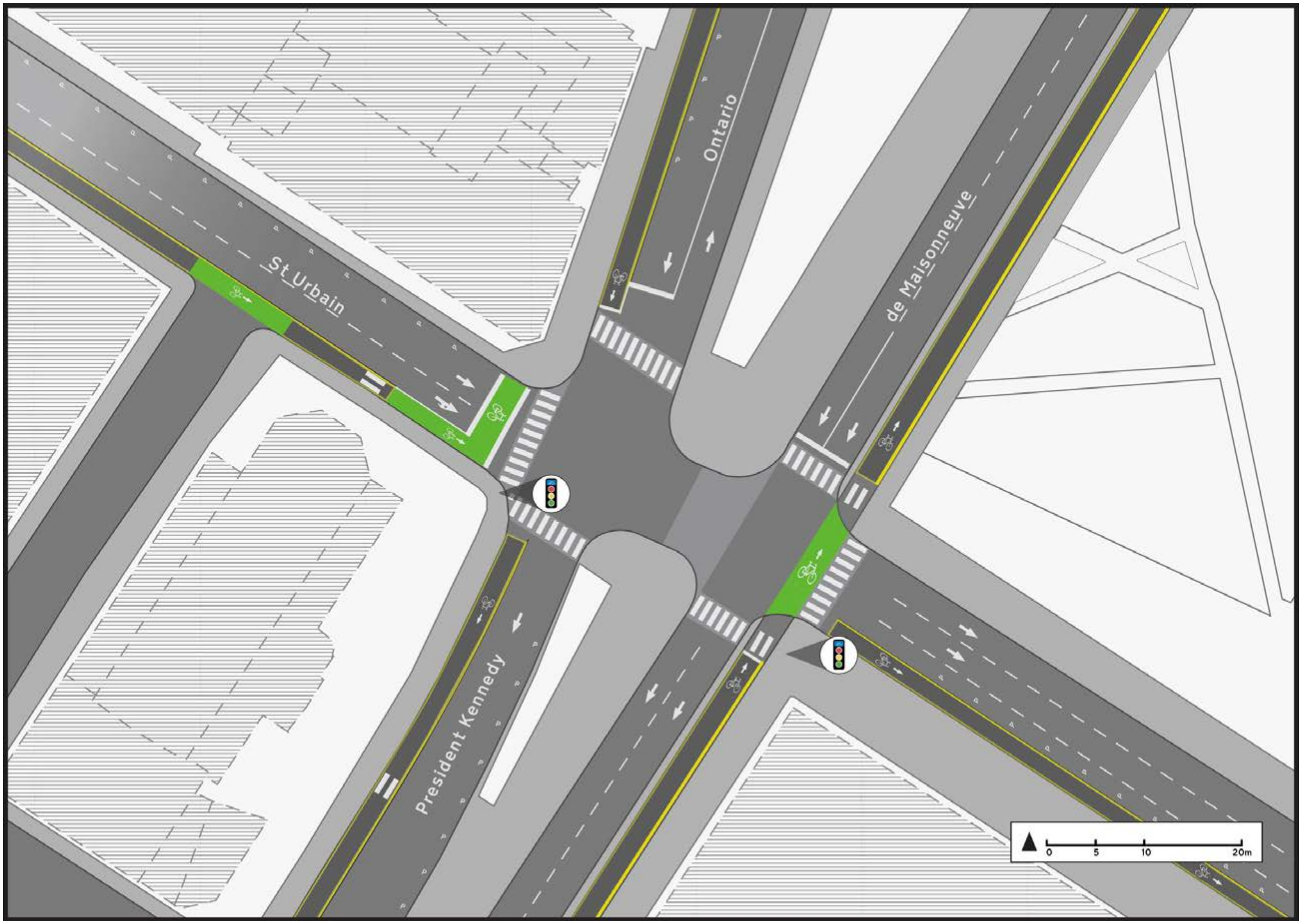


FIGURE 16: Design recommendations for Saint Urbain & de Maisonneuve

Choreographic Design

As the majority of observed conflict was concentrated around the bidirectional cycle track at this intersection, the primary design intervention here is again to separate directional flows into a more choreographic arrangement of unidirectional cycle tracks. Eastbound users will continue to use the cycle track on de Maisonneuve, but it has been converted to a solely eastbound cycle track, with its westbound counterpart located along the north edge of Ontario and President Kennedy. Unidirectional cycle tracks of adequate width rectify issues of bunching and two-way awkward manoeuvres, allowing faster and slower users to interact safely. A bicycle signal installed on the now-contraflow eastbound cycle track should give a light phase to only eastbound bicycles, so that users have the option to safely continue straight-ahead, or take a smooth L-movement to get to Ontario Street without any oncoming traffic.

Prioritized Design

Here again, bold pavement markings identify which transport mode has priority in each direction. Clear and bold differentiation between bicycle and pedestrian crossing areas can help alleviate potential conflicts – as well as draw attention to vulnerable users when motorists are crossing their path. Some treatment – whether greenery or a curb – could also be installed between the eastbound cycle track and the pedestrian sidewalk along the south edge of de Maisonneuve – as several instances of pedestrians unaware of the cycle track were observed. The southbound bicycle box is recommended to be extended in width to allow left turning confident riders to position themselves to the far left side in front of motorists. Bicycle users less confident may continue to make a two-stage box left turn onto the eastbound cycle track, without the worry of a head-on counter directional approaching bicycle as they wait for the light. Here also a bicycle signal will give advanced priority of 5 seconds to southbound users to alleviate right turning motorist potential conflicts.

Predictable Design

These design interventions eliminate the possibility of observing desire lines A, C, D and N which were all contributors to conflicts with bicycle users approaching from surprising directions. Southbound users turning right now have a dedicated cycle track on President Kennedy, as do the other westbound users from Ontario and de Maisonneuve. Additionally, a cycle track has been added to the south side of Saint Urbain for continuity as users move southwards in a straight-though movement. A uniform directional logic is employed for all transport modes, except for one contraflow movement along the south-edge of de Maisonneuve eastwards – which is controlled by a dedicated bicycle signal phase. During the course of analyzing this intersection, a small number of counter-flow northbound bicycle users were observed on the south side of Saint Urbain – either on the street or sidewalk. As a means of addressing this, it is recommended that a protected northbound bicycle corridor be implemented on a nearby street to complement the southbound movement of Saint Urbain.

CONCLUSION

The purpose of this study was to better understand negative perceptions surrounding intersections in Montreal with protected bidirectional bicycle facilities. The interplay between intersections and user behaviour are important to analyze as 58% of bicycle collisions in Montreal occur at an intersection (Morency & Cloutier, 2005). The Desire Lines Analysis tool was used to perform a fine-grained analysis of bicycle user behaviour at two carefully selected intersections in the city. Both intersections saw the predominant flows of bicycle movement follow the prescribed design of the infrastructure, but over a quarter of the observed desire lines in both instances did not. An analysis of these questionably legal behaviours and the collection of observed bicycle conflicts led to the creation of a conflict typology and recommendations for design interventions to rectify these observed conflicts. This typology identified three major themes from the observed conflicts – counter-flow interactions, priority confusion, and directional awareness. Recommendations were put forward for design that is choreographic, prioritized and predictable.

This study shows that a fine-grained observational analysis such as The Desire Lines Analysis can be used to shed light on human behaviour-inspired designs for bicycle infrastructure. This tool can serve as a useful complement to a citywide network analysis – informing elected officials, planners and engineers where and how citizens are using bicycles in the city, where there is conflict, and how it might be improved. This study has the potential to be further expanded by including a larger number of intersections with bidirectional facilities in the city. It was however limited to two, due to constraints of time and resources. This analysis may also serve as helpful for cities to investigate intersection redesigns before and after interventions, as well as short-term pilot projects. This study, along with the words of Jacobs, Whyte and Gehl (Jacobs, 1958; Whyte, 1980; Gehl & Svarre, 2013), affirm that by actively observing the urban environment, we can challenge our assumptions and build better life-sized cities for all citizens.

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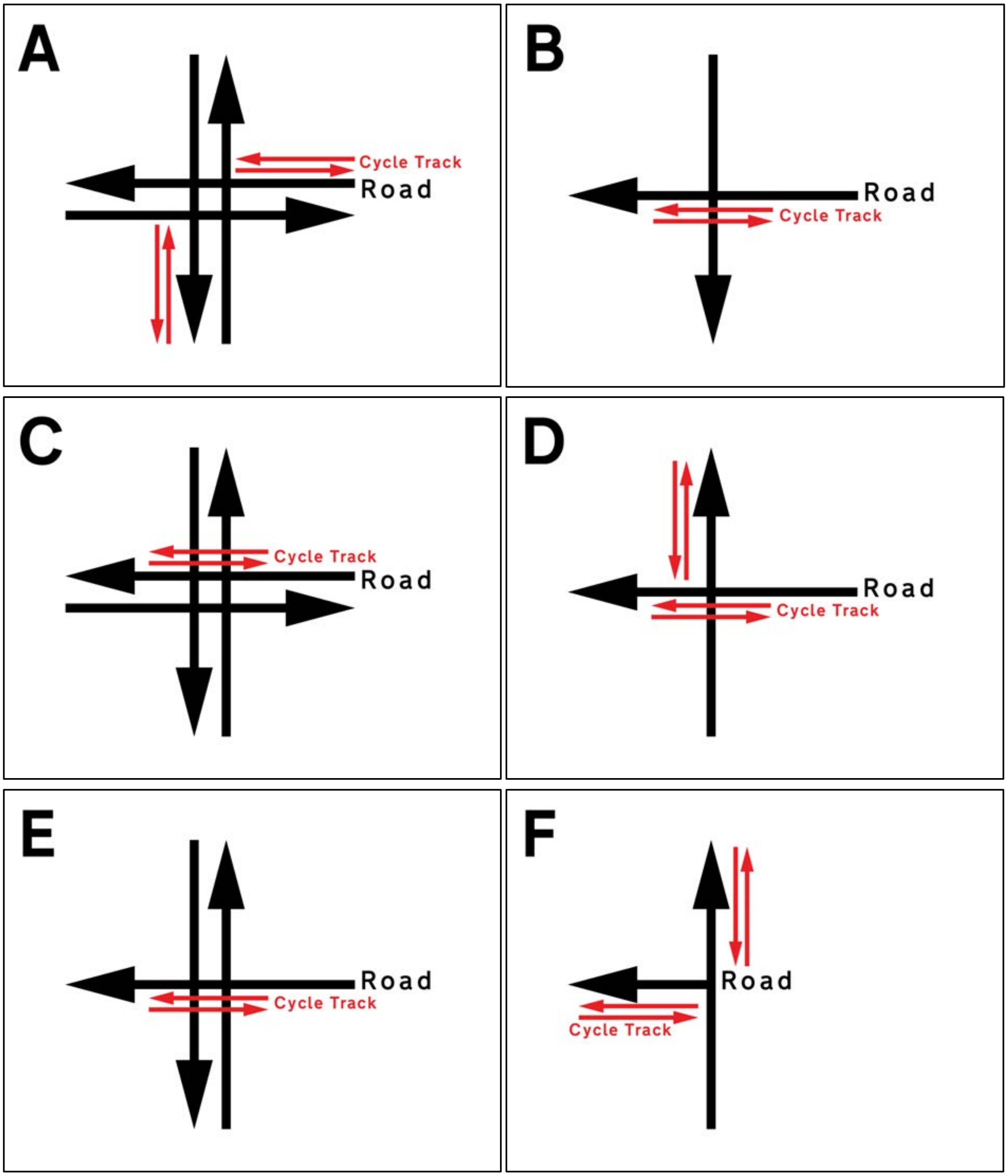
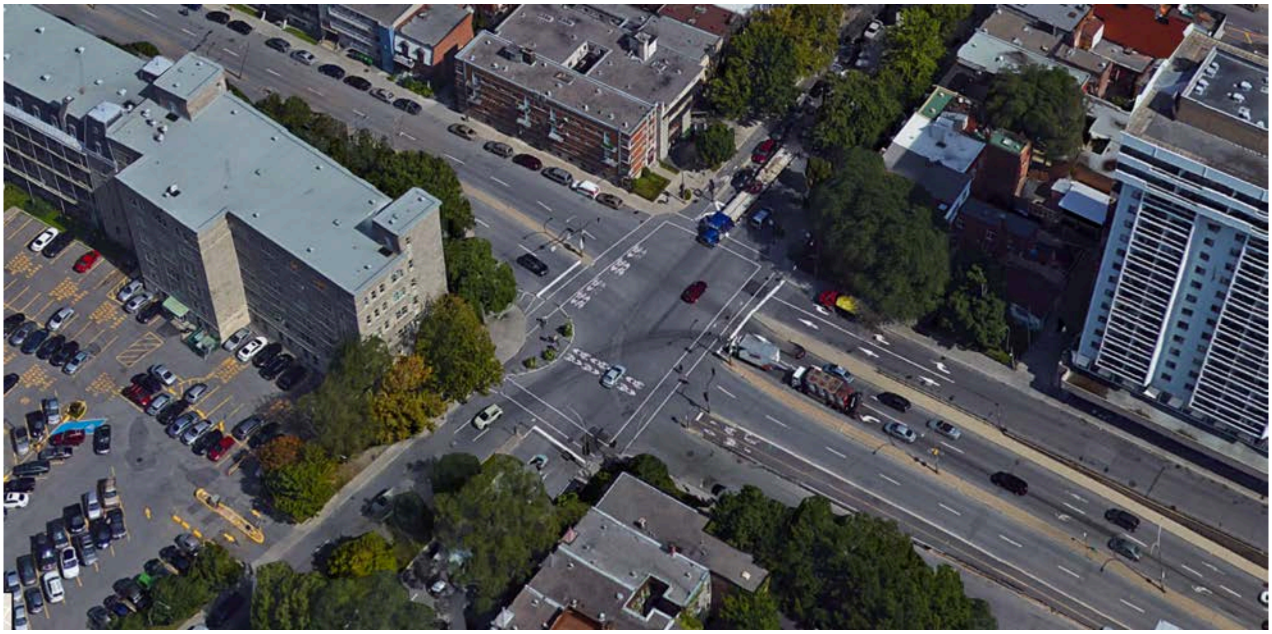
APPENDIX

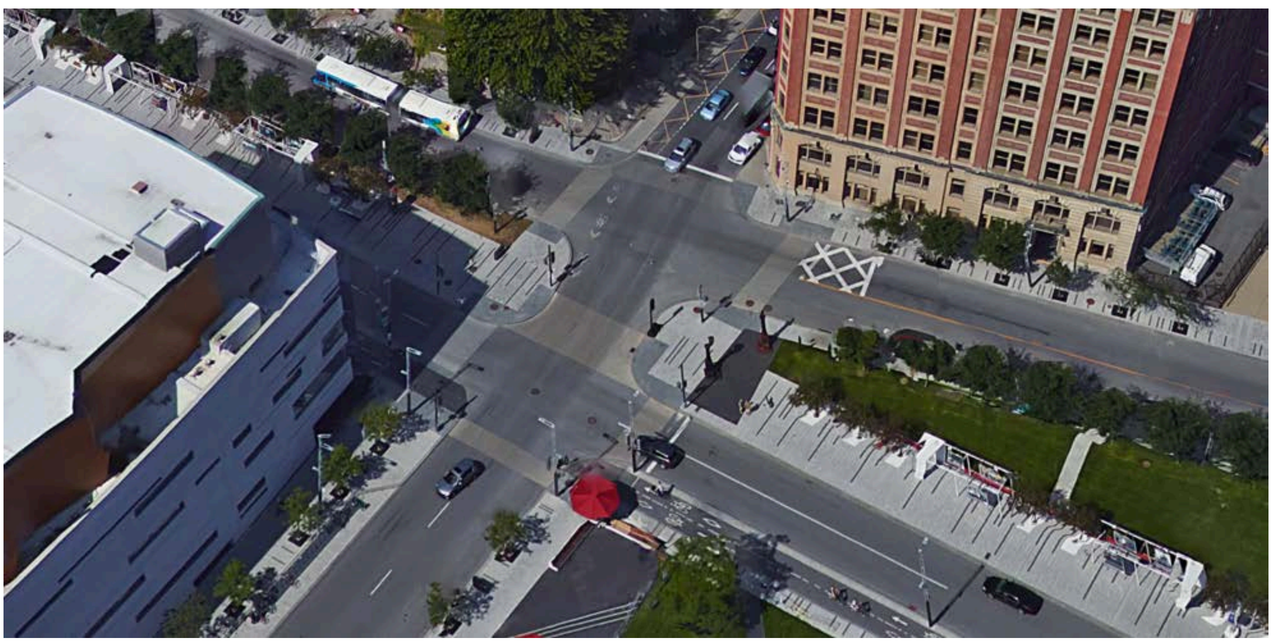
A – Schematic figures of identified road configuration types in Montreal



B – Aerial photos of the studied intersections



Berri & Cherrier



Saint Urbain & de Maisonneuve

C – List of observed conflicts at the studied intersections

Berri & Cherrier

Observed Conflict	**Desire Line(s)**	**How many?**
Counter-Flow Interaction		
North-South bunching from cycle track, northbound flow cannot turn left – left waiting at oncoming traffic	C, K, O, P, S, T	8
Northbound forced to wait in dangerous spot at mouth of cycle track from large southbound group	C, K, O, P, S, T	4
East-west bicycles on north side of Cherrier near misses and bunching with pedestrians	A, C, G, M, S	6
Southbound bicycles waiting in box block north-east turns from cycle track	C, G, K, S	4
Eastbound bicycle bunching and near misses with southbound right turns – cars and bicycles	G, L, S	6
Priority Confusion		
West/Southbound bicycles wait in dangerous spot between streams of vehicle traffic	D	7
No room for pedestrians to navigate and cross east-west due to bike bunching in waiting box	A, C, G, M, S	3
Southbound bicycles cannot pass through bike bunching in the waiting box	C, G, K, S	2
Significant bunching from single group north/eastbound	S	3
Pedestrians east-west on median in dangerous spot	N/A	2
Directional Awareness		
North-south pedestrians awkwardly manoeuver around bicycles not using cycle track box turn	D, R	4
East-west pedestrians awkwardly manoeuver around west/southbound bicycles on the south side of Cherrier	D	5
Westbound waiting bicycles in cycle track squeezed by incoming northbound tight turning bicycles	R	2
Northbound waiting bicycles in cycle track squeezed by incoming southbound tight turning bicycles	D	3
Bicycle near-hit by eastbound car turning right	R	1
	Total Observed Conflicts	*60*

Saint Urbain & de Maisonneuve

Observed Conflict	Desire Line(s)	How many?
Counter-Flow Interaction		
Near hit between east and west bicycles on cycle track as well as pedestrians	A, G	6
Westbound bicycles squeezed and near hit from waiting eastbound bicycles	A, G, O	4
Southbound car stopped in traffic and blocks both east and westbound bicycles	A, G	2
Westbound bicycles choose to ride on the street as the cycle track is past capacity and bunching	A	6
Priority Confusion		
Southbound bicycles near hit from southbound right turning vehicles	L	13
South/westbound bicycles squeezed by southbound vehicles at median	C	2
Southbound bicycles stuck behind bus at north side	L, M, N, O, P	2
Westbound bicycles and southbound turning bicycles in conflict with pedestrians as they block them in	A, D	8
Eastbound bicycles and southbound turning bicycles in conflict with pedestrians as they block them in	G, O	5
Pedestrians do not see cycle track or know it is two-way and so they walk on it and create conflict	All on cycle track	7
Directional Awareness		
East and westbound bicycles near hit with westbound left turning vehicle	A, G	11
Incoming southbound turning bicycles surprising waiting bicycles and pedestrians at west corner – near hits	C, I, N	12
Incoming southbound turning bicycles surprising waiting bicycles and pedestrians at east corner – near hits	A, D, H	8
Southbound left turning bicycle near hit waiting westbound bicycle and pedestrians	P1	2
Southbound riders awkwardly manoeuver around northbound illegal contraflow bicycles	L	2
	Total Observed Conflicts	*90*