Rethinking the Dundas Dupont Annette Intersection
Final Design Specifications

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April 14, 2015

Engineering Strategies and Practice

Executive Summary

This design project aims to solve the current hectic traffic patterns around the intersection of Dupont, Annette, and Dundas. This location creates safety hazards for motorists, cyclists, and pedestrians, and lowers the efficiency of traffic through the intersection. The client team is of varying professions and represents the surrounding communities, and is led by Jim Chisholm. The design team is composed of six University of Toronto undergraduate engineering students. This document discusses the design requirements of the project and discusses the detailed specifications of the final design.

Stakeholder analysis reveals that in general, relevant stakeholders want the design to maximize safety and efficiency of traffic flow, be easy to use, and reduce environmental impacts of the intersection. Through functional basis analysis, primary functions have been identified as to connect nearby roads and communicate traffic instructions to all users. The three objectives with highest priority were determined to be: the design should be as safe, as efficient, and take as little time to implement as possible. Potential solutions must not affect the nearby railway, not relocate local residents, be politically favourable, and must abide by existing regulations and guidelines. The service environment of the intersection features a grade drop of 4 metres between Dupont and the other roads, and variable seasonal weather conditions which potential designs must address.

The team presents the Four-Way Intersection as the final design. This design involves removing the 2 stretches of Dupont at the split, extending Dupont, and straightening Annette so that Dupont and Annette form a right-angled four-way intersection with Dundas. The traffic island is excavated so that Annette meets Dupont at a slope. This design simplifies the intersection into a conventional intersection to avoid confusion among drivers and pedestrians. The simplicity of the design is intuitive for users, reducing human error and in turn, increases safety. Efficiency is also increased as the traffic light durations will be less irregular. In this way, the design meets the functions, objectives, and constraints and solves the design problem.

The simplicity of the design takes human factors into consideration, and is easy to use for all users. All construction metrics must abide by federal and provincial construction and environmental guides and standard. Safety and efficiency of the design will be tested through surveys given to volunteers, and implementation time will be obtained through stick estimation.

Implementation requirements include hiring labourers, purchasing raw materials and equipment, relocating utilities, and setting up temporary lanes during construction. The most negative environmental impacts arise from the use of asphalt, which releases waste during its lifecycle. These can be ameliorated through eco-friendly practices. Major costs arise from the design's construction and maintenance, and external costs feature inconvenience to the surrounding neighbourhoods during construction. The design will cost around $8 million total and take upward of 3 years to implement.

This document has fully described the details of the final design. The design project is now complete, and the design team will be formally presenting the final design to the clients and the project manager on April 27.

1.0 Project Requirements

The client, Jim Chisolm, has presented the design team, composed of six University of Toronto undergraduate engineering students, with a design problem to improve an intersection in West Toronto. This section defines the requirements by which the design project must proceed.

1.1 Problem Statement

The intersection of Dupont, Annette, and Dundas St. W (DDA) is a major intersection in suburban Toronto which poses problems for drivers, cyclists, and pedestrians passing through. Heavy volumes of traffic cause traffic congestion. Drivers entering DDA are often over the speed limit, and DDA's low visibility conditions increase chances of vehicular collision[1][2][3]. DDA lacks comprehensive signage and clear traffic lanes, and non-intuitive signal changes create confusion for users and increase the risk of accidents[4][5]. Consequently, travel time through DDA is increased for all parties. DDA also lacks bicycle lanes and sidewalks in some areas, increasing safety risks for cyclists and pedestrians. Thus, the current intersection is both unsafe and inefficient in practice.

The client need is to channel mass in the form of vehicles and people between the areas connected by the intersection. For the above reasons, the design is required to maintain flow of traffic of drivers, cyclists, and pedestrians in an organized and safe manner. The design cannot affect the nearby railroad or relocate residents. It also must be politically favourable to acquire funding and permission for implementation. The design should reduce the chances of collision, maximize cyclist and pedestrian safety, and be intuitive to use to reduce human error. Finally, the design should encourage a smoother flow of traffic to increase efficiency.

1.2. Identification of Stakeholders

The interests of relevant stakeholders are important to consider to ensure that the design benefits as many parties as possible [6]. The following table discusses stakeholder interests and their implications.

Stakeholder	Independent Interest	Influence on Design
Local residents	Convenience and safety	Objectives: Be easy to navigate for pedestrians [7] Minimize traffic noise [8]
Construction workers	Safety of construction site [9]	Constraints: Avoid the use of hazardous materials to minimize the health risks [10]
Toronto Transportation Services[8]	Road safety [11] Increase profit [12]	Objectives: Minimize cost [12] Maximize lifespan.[12] Maximize safety for users [13]
Toronto Transit Commission (TTC)	Flow of traffic Alteration of bus routes and stops [14]	Objective: Accommodate large traffic volume
StreetARToronto	Promote street art [15]	Objective: Be aesthetically pleasing [15]
Local business owners	Increase profit	Function: Increase people flow
Cycle Toronto (NGO)	Promote safe bicycling [16]	Objective: Provide a safe bicycle lane [16]
Toronto Environmental Alliance	Promote a greener Toronto [17] Encourage public transit [18]	Objective: Facilitate the use of public transit Maximize green space.[13]
Canadian National Railway	Railroad safety[19] Delivering goods efficiently [20]	Constraint: Cannot affect nearby railroads.
Utilities (Toronto Hydro, natural gas, Toronto water)	Supply utility efficiently	Objective: Minimize alteration to pre-existing utility systems
Emergency services[13]	Decrease time required to reach destination[13]	Objective: Be easy to navigate for emergency vehicles

1.3 Functions

The functions of the design were generated through the functional basis and black box methods (Appendix A).

1.3.1 Functional Basis
- Control mass

1.3.2 Primary Functions:
- Connect nearby roads
- Communicate traffic instructions to users [21][22]
- Channel movement of vehicles and people

1.3.3 Secondary Functions:
- Allow users to enter/exit design
- Reduce commuter travel time

1.3.4 Unintended Function:
- As a landmark for geographical orientation

1.5 Objectives

Objectives serve as criteria by which to compare alternative designs and evaluate tradeoffs. The client has specified that cost should not be a factor in the design process. Objectives were generated through how-why trees, prioritized through a pairwise comparison chart (Appendix B), and listed below in order of importance.

- Maximize safety
    - Maintain an eCCDF value of 0.6 or higher [23]
    - Implement all necessary communication methods as defined by the Ontario Traffic Manual [24]
- Minimize travel time
    - Design should reduce the time spent navigating the intersection as much as possible, in minutes
    - Limited number of steps needed in order to reach respective destination
- Minimize time required to implement the design, in days
    - Abide by the typical construction times of similar designs defined by the city of Toronto records [25]
- Minimize noise pollution, in decibels
    - Noise reaching surrounding neighbourhoods should not exceed 70 db for more than 8 hours at a time for safety [26]
- Increase green space, in square meters
    - Green space should be increased as much as possible to maximize the mental health benefits. [27]

- Minimize carbon footprint, in carbon dioxide equivalents

1.5 Constraints

Constraints are criteria the design must abide by. Designs which fail any one of these criterion cannot be considered.

- Cannot infringe on the existing railroad line on east side of the intersection, per client instructions
- Cannot relocate any surrounding residents, per client instructions
- Must be politically favorable to obtain approval and funding, per client instructions
- Cannot involve use of hazardous materials outside of Ministry of Labour standards [28]

1.6 Service Environment

The DDA intersection is a complicated system and the service environment is diverse. Operational year round, the design is influenced by passive and seasonal conditions as follows (Appendix D).

1.6.1 Living Environment

- Animals
    - Small urban rodents live in the area [29]
- Plants
    - Small trees and grass (Appendix D)

1.6.2 Physical Environment

- Road Structures:
    - The bridge of West Railpath covers one entrance of the intersection with a width of 3.5 meters (Appendix D)(Appendix E) [30]
    - 1000 m^2 traffic island located at center of the intersection (Appendix E)
    - 3 meter grade difference separates Dupont and Dundas
    - Bus stop at the centre of intersection (Appendix C)
- Buildings:
    - Auto centre on the southwest side (Appendix C)
    - Cafe at DDA (Appendix C)
    - Cash Money at corner of Dundas/Annette (Appendix C)
- Weather
    - Average wind speed: 11 to 18 km/h [31]
    - Average annual rainfall: 828.3mm [32]
    - Temperature range: -31 degrees to 36 degrees Celsius [32]
    - Average annual snowfall days: 31 [32]
- Noise
    - Public roads generally produce noises between 70 to 80 dB [33]

- Base
    - Current roads composed of mainly cement and asphalt [34]
    - Salt used to prevent the road from freezing in winter [35]

1.6.3 Virtual Environment

- Underground electricity supply
- Wifi and cellular networks available

1.7 Client Ethics and Values

The client Jim Chisholm represents the West Bend Community Association, which regularly receives notices from the City of relevant issues regarding the area. WBCA reflects the interest of the West Bend community, and collaborates with all levels of government to express resident concerns [37]. WBCA's primary interest is to create a safe living environment for the residents of West Bend [37]. Thus, the design's top priority is ensuring convenience and safety for users. The client also places importance on the design to be politically favourable, and thus the final design needs to appeal to as many users and stakeholders as possible.

2.0 Detailed Design

The design team and the client have agreed to move forward with the recommended design, the Four-Way Intersection (FWI). FWI was generated through Design for Safety and Design for Efficiency. Problems in the current DDA intersection arise from the lack of signage and visibility, and overall, the non-intuitive nature of the junction. These factors create confusion among all users and decrease safety and efficiency of the intersection [38]. FWI is based on the principle that simplicity, familiarity, and meaningfulness of a design increases user comprehension [39][40][41]. Note that all figures in this section are to scale.

FWI involves the following changes to DDA and surrounding area (Figure 1):

- Removal of two stretches of Dupont from the split until Dundas, 2300 m^2 of road
- Removal of Old Weston Rd between where it meets Dundas and where it curves, 280 m^2
- Removal of Annette between Indian Rd and Dundas, 500 m^2
- Expropriation of the Cash Money property, freeing up 1200 m^2 of land
- Removal of traffic island, freeing up 1100 m^2
- Lowing elevation of area between Dundas and Dupont to reduce the 4 m grade difference by a slope from Annette to Dupont

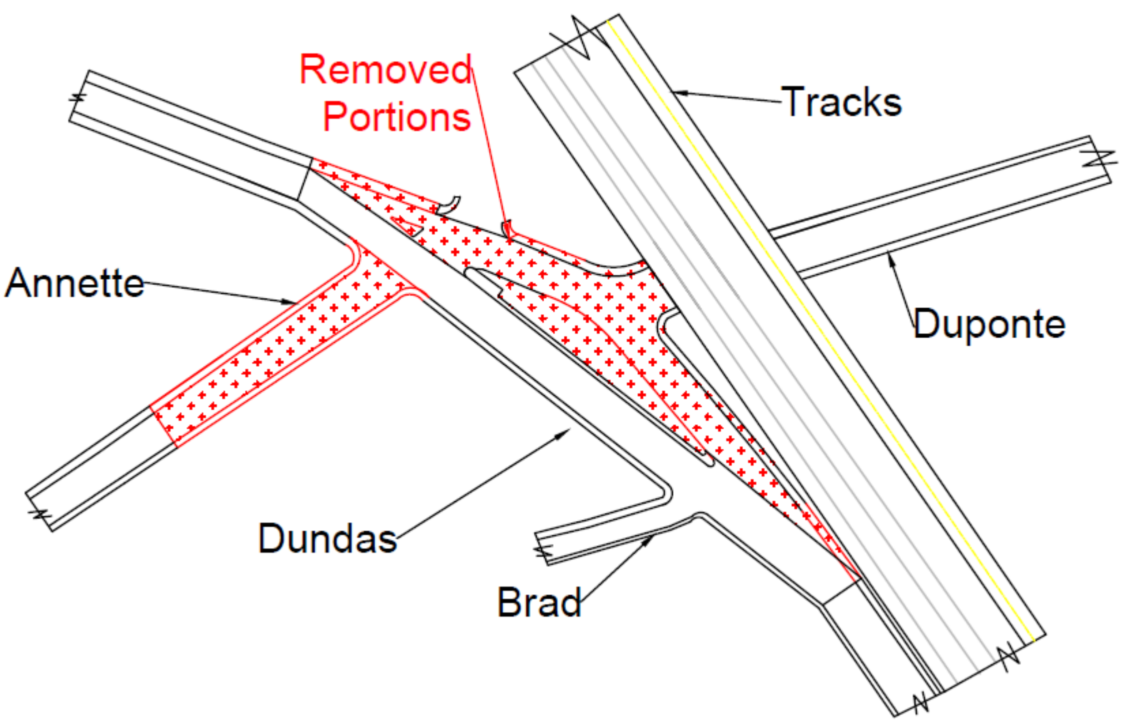

Figure 1. Portions removed from the current intersection

FWI involves the following additions (Figure 2) (Figure 3):

- Extension of Dupont to meet Dundas, an addition of 450 m^2 of road
- Extension of Annette from Indian Rd to meet Dundas and Dupont, 880 m^2
- Construction of cul-de-sac where Old Weston is cut off
- Addition of 1 extra lane, both ways on Dundas, 1450 m^2
- Addition of separate right-turn lanes in all four directions, along with small triangular traffic islands
- Addition of bicycle lanes and sidewalks in all directions

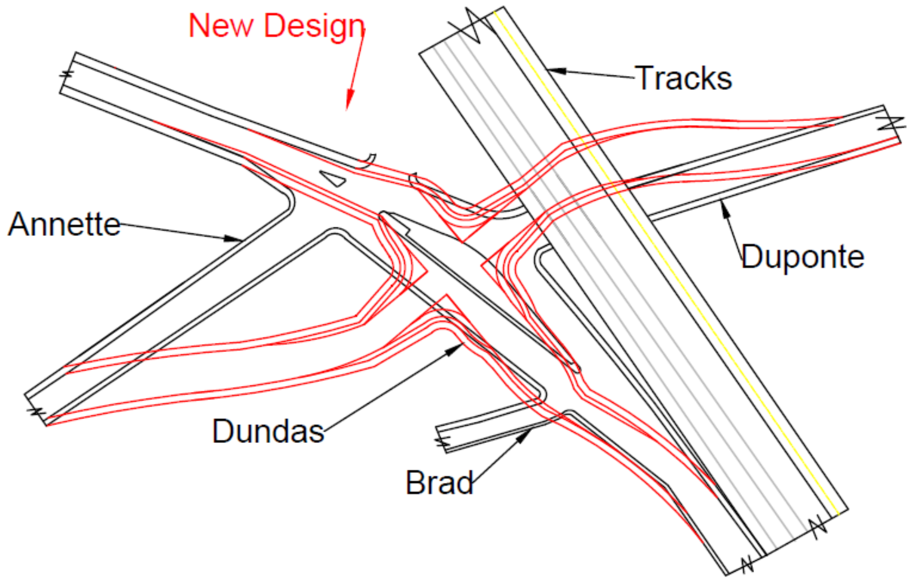

Figure 2. Superposition of FWI over the current intersection

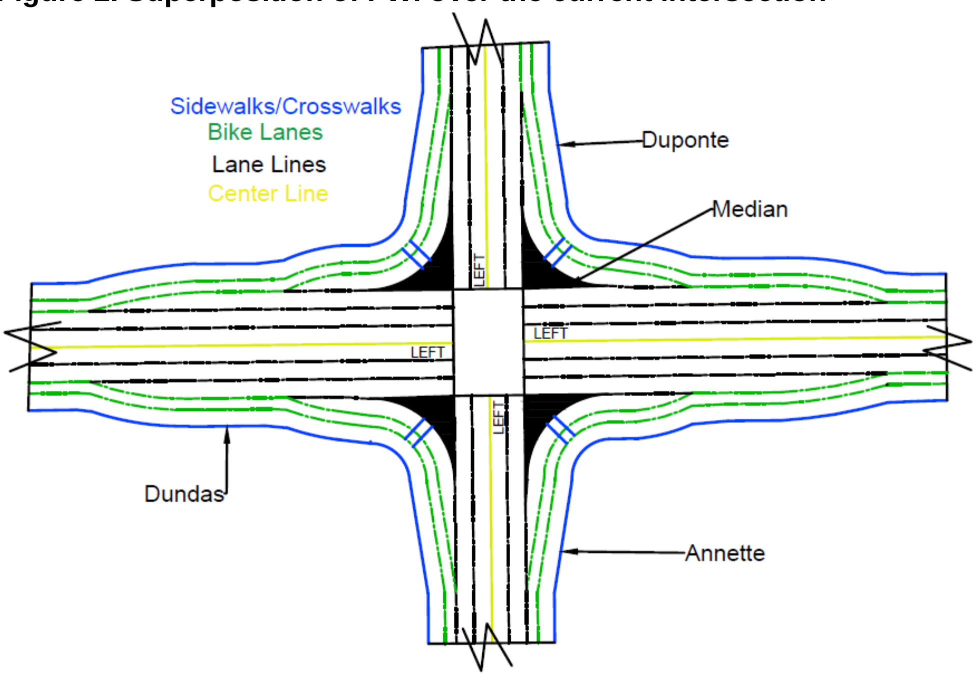

Figure 3. Detailed lane specifications of FWI

In essence, FWI involves the following changes to DDA:

- The 4 meter grade difference becomes a slope from Annette to where Dupont dips below the railpath
- Dupont becomes a single road and Annette straightens to join Dundas and Dupont at near-90° angles
- 200 m stretch of Dundas lowers in elevation to create an unsloped intersection
- DDA becomes a regular, 340 m^2 four-way intersection
- Parking lot of Cash Money and nearby construction site freed up, 1500 m^2
- 4000 m^2 total is freed up in the surrounding area (the extra 4000 m^2 of free space can be transformed into greenspace to mitigate negative environmental impacts of the project (Section 2.4) or be sold as commercial property to reduce costs.)

FWI meets the functions and objectives in the following ways:

- Function: the design connects Annette, Dupont, and Dundas into one four-way intersection and channels the movement of people among these roads.
- Function: simplicity of FWI communicates clear and familiar traffic instructions to users.
- Objective: simplicity and familiarity of FWI's design increases user comprehension, reducing human interpretation errors and therefore increases safety[39].
    - Reduction of shared space among all vehicles and pedestrians reduces chance of collisions.
    - Roads joint at right angles increases visibility[42].
- Objective: user familiarity with design and introduction of right turning lanes encourages traffic flow and reduces travel time[43].
- Objective: one turn is required from any road connected to another.

However, the design is expensive with a long implementation time, costing around $8 million and 2 years to implement (Appendix O).

By meeting these functions and objectives, the FWI design solves the current problems of confusion within the intersection and high chance of collisions. Through the intuitiveness of FWI, the design is comfortable to use for motorists, cyclists, and pedestrians. The design creates a shared road for all users. This encourages people flow in the area and solves the current problem of DDA being perceived as a dangerous intersection for non-motorists. Therefore, the FWI design creates a safe and efficient intersection which meets the client needs and major interests of all users.

Engineering Strategies and Practice

2.1 Regulations, Standards and Intellectual Property

This section outlines the intellectual property laws and standards that impact the design. Federal, provincial and municipal standards are taken into consideration with regards to the their respective portions of the design.

2.1.1 Intellectual Property

The design is composed of surface infrastructure methods currently implemented by the Canadian government, therefore the necessary patents for these components have already been properly purchased and protected.

2.1.2 Regulations and Standards

The following table outlines all the various standards and regulations that are essential to our design, and their impact on the design specifications.

Standard/Code/Regulation	**Impact on Design**
Geometric Design Guide for Canadian Roads[44] Section 2.2.2: Lane Width	Lane width must abide by standards in table 2.2.2.3 (Appendix J)
Geometric Design Guide for Canadian Roads [44] Section 2.1.3: Vertical Alignment	Grade differences must abide by values in section 2.1.3.3 (Appendix K)
Geometric Design Guide for Canadian Roads[44] Section 3.4.2: Bicycle Lanes	Bike lane width and clearance must abide by the values in section 3.4.2.1(Appendix L)
Geometric Design Guide for Canadian Roads [44] Section 2.3	All other lane configurations and intersection specifications must abide by standards defined in this section. These details include: ● Tapered Lanes ● Bike Lanes ● Sidewalks ● Turning radius
Ontario Provincial Standards for Roads and Public Works[45] Volume 1-General and Construction Specifications	● All interference with utilities must abide by section 4 ● Concrete work must abide by section 3 ● Construction safety in terms of traffic must abide by section 7 ● Any excavation on ground materials (eg. soil, rock) must abide by section 8
Canadian Environmental Assessment Act [46]	All materials and construction methods must abide by the regulations in this act

2.2 Testing

This section outlines tests to ensure the design meets the objectives. The following table presents testing methods to measure how well the design meets the top 3 objectives. Column 3 defines how results are to be interpreted.

Objective	**Proposed tests**	**Results**
Clear communication and maximize safety	• Conduct Visual Field survey with users and calculate the average ”Visual Field Score”(Appendix M). • Check all the staffs of the intersection according to Ontario Traffic Manual[47].	• Visual Field Score:(Appendix M) ○ Drivers: ■ 86%+ excellent ■ 72%+ good ■ 50%+ passed ○ Pedestrians: ■ 91%+ excellent ■ 77%+ good ■ 55%+ pass • If the intersection contains all necessary communication methods from Ontario traffic Manual, it passes[48].
Minimize travel time	• Conduct “Blind Intuition Test” and calculate the matchup score.(Appendix N) • Measure traffic flow rate and calculate the maximum traffic load of the intersection[49].	• Matchup Score:(Appendix N) ○ 90%+ excellent ○ 80%+ good ○ 70%+ pass • If the maximum traffic load is larger than the measured traffic flow rate, the intersection passes .
Minimize implementation time	• Estimate the total construction time using stick estimating[50].	• If there is no conflict between design implementation time and City standards, the design passes [51].

2.3 Implementation Requirements

This design must be approved by the local municipality. It will be fully conducted by the government and construction companies.The following table lists the main implementation requirements and procedure and descriptions accordingly. The specific estimate cost of each is included in Appendix O.

Implementation Requirements	**Descriptions**
Surveying	Surveying is helpful to give feedback from local residents. The estimated cost is $1.20 per stake[52]. The cost has take account into inflation of dollars from 1992 to 2015.
Hiring Labourers	Minimum wage:$11.25/hour[53] Suggested wage: $20/hour[54] Amount of labour: 120 (Using Benchmarking)[55]
Utility Relocation	Utilities involved include:[56] ● Water and sewer lines ● Underground power and communication ● Wireless communication ● Pipelines
Setting Up Temporary Lanes to Channel Traffic	To minimize the influence of construction on traffic, the design will be implemented in stages: ● First stage: close Dundas and use Dupont as a T-intersection ● Second stage: close Dupont and open Dundas

Business and Land Expropriation	Cash Money requires expropriation.
	By Expropriation Act, the expropriation has the main procedure of [57]:
	● Notice of expropriation
	● Business valuation
	    ○ Use Asset-Based Approach[58]
	● Compensation:
	    ○ Market value of land and business
	    ○ Damage caused by disturbance
	    ○ Any special difficulties in relocation
	● Negotiation or arbitration

Purchasing Raw Materials	Main materials used:[59] ● Fill materials: Organics (sand, clay, decomposed rock) ○ Must meet minimum California Bearing Ratio(CBR) ● Surface materials: soil, asphalt and concrete ● Separation materials: geosynthetics

Renting Equipment and Machinery	There are 4 basic stages of construction [60]: ● Excavation and loading ● Compaction and grading ● Lifting and Erecting ● Mixing and paving Main machineries include [61]: ● Excavator ● Asphalt paver ● Compactor

2.4 Life Cycle and Environmental Impact

This section outlines the major environmental impacts the design encountered during its lifetime, from assembling raw materials to road rehabilitation. The fundamental and most used material in road construction is concrete or asphalt. The use of asphalt is recommended in this design due to its benefits (discussed in impact analysis). Hence the life cycle assessment (LCA) will examine the key impacts that arise from asphalt whereas the miscellaneous materials such as road paints and signages are not accounted for.

2.4.1 Inventory Analysis

The following diagrams (next page) identify mass and energy consumed and produced from each lifecycle stage of asphalt production and the design[62][63][64][65][66][67]. The asphalt lifecycle includes extraction, refinery and production, where majority of the pollution came from extraction process. The design lifecycle consists three parts: construction, operation and rehabilitation. Each parts consist of their respective negative impacts.

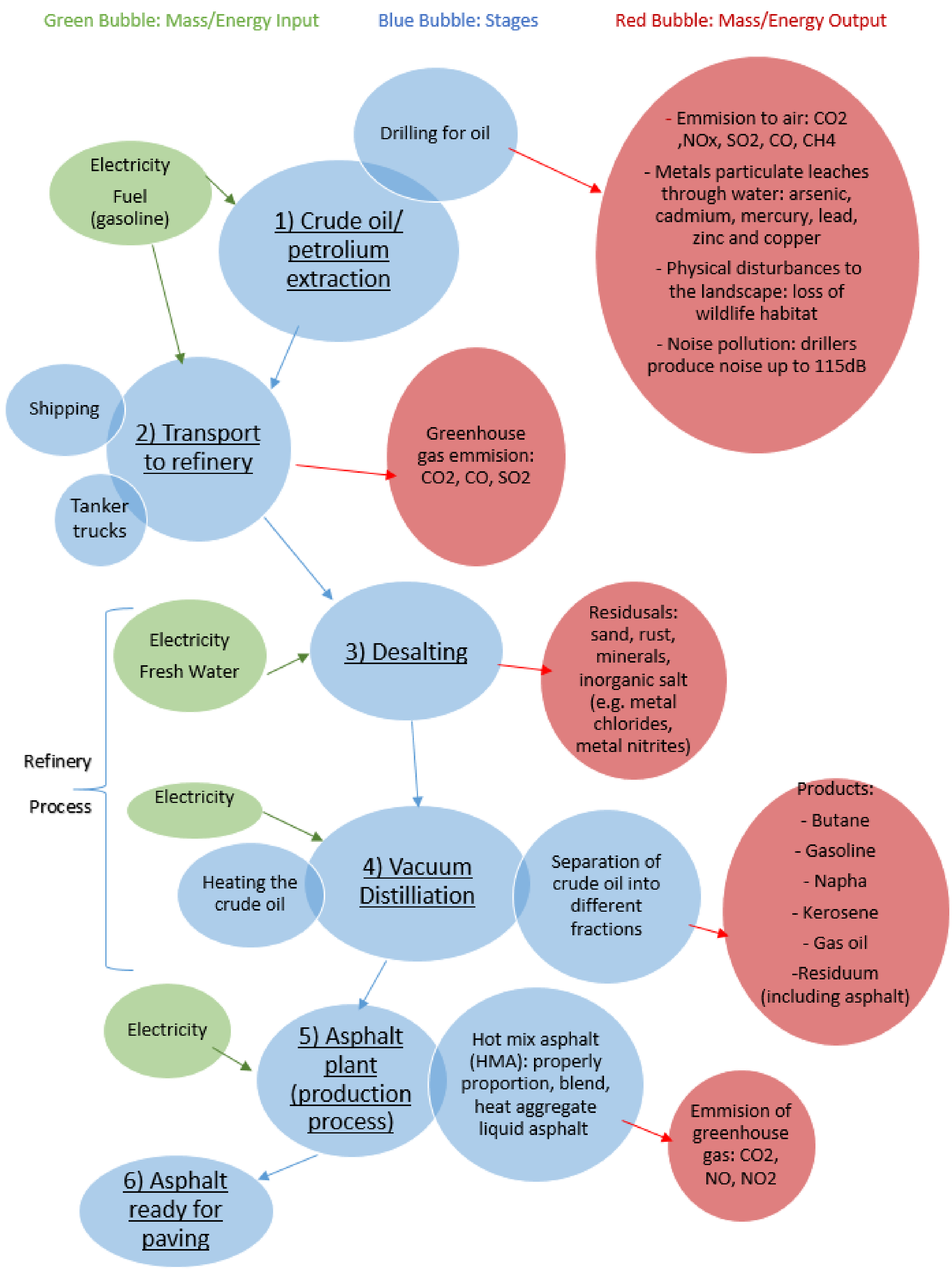

Figure 5. The LCA of asphalt production

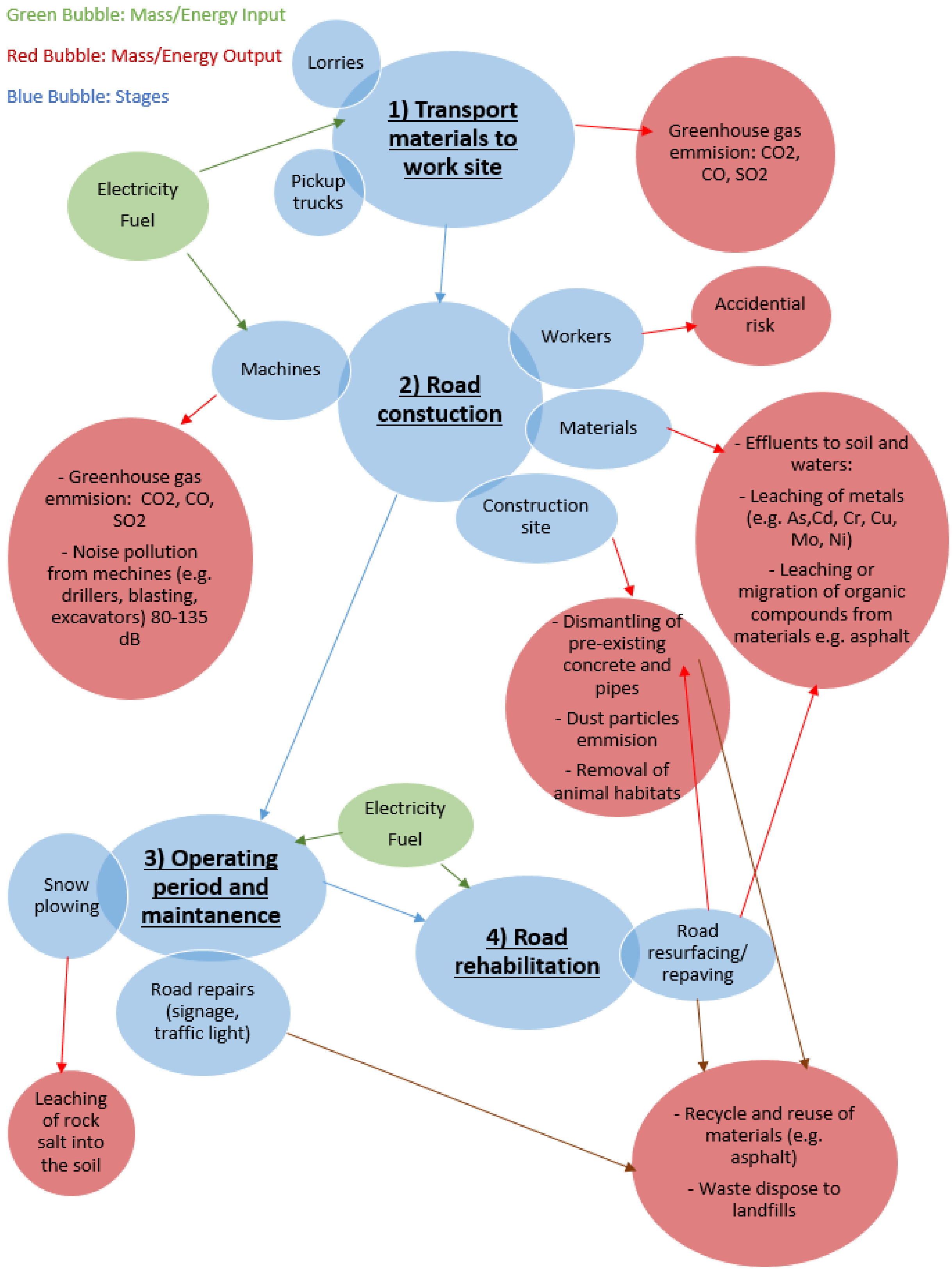

Figure 6. The LCA of the design

2.4.2 Impact Analysis

The environmental impacts and benefits of asphalt:
Production

- Greenhouse gas (GHG) emissions from asphalt plants are low [68] compared to concrete production (5% of global GHG emissions)[69].
- Asphalt plants emit highly odorous chemicals but are at levels below that pose health threats[72].

Construction

- Asphalt contains low level of heavy metals (50 folds below hazardous level) [71] and organic compounds that leaches into the soil or emitted through air during paving.

Operating period

- Asphalt can withstand cold temperature while concrete cracks[72].
- Asphalt unaffected by salt in snow plowing whereas concrete corrodes[73] and produces hazardous compounds [74].
- GHG emission of asphalt during 50 year service life is 30% of concrete[68].
- Rainwater drains through asphalt surface[75].

Road rehabilitation and disposal:

- Over 99% of asphalt can be reused or recycled into new asphalt pavement[72].

2.4.3 Improvement Assessment

According to inventory analysis, both asphalt production and the design contributes to a considerable amount of waste. Therefore, the following table outlines sources of impact in different lifecycle stages and recommended improvements that can be made in order to reduce and prevent them.

Stage	**Source of Impact**	**Mitigation**
Raw material extraction and production	Emission of metal particulates and air pollutants during drilling and extraction	Use directional drilling technique to minimize waste production[76] Use drilling recovery system that recycle drilling fluids[76] Use baghouse filters to capture particulates[68]
	Loss of wildlife habitat due to increase in ocean drilling rigs and platforms	Minimize amount of land disturbance Implement dust control and erosion practice[77]
	Disposal of toxic wastewater during desalting	Use water treatment plant to purify wastewater[78]
Transportation	Particulates generated by vehicles	Use renewable energy sources[79]
Construction	Dust particles emission	Cover the soil and construction materials[80] Keep waste moist when loading into dump trucks[80]
	Noise generated by machines	Implement different noisy activities at the same period to minimize noise emission time[81]
Operating period	Energy required to light signals and equipment	Use solar rechargeable battery[79]

2.5 Human Factors

This section discusses how the design addresses different levels of human-tech ladder, which shows how the design reflects human needs from different perspectives, starting from the basic level of physical demands to applying higher organizational and political systems. Physical and psychological levels try to address the issue of the usage of the design. For organizational and political level, the design takes consideration of municipality, construction company and government, trying to have a grand view of the design. The table discusses four of the levels and justifies how the design addresses each.

Human-tech levels	**Relevance in the design**	**Explanation**
Physical	Right-angle four-way intersection for ease of use. Lowering the elevation of traffic island for ease of use.	Users reach their destination with at most one turn for drivers or two crossings for pedestrians. Balancing the elevation of roads reduces chances of slipping in extreme conditions[82].
Psychological	Elimination of two traffic islands for simplicity. FWI reduces human error due to increased familiarity of the people.	Increases visibility and reduces blind spots[83]. People are more familiar to the usage of FWI. Thus the design reduces human error which causes collisions and accidents[83][84].
Organizational	Requires cooperation between municipality and contractors for maintenance. Requires cooperation of the local residents and city organizations.	During the construction period, the design involves the cooperation of the three parties, namely the municipality, the contractors and the residents. The temporary roads may affect the travel plans of the users[85].
Political	Raises land value.	High efficiency of the intersection attracts more traffic. The area in the northeast and southeast of the intersection will be available for commercial usage which will attract funding[86].

2.6 Social Impact

The proposed design tries to cater towards every user and stakeholder interest while minimizing negative social impacts. The table below identifies types of users/stakeholders, their respective interests and hence leads to different impacts on the design. Note that the design's impact does not necessarily support the stakeholder interest.

User and Stakeholder	Independent Interest	Design Impact
Motorists	Quality road conditions	Removes blind spots/sharp turns Increases visibility Reduces number of turns required
Local residents/ commuters	Improve living quality Improve safety and convenience	Increases greenspace[27] Reduces traffic noise[87] Decreases steps and distance to reach destination
Municipal government	Improve road safety Increase profit	Reduces risk of accidents Reduces cost through long lifespan[88]
TTC	Improve traffic flow	Relocates bus stop
Local business owners	Increase profit	Increases people flow
Cycle Toronto/cyclists	Promote safe bicycling	Reduces number of turns Makes bike lanes easier to use
Toronto Environmental Alliance	Promote a greener Toronto	Increases greenspace
Canadian National Railway	Delivering goods efficiently	Inconveniences railroad system temporarily
Utilities (electricity, natural gas, water)	Supply utility efficiently	Require to reconstruct part of the pipe and cable system
Emergency service [89]	Decrease time required to reach destination[89]	Reduce travel time through the intersection

Other impacts include:
- Enhance in aesthetic appeal due to more greenspace and conventional intersection design
- Increase in air pollution due to increase in traffic flow
- Increase job opportunities for workers and businesses due to construction and increase in people flow
- Increase property value of nearby houses and lands due to improve in living quality
- Increase in local rent due to increase in people flow

2.7 Economics

This section estimates the cost of FWI in its lifecycle. The following table identifies different types of cost which occur in each phases of the lifecycle. There are three segments in this part: capital, operation and disposal cost. Each cost consists of internal costs which are direct, monetary costs and external costs which are indirect and concern the interests of the social surroundings. Rough internal cost estimation is available in (Appendix O).

Life-cycle	**Internal cost**		**External cost and benefits**
	Fixed cost	**Variable cost**	
Capital cost	Landscape construction permit[90] Construction bond and insurance[91] Expropriation cost Concrete and asphalt application cost	Labor[90] Material[90] Equipment[90]	The construction involves noise and air pollution.[92] The temporary road will cause traffic congestion due to the reduced area used for traffic flow at the intersection. The construction will cause temporary inconvenience for users (local residents, commuters, cyclists and drivers).[93] The usage of heavy machine will result in greenhouse gas buildup.[93] The construction increases local job opportunity.

Operating cost	Contract cost with service department	Maintenance[94] ● Annual maintenance ● Drainage maintenance ● Snow plow[95] Running cost ● Electricity ● Road cleaning Incidental cost ● Accidents ● Natural hazards	The usage of salt and solution damages the road condition. The usage of the design will continuously has greenhouse gas buildup due to large sum of electricity used. Accidents and natural hazards will damage the facilities in the design.
Disposal cost	Landscape construction permit.[84]	Rehabilitation ● Resurfacing Construction[92] ● Labor ● Equipment	Inconvenience for the users due to the construction[94].

3.0 Updated Project Management Plan

The team had a total of three meetings with the client on January 23rd, February 26th and March 18th. During the third client meeting, the clients and the team discussed the contents in conceptual design specification, and discussed the recommended design in detail. This document addresses feedback from the client and presents more detailed design specifications. The final project will be formally presented to the clients on April 27.

4.0 Conclusion

This document marks the end of the design project. The design team has identified the client needs, scoped the design problem, defined the project requirements, generated solutions, recommended FWI, and provided detailed design specifications in this document. The design team will be giving a formal presentation of the design to the clients and project manager on April 27, at which point the project is fully finished and the team is adjourned.

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6.0 Appendices

Appendix A. The black box method

Component	Input	Output
Mass	Vehicular traffic Pedestrian traffic Cyclists	Outgoing Vehicles Outgoing Pedestrians Outgoing Cyclists
Energy	Electric Mechanical	Mechanical (i.e vehicles)
Information	Pedestrian notification of entry Vehicular notification of entry Cyclist notification of entry	Notification of absence of various traffic Directions for traffic

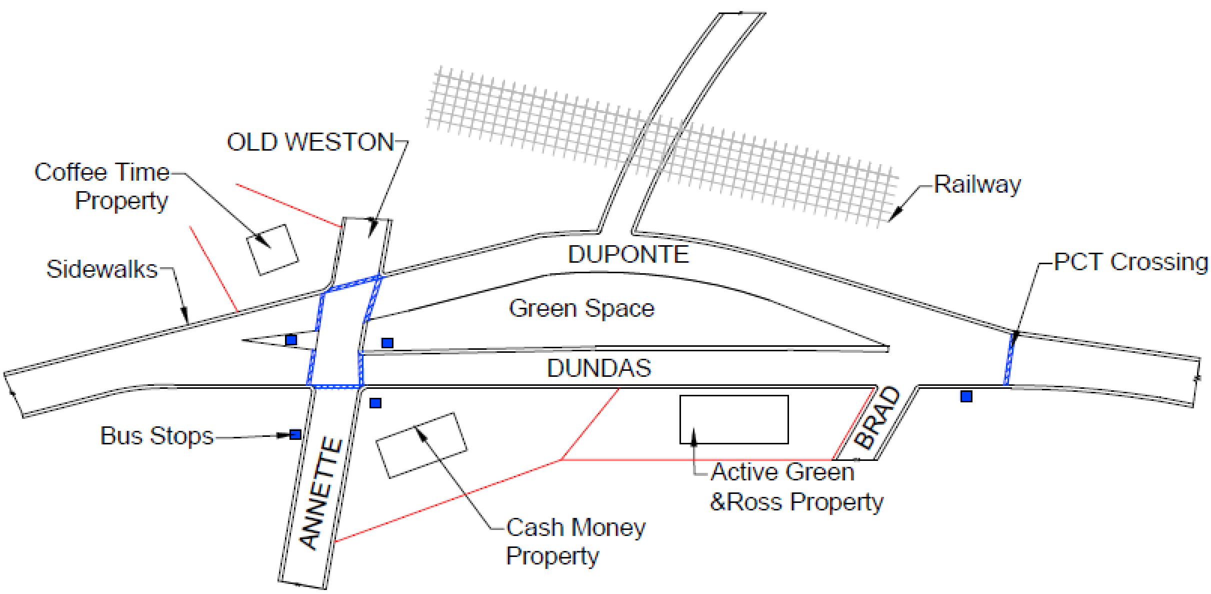
Appendix B. Pairwise comparison table of objectives

	A	B	C	D	E	F	G	Total
A	x	*	*	*	*	*	*	6
B		x	*	*	*	*	*	5
C			x	*	*	*	*	4
D				x	*	*	*	3
E					x	*	*	2
F						x	*	1
G							x	0

A - Clear communication
B - Time-saving
C - Limited steps
D - Fast to implement
E - Minimal noise pollution
F - Green space
G - Carbon footprint

Appendix C. Google Maps view of intersection

Appendix D. Labeled sketch of the intersection



Appendix E. Street view of Dupont St showing grade difference

Engineering Strategies and Practice

Appendix J. Lane width regulations

	Major Through Lane	Curbed Lane	Left/Right Auxiliary Lane
Minimum	2.8m	2.8m	2.7m
Goal	3.2m	3.2m	3m
Maximum	3.6m	3.6m	3.2m

Appendix K. Grade differences (the minimum grade difference for any road is 0.3% for drainage purposes)

Speed (km/h)	Grade Percentage (meters inclined/100 meter stretch)
<50	12-7
50	7
50-100	7-5
100	5
>100	5-3

Appendix L. Bike lane regulations

Clearance Zone	Distance (m)
width of bike lane	1
overhead clearance	0.2
distance from curbs or traffic lines	0.5

Appendix M. The Visual Field Test

<table>
<tr><th>Questions</th><th>Selections (for each question)</th></tr>
<tr><td>1. When you are at Dupont St. E, can you observe the condition about Dupont St. W?</td><td rowspan="12">A. Everything can be observed
B. Necessary information can be observed
C. Can not get all necessary information
D. Nothing can be observed</td></tr>
<tr><td>2. When you are at Dupont St. E, can you observe the condition about Dundas St. N?</td></tr>
<tr><td>3. When you are at Dupont St. E, can you observe the condition about Dundas St. S?</td></tr>
<tr><td>4. When you are at Dupont St. W, can you observe the condition about Dupont St. E?</td></tr>
<tr><td>5. When you are at Dupont St. W, can you observe the condition about Dundas St. N?</td></tr>
<tr><td>6. When you are at Dupont St. W, can you observe the condition about Dundas St. S?</td></tr>
<tr><td>7. When you are at Dundas St. N, can you observe the condition about Dupont St. E?</td></tr>
<tr><td>8. When you are at Dundas St. N, can you observe the condition about Dupont St. W?</td></tr>
<tr><td>9. When you are at Dundas St. N, can you observe the condition about Dundas St. S?</td></tr>
<tr><td>10. When you are at Dundas St. S, can you observe the condition about Dupont St. W?</td></tr>
<tr><td>11. When you are at Dundas St. S, can you observe the condition about Dupont St. E?</td></tr>
<tr><td>12. When you are at Dundas St. S), can you observe the condition about Dundas St. N?</td></tr>
</table>

Rules of the questionnaire:

1. For each question, A worths 3 score, B worths 2 score, C worths 1 score, D worths 0 score.
2. The total score of the questionnaire is 36.
3. Visual Field Score = Score/Total score * 100%.

Appendix N. The Blind Intuition Test

Procedure of “Blind Intuition Test”

1. Select 200 volunteered pedestrians as the sample of the test.
2. Assign different starting points and destinations to each individual.
3. Set up theoretically shortest routes between the starting points and destinations.
4. Record the path of each individual when they pass through the intersection.
5. Compare the practical path with the theoretically shortest routes.

Formula of “matchup score”:

Matchup score = Number of (practical path == theoretically shortest routes) / 200 * 100%

Appendix O. FWI lifetime cost analysis

The following table accounts for the costs associated with each stage in the life cycle of the design. Columns 2 and 3 identify the source of each cost and the required amount for each itm. The last column indicates the subtotal in CAD for each item.

Life-cycle	Item(s)	Amount	Subtotal(in Canadian dollars)
Capital cost	Logistic cost • Construction permit • Expropriation cost	3000 (construction permit) * 1.13 (HST) 200000 (expropriation)[96]	203390
	Labor	20 (dollars/person/hour) * 8 (hours/day) * 400 (days) * 120 (persons)[98]	7680000
	Material	Asphalt: (60(length) * 25(width) * 4(ways)) (m^2) * 4.06 (dollars/m^2) * 1.13(HST)[97] Concrete: 6000(m^3) * 77 (dollars/m^3) * 1.13(HST)[99]	549587
	Equipment	Concrete equipment: 1000(dollars/machine/month) * 4 (months) * 12 (machines)*	191648

		1.13(HST)[100] Asphalt pavement machine: 40000(dollars/machine/month) * 2 (months) * 2 (machines)* 1.13(HST)[101] Excavator: 4250(dollars/month) * 6 (months) * 4 (machines)* 1.13(HST)[102] Cleaning equipment: 900 (dollars/month/machine) * 1 (month) * 4 (machines) * 1.13(HST)[103]	
	Capital cost total	8 624 625	
Operating cost	Electricity	[Based on years of usage]	[Not applicable]
	General service(snow plow, drainage)	[Based on years of usage]	[Not applicable]
	Annual maintenance	[Based on years of usage]	[Not applicable]
	Operating cost total	[Not applicable]	
Disposal cost	Road resurfacing	60 (meters) * 25 (meters) * 4 (ways) * 70 (dollars/m^2)[104]	420000
	Material disposal	8 (tons) * 75 (dollars/ton)	600
	Disposal cost total [105]	420600	
Total cost	[Not applicable due to lack of data on years of usage]		