102 Avenue – Multi-Modal Safety Analysis, Best Practices, and Results

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Introduction and Background

The City of Edmonton is Alberta's vibrant Capital City, and is one of Canada's largest municipalities, with over 800,000 residents. The City's population is expected to surpass one million residents over the next thirty years, which will place increasing pressures on its transportation system. The City recognizes the need to balance the needs of all road users – including drivers, pedestrians, bicycle users, and transit users.

Light Rail Transit (LRT) expansion is one of the City of Edmonton's top priorities for new infrastructure investment. In 2009, the City adopted a long-term LRT Network Plan that defines the future size, scale and operation of Edmonton's LRT system[i]. Construction has now started on a new LRT route from Downtown to Southeast Edmonton - the *Valley Line LRT*. By 2020, this new low-floor LRT line will be complete, including a section through Edmonton's Downtown Core along 102 Avenue. The LRT alignment through Downtown Edmonton will run along 102 Avenue. 102 Avenue is an important east-west corridor and serves an important multi-modal function for LRT, cyclists, and pedestrians[ii].

Recognizing the important multi-modal role of 102 Avenue, Edmonton City Council has approved a Downtown LRT Concept Plan for the corridor. City Council has also recently approved funding for the implementation of a physically separated cycle track on 102 Avenue prior to the completion of the Valley Line LRT[iii].

The purpose of this study was to review the previously approved plans and designs for the 102 Avenue corridor to identify safety and operational issues for all modes of transportation and to develop mitigation measures and alternative concepts to address the identified issues. The previously approved concept included a mixture of modes within the street cross-section, including:

- a two-way LRT alignment along 102 Avenue, which would run along the north side of the street;
- a two-way bicycle facility along the centre of the corridor directly to the south of the two-way LRT alignment and between motor vehicle traffic;
- a single one-way eastbound general purpose traffic lane on the south side of the corridor; and
- sidewalks for pedestrians on both sides of the street.

[i] A summary of the long term LRT Expansion is available at http://www.edmonton.ca/transportation/PDF/Long_Term_LRT_Network_Plan_March_2012.pdf

[ii] Reference information and related concepts and approvals on the Valley Line LRT is available at http://www.edmonton.ca/transportation/ets/future_transit/southeast-to-west-lrt-mill-woods-to-lewis-farms.aspx

[iii] Details on the plan and concept development for the 102 Avenue cycle track, including engagement and approvals is available at http://www.edmonton.ca/transportation/cycling_walking/downtown-bike-route.aspx

During the preliminary design process and review for the *Valley Line LRT*, the City engaged peer and external design specialists to conduct a Peer Review of the original previously approved concept. Through this Peer Review, several operational and safety concerns were identified based on the designs. The Peer Review recommended that bicycle facilities be removed from the corridor and relocated to 102A/103 Avenue (a nearby east-west route). The recommendation to remove a mode of travel from 102 Avenue did not align with the overall intent of the concept plan endorsed by Council, and did not align with the City's Bicycle Transportation Plan, which identifies 102 Avenue as an important future bicycle route through the City's Downtown Core. Urban Systems was retained to complete an independent review of the 102 Avenue corridor to further evaluate safety and operational characteristics and to identify recommended mitigation measures and/or alternate configurations to address issues and improve safety and operations for all road users while maintaining bicycle facilities on 102 Avenue if feasible.

This paper discusses the methodology, analysis, and outcomes of this multi-modal safety review undertaken to identify the issues and recommendations for the 102nd Avenue corridor.

Study Process

The safety review was completed independently by the consultant team. The study was led by Facility and Capital Planning at the City of Edmonton. An Internal Steering Committee was established for this study, which consisted of representatives from various City of Edmonton department. The Internal Steering Committee was involved in identifying safety and operational issues from their perspective, providing feedback on identified issues from the consulting team, and providing input into alternative configurations. The study process included the following key components.

- Site Visit
- Internal Project Team Workshop
- Case Study Reviews
- Safety, Operational, and Constructability Issue Review
- Identification of Recommendations and Mitigation Measures
- Internal Stakeholder Meeting
- Finalization of Final Report

Methodology Used

A multi-disciplinary team was assembled to identify recommendations from various perspectives, including road safety, traffic operations, transit, and active transportation. The design identified improvements for all users without negatively impacting safety or operations and incorporated innovative best practices in multi-modal design to create a win for all users,

including Edmonton's first cycle track design and enhancements for pedestrians and transit operations. The study demonstrated how all modes can safely be accommodated within the same right-of-way.

In addition to the traditional aspects of an in-service road safety review utilized to help identify the issues and opportunities associated with the bicycle facilities implemented, five key innovation strategies were leveraged, leading the successful outcomes previously discussed.

- **The analysis process cohesively evaluated safety, operational, and constructability issues across five different zones:** the corridor, stations, intersections, conflict points, and transitions/end points**.** This methodology ensured that all issues were identified with each zone, and that the complexity of multi-modal movement was analyzed at all locations along the corridor.
- **Modified design criteria were investigated and affirmed as part of the study.** The City of Edmonton prompted innovative solutions by affirming modal priority through the design criteria utilized for the analysis and improvement recommendations. Specifically, a restriction of access to emergency vehicles and garbage trucks and local vehicle access (ie. no through traffic) only allowed for reduced lane widths, reduced curb return radii, and increased cross sectional width for bicycles, pedestrians, and transit passengers.
- **Separation of modes was strategically balanced between space and time.** The development of a recommended design concept utilized equal consideration of geometric separation and signal phasing separation to minimize the conflicts between all road users. Specifically, all signal phases which permitted potential conflict between turning motor vehicles and through moving bicycle users and pedestrians were eliminated. Turn restrictions were provided in conjunction with the LRT crossing to maximize travel time reliability for the LRT while still enabling permeability for pedestrians, cyclists, and the intersecting cross streets with 102 Avenue. Finally, physical separation for the bicycle lane was provided to encourage use by bicycle users of all ages and abilities. The width and design of this facility was carefully evaluated on a block by block basis to ensure adequate access for snow clearance and emergency access, while maximizing space within the pedestrian realm.
- **A thorough investigation of maintenance requirements and the feasibility of road design tactics was undertaken**. The City of Edmonton worked with roads maintenance departments to ensure the feasibility of all proposed cross section widths for snow clearance access (at a minimum of 3.1m). Collaboration with the Emergency Services also allowed for a creative strategy of separation to provide comfort for bicycle users discussed further in the Design Rationale section below. Finally, the appropriate design vehicle for the City was confirmed and checked on all curb returns through the corridor to minimize vehicle turn speeds and pedestrian crossing distances, whilst ensuring appropriate access was provided for businesses along 102nd avenue.

- **International best practices were referenced to inform the recommendations.** Design and analysis guidance from across North America and Europe was referenced to bolster innovations, and understand at a greater level of detail what types of treatments have worked successfully in other jurisdictions. The National Association of City Transportation Officials (NACTO) Urban Street Design Guide, the NACTO Bicycle Facility Design Guide, and the CROW Design Manual for Bicycle Traffic (Netherlands) were all referenced as a starting point for design intervention considerations. Several specific case studies were also conducted with several cites in North America that have successfully integrated LRT and cycling facilities (including the City of Seattle's Broadway Streetcar and Cycle Track integration) to provide best practices and lessons learned for effective multi-modal integration for the City of Edmonton.

Issues

Safety and operational analysis is critical with the implementation of LRT in combination with other modes, particularly vulnerable road users such as pedestrians and cyclists. In Edmonton, the design and construction of low-floor LRT is a relatively new concept. Combined with on-street bicycle accommodation along the same corridor, it is essential to ensure that safety is strongly considered and built-in to the design of these new facilities. 102 Avenue is envisioned as a high quality multi-modal corridor, with transit, pedestrian, and cycling facilities and the design set on 102 Avenue has the potential to pave the way for other parts of the City.

A typical cross section of the initially proposed configuration for 102 Avenue within the Preliminary Design at a Non-Station Location is shown in **Figure 1**.

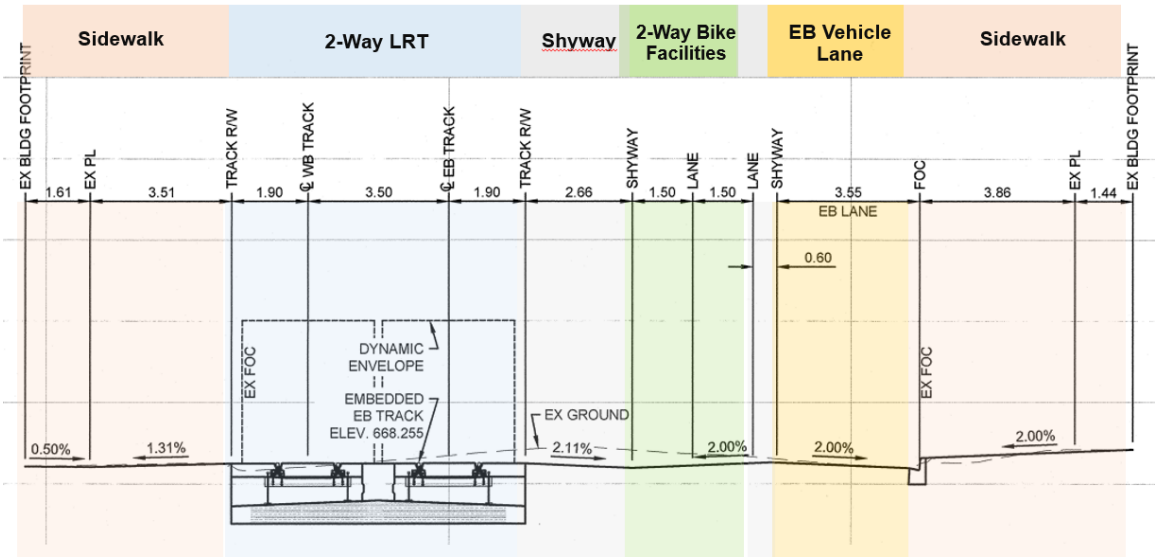


Figure 1 – Preliminary Design Cross Section Configuration Proposed for 102 Avenue

Through the review of this proposed design completed by Urban Systems, a number of concerns were identified. Some of the key issues are discussed below:

- **Cyclists were proposed to be placed in between LRT and motor vehicles.** The overall corridor concept included centre-running bi-directional bicycle facilities which position bicycle users in the centre of the street in between two-way LRT operations and one-way eastbound motor vehicle traffic. The placement of bicycle facilities in the centre of the street presents numerous conflicts at intersections and is not comfortable to people of all ages and abilities.
- **Lack of physical separation between motor vehicle travel lane and bicycle facilities.** The original design recommended that the 3.0 metre wide bi-directional bicycle facility be separated from a 3.55 metre eastbound vehicle lane by a 0.6 metre shyway. However, there is no indication that any physical separation will be provided within this shyway between the bicycle facilities and the eastbound motor vehicle lane. Based on the TAC Geometric Design Guide, a minimum of 1.1 metres of shy distance should be provided for motor vehicle travel speeds of 50 km/h or greater. Ideally, the bicycle facilities should exhibit a minimum of 1.0 metre shy distance between the motor vehicle lane, and some form of physical separation should be provided within this shy distance to enhance the safety and comfort of bicycle users. Considering the potential for both bicycle users and motorists to encroach into the adjacent travel lanes, bicycle users are at risk to side-swipe related collisions/conflicts.
- **Lack of buffer between travel lane and pedestrian sidewalk.** For streets that do not exhibit on-street parking and that exhibit typical urban speeds (i.e. 50km/h or greater), a buffer between the motor vehicle lane and the sidewalk is desirable to enhance pedestrian safety and comfort. The width of the buffer between motor vehicles and pedestrians should be at least 2 metres. Under the original concept, on-street parking was not permitted and there was no buffer between the motor vehicle lane and the sidewalk. In addition, with the LRT along this corridor as well as significant residential development planned along this corridor, it is anticipated that pedestrian volumes will increase significantly in the future. Considering the limited sidewalk space and anticipated high pedestrian volumes, some pedestrians may be induced to walk very close to, or onto the motor vehicle lane, which is considered to be an undesirable outcome.
- **Lack of space for turning bicycle users to wait.** Although the original concept included eastbound bicycle facilities with bike boxes at all intersections, there was no space for eastbound bicycle users to wait if they were wanting to make a left or a right turn. In the westbound direction, no facilities were provided for bicycle users to wait if they were making a left or a right turn. This may result in conflicts between bicycle users, as turning cyclists may be stopping in the path of through travelling cyclists.

- **Potential for northbound turning bicycle users to slide across tracks as the turns are not perpendicular.** The original concept did not indicate any turn restrictions for bicycle movements, which can introduce safety issues for bicycle users turning northbound across the LRT tracks. As noted previously, without dedicated provisions for eastbound to northbound left turns or westbound to northbound right turns by bicycle users, there is a high likelihood that bicycle users will make this turn as a vehicular cyclist, and may cross the LRT tracks at an angle. As a result, the bicycle tires could get caught in the LRT rail tracks, resulting in severe injury collisions.
- **Long crossing distances on many cross streets.** Under the original concept, pedestrians were required to cross up to six travel lanes on some cross-streets, while several other cross-streets would require pedestrians to cross up to four travel lanes. Ideally, the crossing locations should be as short as possible to encourage safe pedestrian movements. Pedestrian crossings can be improved through the use of curb extensions, lane reductions, and curb radii reductions where feasible; and further enhanced through the provision of a Leading Pedestrian Interval.
- **Left turn motor vehicle movements.** Southbound to eastbound left turn movements in the original design required motorists to cross both the LRT tracks and the bicycle facilities before making the left turn onto 102 Avenue. Depending on the traffic volumes, there is a potential for motorists to queue on the LRT tracks or the bicycle facilities, which may present safety issues.
- **Vehicle swept path.** The turning geometry off the cross-streets in the original design, specifically for the northbound to eastbound right turn, may be challenging for some of the design vehicles within the downtown core. These vehicles may sweep into the bicycle facilities or sidewalk and induce side-swipe related collisions/conflicts with the cyclists.
- **Conflict points at driveways and alleys.** In addition to intersections, the original design included several mid-block conflict points, which included driveways and alleyways which can act as conflict points.

The overall intent of the Council-approved Downtown LRT Concept Plan and subsequent preliminary design was to provide a high quality corridor along 102 Avenue that accommodates all modes of travel, including transit users, bicycle users, pedestrians, and motorists. As such, the types of collisions or conflicts along this corridor could involve pedestrians and cyclists, and if a vehicle and/or a LRT train are involved in a collision with a pedestrian or cyclist, the expected collision severity is likely to result in a probable fatality or very serious injury. Based on the Collision Risk Assessment Method outlined in the TAC In-Service Road Safety Review Guide, the severity rating for these types of collisions (i.e., those involving pedestrians and cyclists) are defined as extreme, which then translates to a high-risk rating. It is noted that this risk assessment is the same for all frequency ratings. That is, the high-risk rating is the same for frequent and rare collision events. With this in mind, the proposed concept should seriously

consider the interfaces between the various modes of travel and take into consideration the low conspicuity of cyclists and pedestrians.

Overall, the placement of the bicycle users in between the motor vehicles and LRT vehicles presented a significant and high risk potential conflict, with potential for high severity collisions resulting in fatality or serious injury.

Design Principles

The following design principles were established to develop appropriate recommendations for the unique nature of 102 Avenue.

- **Design for the most vulnerable users first.** The design hierarchy should start with pedestrians, bicyclists, transit, and then motor vehicles.

- **Provide separation for pedestrians and bicyclists along the corridor**. When modes are adjacent without physical separation, both pavement coloring and symbols are needed to prevent unconscious mixing.
- **Invest in intersection treatments.** Bicycle signals, leading intervals, and pavement coloring will help bicycles safely move through intersections shared with other modes.
- **Manage multi-modal conflicts at LRT stations.** Elevating pedestrian crossings to platforms and using paint and signage to indicate mixing zones creates awareness for bicyclists and pedestrians to look for each other. Railings can help corral pedestrians and keep them from accidentally falling into, or spilling over into cycle tracks.
- **Enable safe and comfortable bicycle turn movements from the bikeway.** Turn boxes that promote two-step left turns keep bicycles from making shallow turns across tracks and keep bicycles to the correct lane.
- **Embrace desire lines.** If a streetcar runs along a strong desire line, do not direct bicyclists to adjacent facilities they may be less likely to use.
- **Educate users on new facilities.** Businesses and delivery services need education on where parking and loading are permitted.
- **Enforce parking restrictions.** In cycle tracks, temporarily parked vehicles can force bicyclists abruptly into traffic lanes where cars are not expecting them.
- **Explore alternative pavement treatments,** including bricks and concrete pavers, to help demarcate different users' spaces and to create a unique environment that signals the need for additional attention from all road users.

Design Rationale

In conjunction with the design principles, appropriate rationale for deviation from City of Edmonton standards and interpretation of guidelines was necessary to confirm as part of the recommendation assessment.

Design rationale of this nature is particularly important to emphasize on corridors where automobile transportation is not being prioritized. When the design standards and available design criteria do not provide guidance on how to effectively implement multi-modal corridors, detailed investigation into the first principles of road design constraints is necessary in order to inform the effective implementation of corridor plans and objectives.

In the context of 102 Avenue, the following rationale was important to assess and confirm with impacted City of Edmonton departments to establish appropriate recommendations:

- **Maintenance and snow clearance operation.** The City of Edmonton Roads Maintenance Department was concerned about the potential challenges associated with clearing snow and debris in a physically separated bicycle facility. Since this type of infrastructure had not yet been implemented in the City of Edmonton, investigation into the tools and approaches of other jurisdictions was helpful to confirm an appropriate minimum width of 3.1 m for snow clearance. Specifically, identification of specialized vehicles used in the City of Calgary to clear their cycle track facilities was necessary to confirm that maintenance of the cycle track was feasible. The details of the snow and maintenance clearance vehicle and associated contract with the design builder for the LRT was identified to be evaluated in more detail by the P3 proponent.
- **Automobile traffic volume throughput de-prioritization.** The City of Edmonton requested that automobile traffic level of service assessed through micro-simulation tools should not inform the cross section treatment and intersection design. While this approach may seem unconventional in a traditional road design where automobile traffic volume throughput is prioritized, the de-prioritization of automobile traffic throughput was important to developing recommendations in line with the modal priority on 102 Avenue. It should be noted that the travel lane has been designed geometrically for a maximum speed of 50 km/h. However, the City may decide to post a reduced speed of 30 km/h upon the completion of detailed design.
- **Accommodation of minimum shy distance requirement.** In consultation with the City of Edmonton, minimum shy distances were established between the motor vehicle lane and the cycle track (1.0 m; including the mountable curb with optional flex posts), as well as between the motor vehicle and the LRT Vehicle Dynamic Envelope (0.6 m). It should be noted that the City wanted to accommodate a minimum sidewalk width of 3.0m. Therefore, in one station location, the minimum shy distance between the motor vehicle lane and the cycle track was reduced to 0.6 m.
- **Emergency vehicle staging width requirement.** The City of Edmonton Emergency Services requires a 6.0m clear width for emergency services vehicle set up. Based on this requirement, there was initial concern that any sort of physical separation between the automobile travel lane and the bicycle lanes would be feasible. However, through demonstration of mountable curb and flexible posts used in other jurisdictions, together

with shy distances and full gutter pan width, Emergency Services was open to specific methods of accommodating the cycle track within the constrained corridor.

- **Swept path of design vehicle.** In order to improve the pedestrian comfort on the corridor, the reduction of intersection crossing distances was identified as a priority. The recommended curb return radius and curb extension configuration was based on the turning movement swept path of the SU-9 Design vehicles. This vehicle was selected by the City of Edmonton to reflect waste collection vehicles, delivery trucks, and emergency services vehicles requiring access on 102 Avenue. A summary of the SPA is shown in **Appendix C**. Tractor Trailer Delivery vehicles will not be permitted to access this road. Deliveries will be made through the lanes and side streets servicing the parcels adjacent to the south side of 102 Avenue.

Ultimately, due consideration was made to ensure the feasibility of the proposed concept, without completing a full preliminary design. This helped provide confidence to both the planning team that the intent of the corridor vision was still being met; while also affirming to the future road maintenance groups, transportation engineers, and fire department that the solution would meet their safety and emergency access requirements.

Recommendations

Based on the findings of this study, the project team has concluded that experience elsewhere demonstrates that bicycle facilities and LRT can safely operate within the same right-of-way, albeit with numerous design considerations to address safety and operational issues. As such, it was recommended by Urban Systems that the cross-section be modified by reversing the placement of the bi-directional bicycle facilities and the eastbound motor vehicle lane as shown in **Figure 2**.

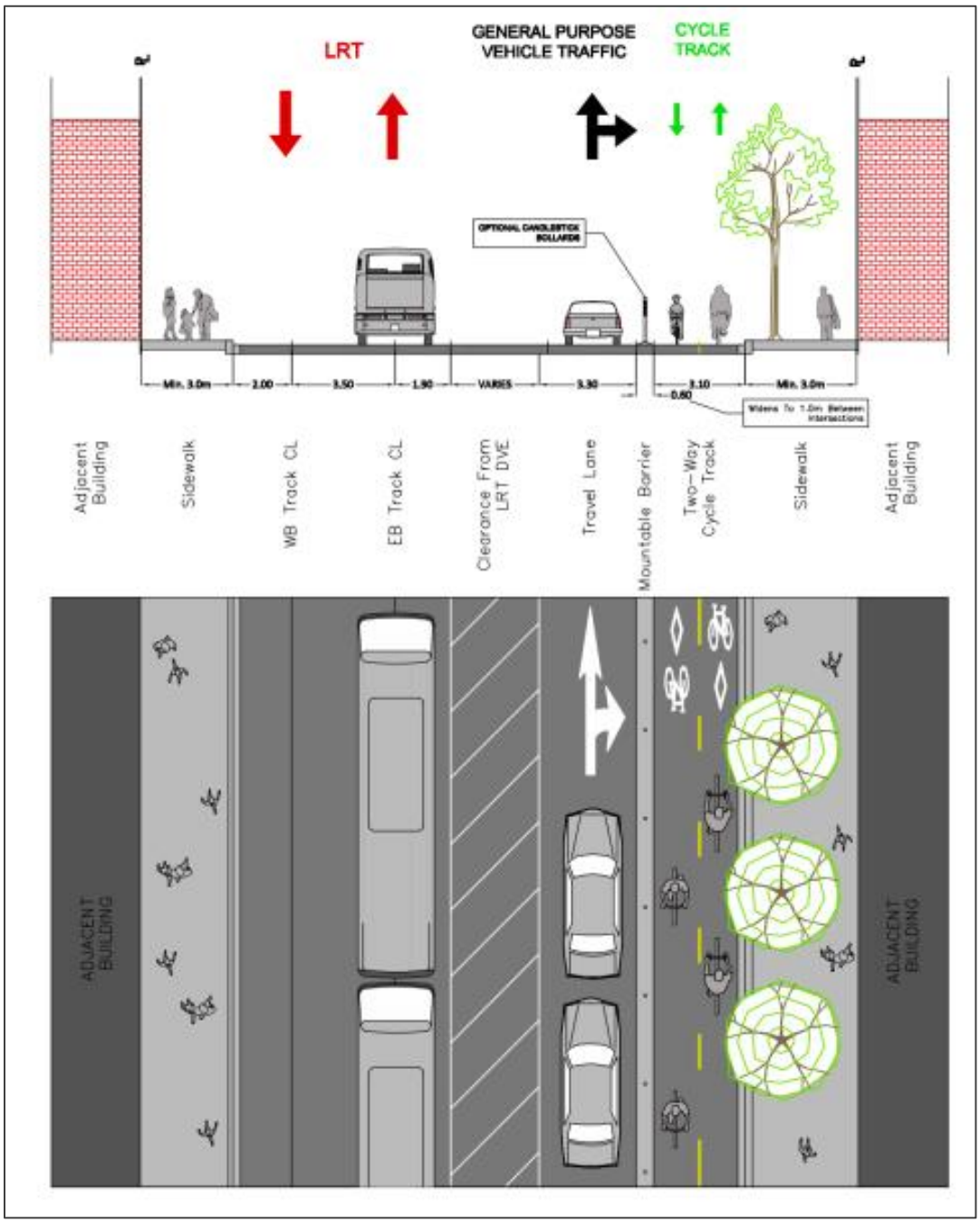


Figure 2 – Recommended Cross Section (Non-Station Location)

Key features of the proposed typical cross-section include:

- Desired sidewalk width of 4.0 metres on both sides of the street where possible, with a minimum width of 3.0 metre to be provided on both sides of the street unless the LRT or cycle track is impacted. As the project proceeds into detailed design and design

refinements are made, the P3 proponent should explore opportunities to widen sidewalks where possible.

- 3.10 metre bi-directional cycle track to be provided on the south side of the street (measured from face of curb), physically separated by a mountable barrier (as noted below);
- 0.6 mountable barrier with optional flexposts to provide physical separation between bicycle users and motor vehicles. An additional 0.2 metre shy distance should be provided on either side of the mountable barrier, resulting in a total shy distance of 1.0 metres. Additional shy distance should taper to 0 metres where required to achieve the minimum 3.0 metre sidewalk width noted above;
- 3.30 metre centre-running eastbound general purpose motor vehicle lane; and
- Shy distance of varying width to be provided between the eastbound general purpose motor vehicle lane and two-way LRT operations, with minimum required separation of 0.6 metre between the LRT Vehicle Dynamic Envelope (VDE).

It should be noted that the combined width of the cycle track, shyway, and eastbound general purpose motor vehicle lane satisfies the minimum staging width of 6.0 minimum metres required by Emergency Services. The mountable curb with optional flexposts would allow for emergency vehicle access.

It should also be noted that the priority in allocating space throughout the corridor is to maximize sidewalk width; as such, where possible, enhanced sidewalk width should be prioritized over providing clearance between LRT and motor vehicles beyond the minimum 0.6 metre required separation from the LRT VDE. The project team reviewed the traffic lane alignment and shifted the lane as much as possible to maximize sidewalk widths taking into consideration the location of the proposed LRT stations and maintaining the design speed for the corridor. However, it is recommended that additional opportunities be taken by P3 proponent to review tightening the curve radii along the travel lane where possible as the design is refined.

Ultimately, the study identified a number of design modifications and added features to be incorporated into the corridor design to improve safety for all users, including:

- a protected cycle track adjusted to a new location within the right-of-way than was originally proposed as shown in **Appendix A**, and **Figures 1** and **2** of **Appendix B**;
- improved protection for cyclists making turn movements across the LRT tracks as shown in **Figures 3** and **4** of **Appendix B**;
- reduced pedestrian crossing distances;
- widened sidewalks;
- added physical buffer space;
- incorporation of shyline offsets;

- addition of conspicuity markings and turn boxes; and
- dedicated signal phasing for each mode.

This design can serve as an example for other jurisdictions looking to safely design multi-modal corridors that include LRT. By providing safe, comfortable, and high quality facilities for transit users, cyclists, and pedestrians, it is anticipated that this will lead to significant behavior change and increased use of sustainable forms of transportation in Edmonton.

At present, this project is in the implementation stages. The LRT and the cycle track along 102 Avenue are scheduled for construction beginning in 2016 for completion by 2020. Until the work is implemented, it is difficult to quantify the benefits in terms of collision frequency or severity reduction as a baseline for this corridor is difficult to establish due to the significant change in nature of this corridor that is expected as the LRT is built and as Downtown development advances. However, research elsewhere demonstrates that this project will likely result in significant benefits in terms of increased cycling volumes and decreased cycling collisions, as the implementation of physically separated cycle tracks across North America has been consistently shown in research to significantly increase bicycle use and improve safety for all road users[iv]. In conjunction with the overall increase in activity along the corridor as a result of the LRT and significant redevelopment along the corridor, it is anticipated that safety will be significantly improved for all road users.

[iv] Research from the Cycling in Cities program at the University of British Columbia provides detailed evidence on the benefits regarding decreased cycling collisions and increased bicycle volumes as a result of physically separated cycle tracks across North America. Specifically, Route Preferences Among Adults in the Near Market for Bicycling: Findings of the Cycling in Cities Study (Winters, Teschke; 2010), and Route Infrastructure and the Risk of Injuries to Bicyclists: A Case-Crossover Study (Teschke, et al; 2012) provide detailed analysis on these topics. Publications are available at http://cyclingincities.spph.ubc.ca/

Appendix A

Proposed Alternative 102nd Avenue Concept Design

URBAN systems

DECEMBER 19, 2014

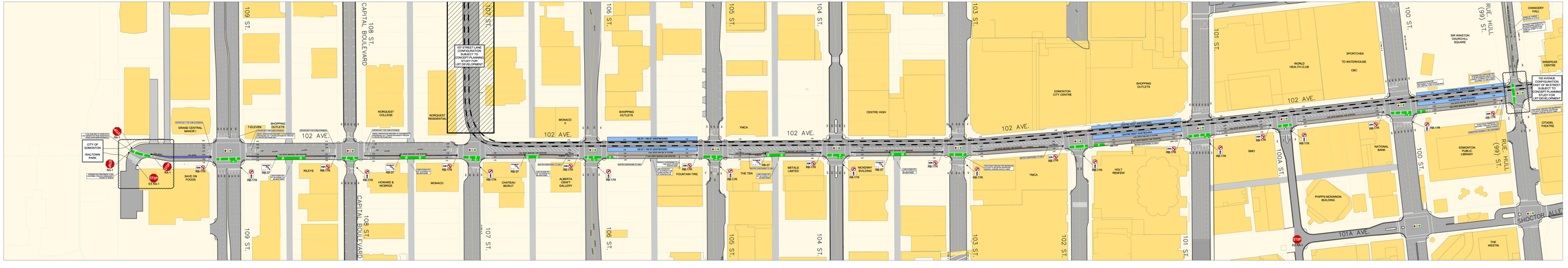
City of Edmonton - 102 Ave

City of Edmonton

Scale 1:50

102 Avenue Roll Plot - Ultimate

FIGURE 2



Appendix B

Supporting Figures

Figure 1: Typical Cross-Section (Non-Station Location)

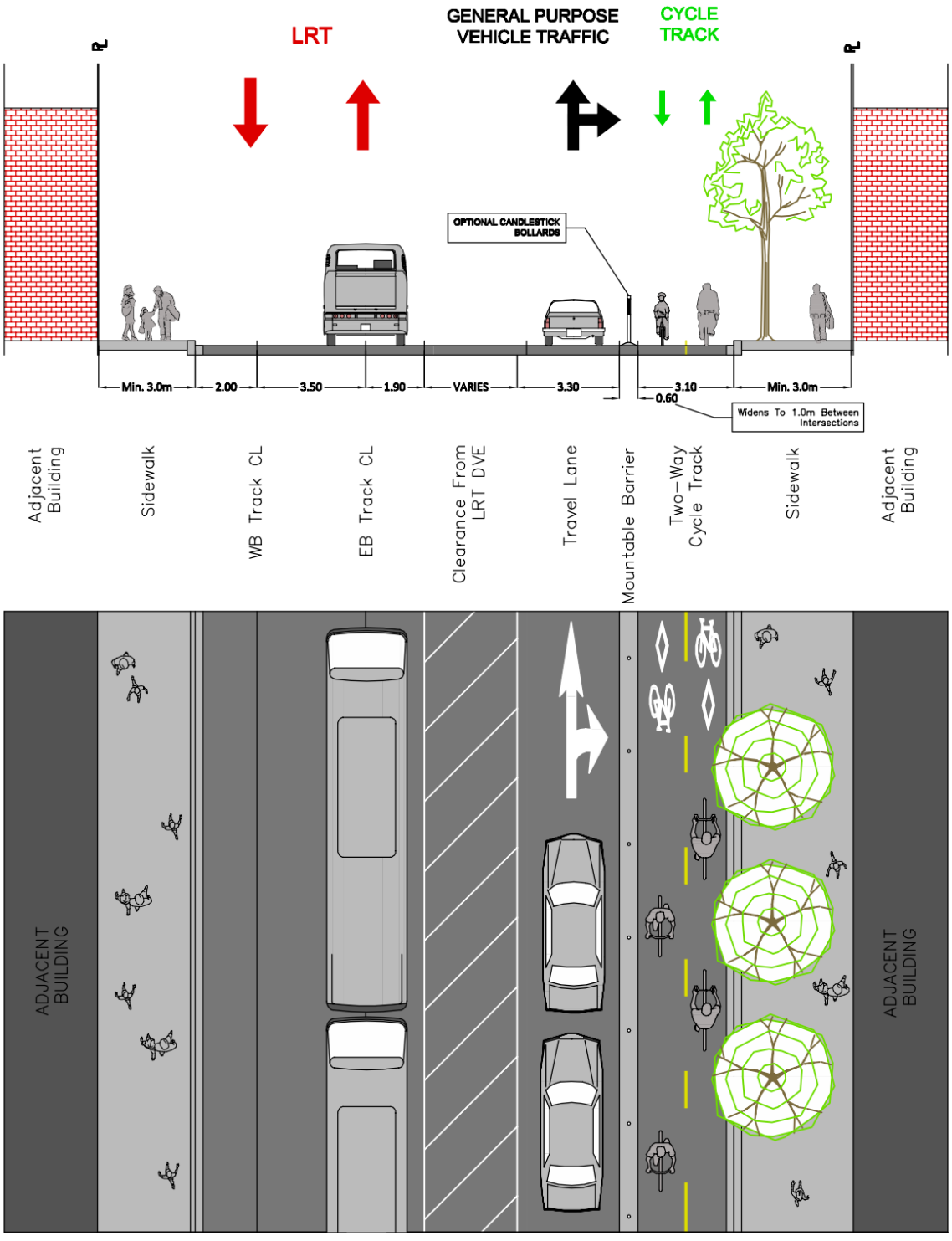


Figure 2: Typical Cross-Section (Station Location)

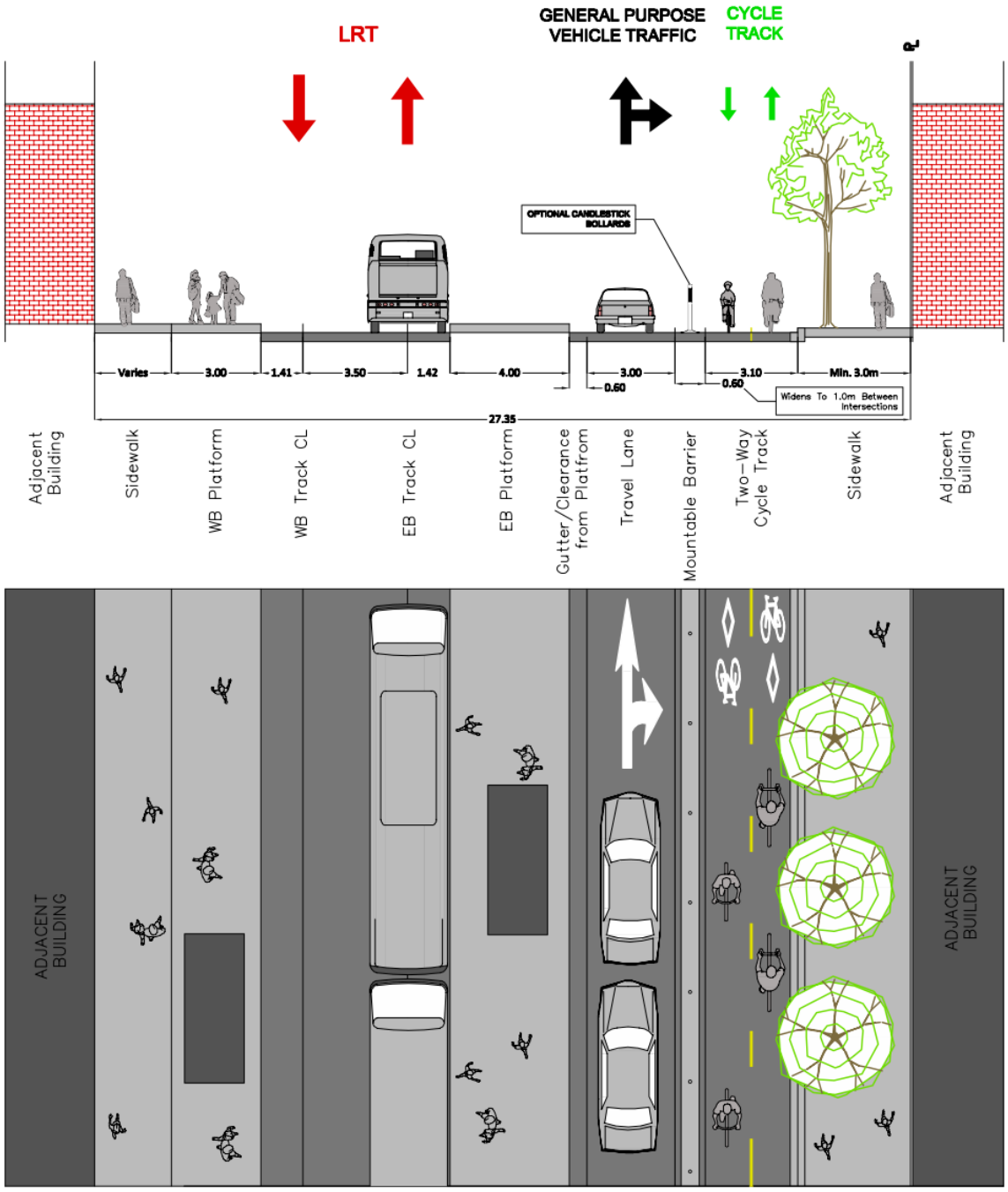


Figure 3: Typical Plan Concept (Non-Station Location)

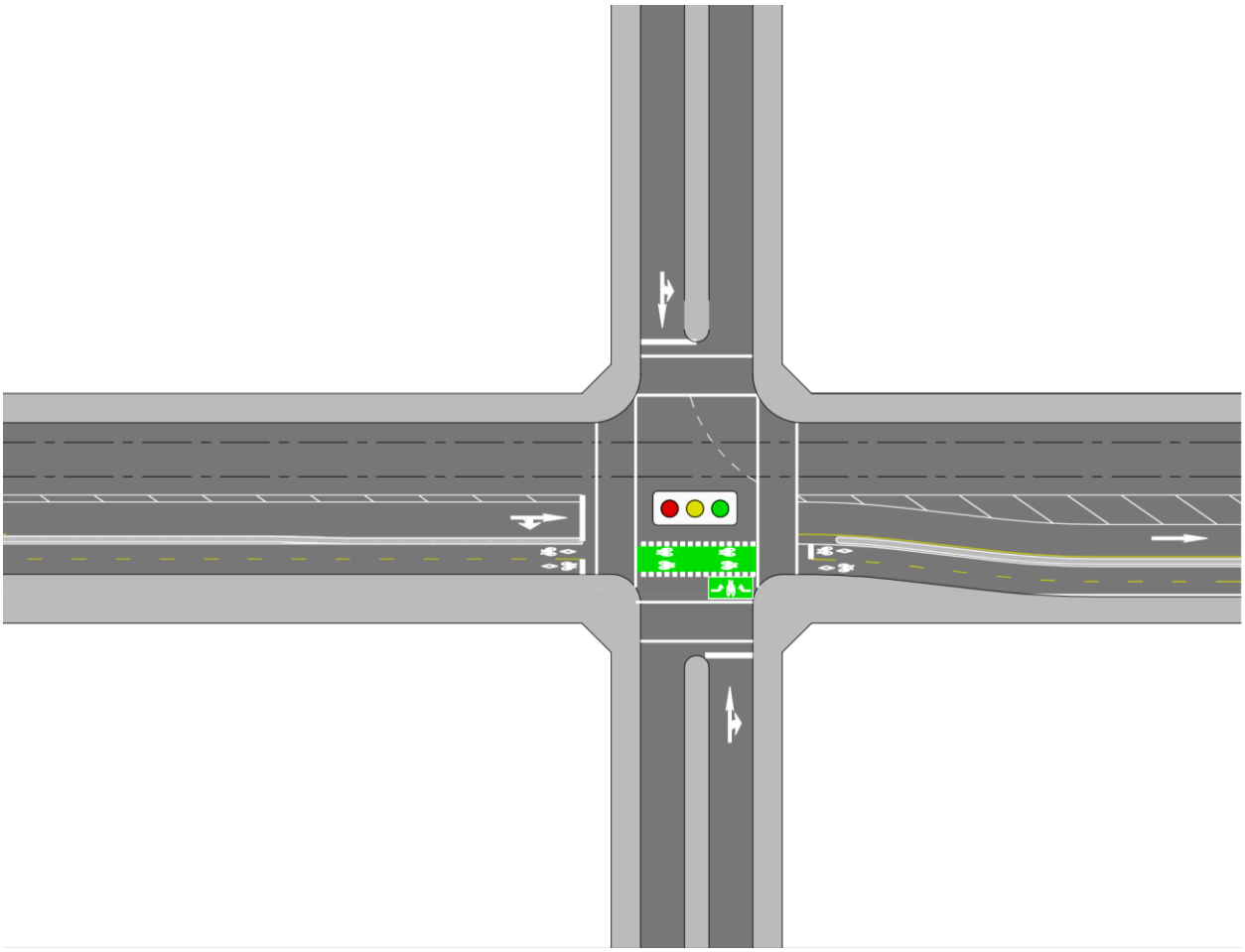
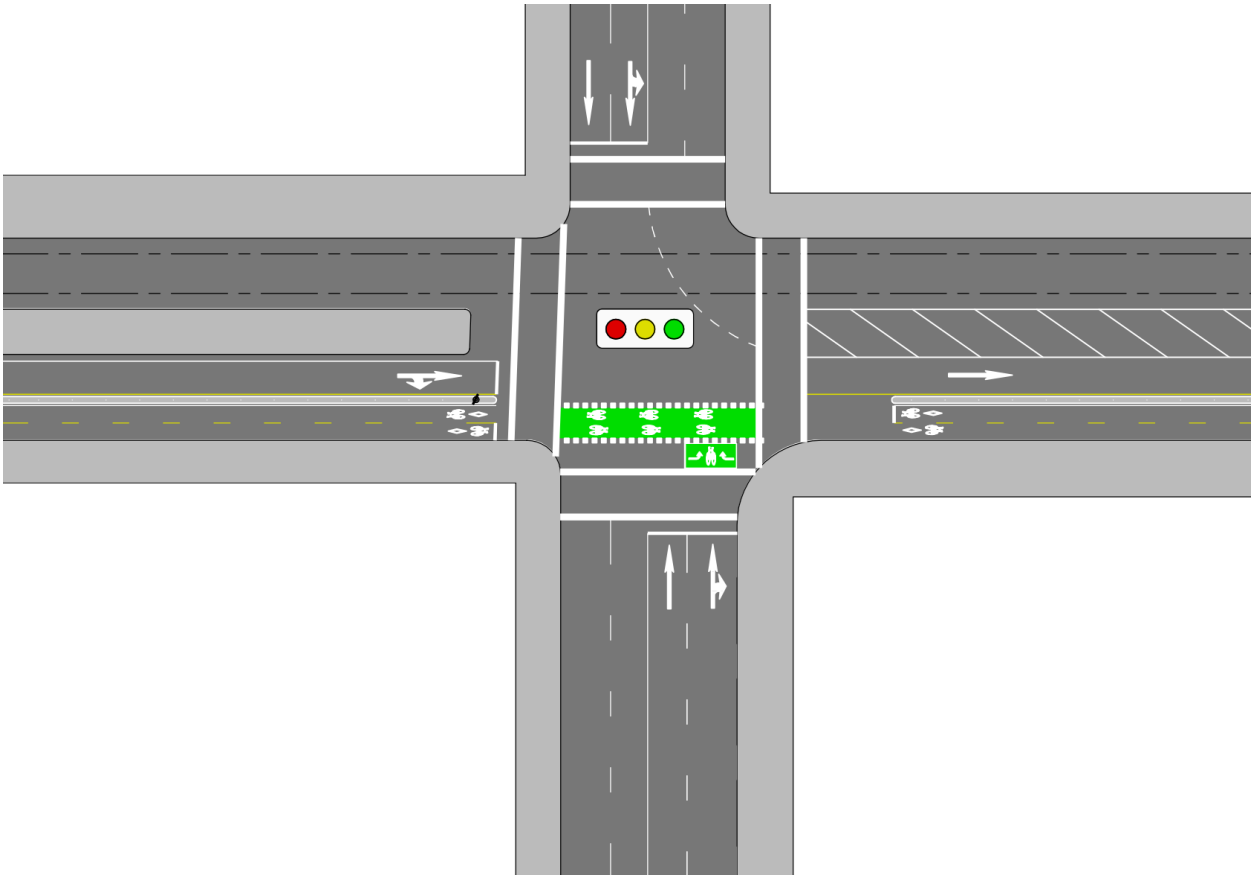


Figure 4: Typical Plan Concept (Station Location)



Appendix C

Proposed Alternative 102 Avenue Concept Design Swept Path Analysis

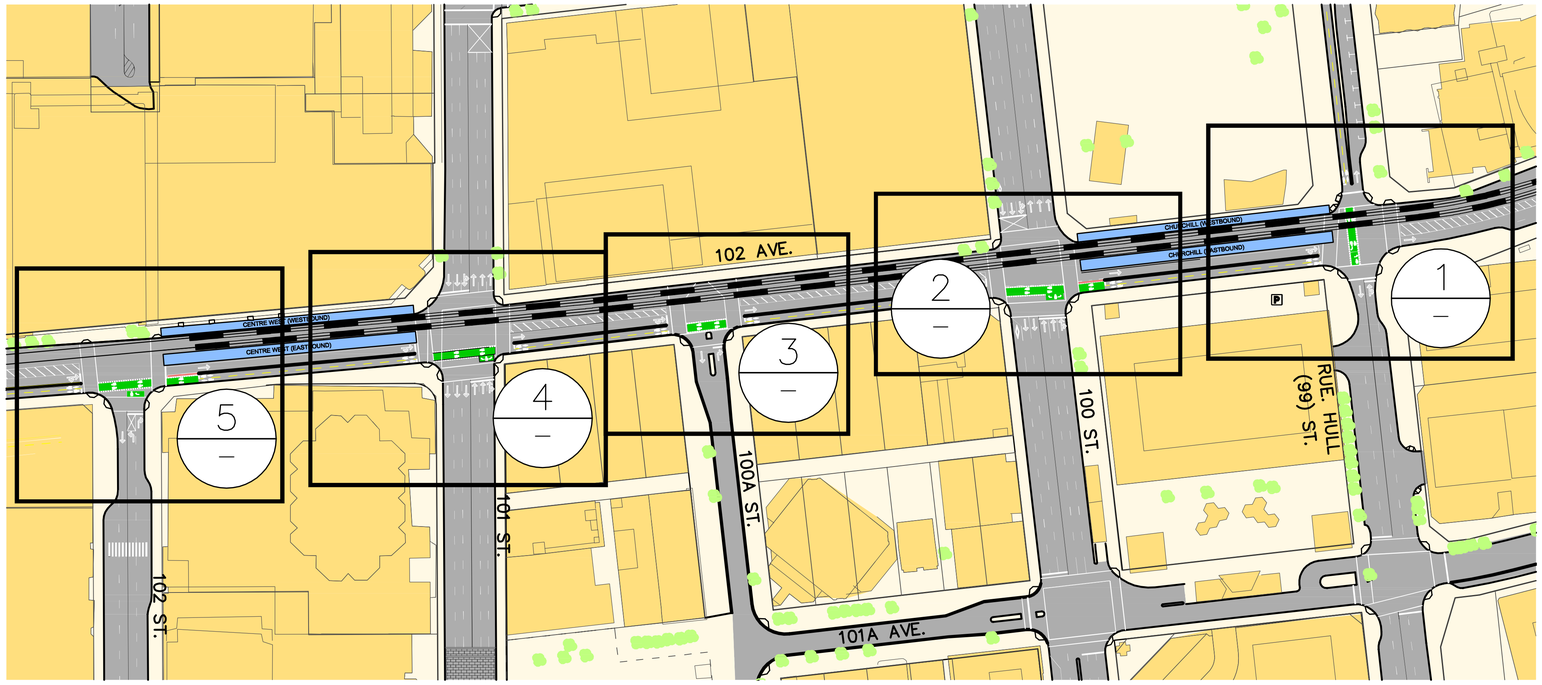
URBAN systems

2014-12-02

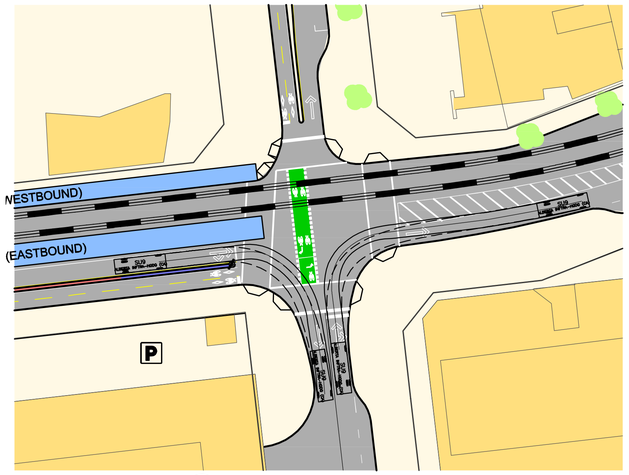
City of Edmonton - 102 Ave

City of Edmonton

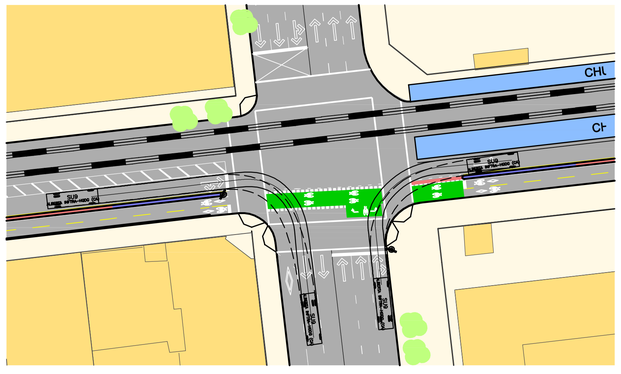
Scale 1:500



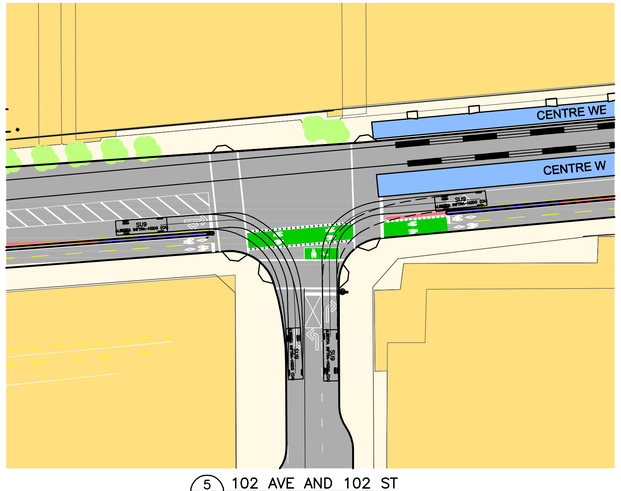
KEY PLAN
SCALE 1:1000



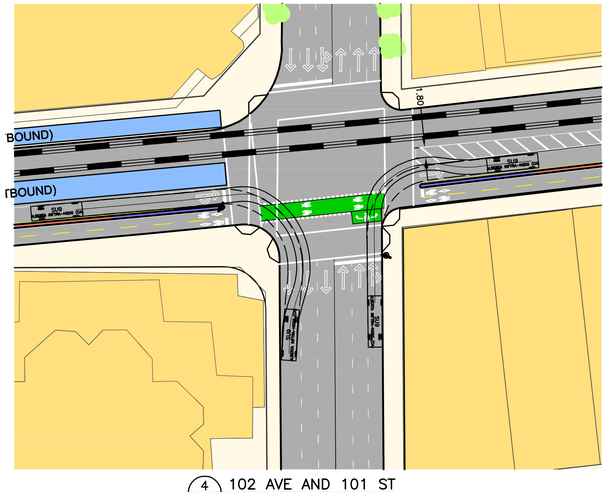
1 – 102 AVE AND RUE HILL
SCALE 1:500



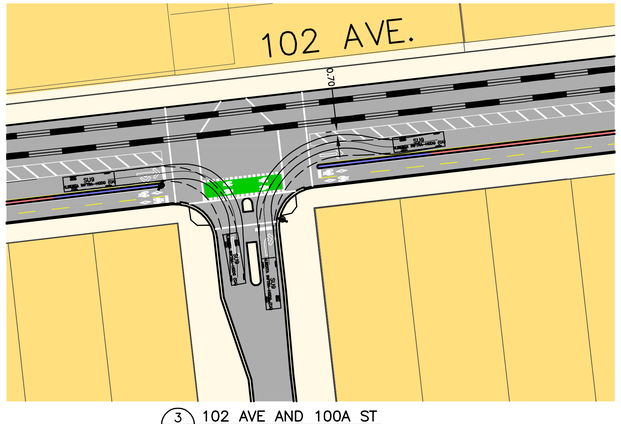
2 – 102 AVE AND 100 ST
SCALE 1:500



5 – 102 AVE AND 102 ST
SCALE 1:500



4 – 102 AVE AND 101 ST
SCALE 1:500



3 – 102 AVE AND 100A ST
SCALE 1:500

AutoTURN Template

FIGURE 3