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Final Design Specification (FDS)

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Executive Summary

Jim Chisholm, P. Eng., Coordinator of the Safe and Sensible Streets initiative within the West Bend Community Association (WBCA) has tasked a group of University of Toronto undergraduate engineering students with a project concerning fatal collisions between vehicles and pedestrians. The target area is encompassed by Keele-Dundas and Keele-Annette intersections in Toronto, ON, Canada.

The causes of the collisions include fast, dense traffic flow, high speed turns on intersections, and lack of visibility. The design will control the movement of vehicles and pedestrians thus reducing the number of collisions among them. Also, the design must abide by the Code of Ethics of engineers and the Toronto Municipal Code for Streets and Sidewalks, and the resources needed for the design must be available in Toronto. Safety, durability, and accessibility were the three main objectives to be satisfied by the design.

The proposed design is a Boundary Sensor. It uses motion sensors to detect the movement of pedestrians on the road, and emits light and sound until the pedestrian leaves the road. The LED lights across the road warn approaching drivers about the hazard. Additionally, LED lights will be installed on the intersections to guide drivers and pedestrians, the time limit for pedestrians to cross the street will be extended to 35 seconds, and the texture of the road will be made more coarse to slow down the speed of vehicles. Finally, the streetscape of Keele Street will be improved through the installation of new street lamps and benches, the planting of new bushes, and the painting of a mural on the storage building on the northern end of Keele Street.

The design needs to abide by all the environment and safety regulations in Toronto. The Boundary Sensor and the road must undergo three standard tests in order to ensure their functionality. In order to implement the design, news of the design must be spread within the public, the design components must be purchased, and workers must be hired to construct the design.

Moreover, a life cycle analysis was conducted on the design to weigh its environmental impact. The design’s impact on the people, the West Bend neighborhood, and the stakeholders was explored. Also, the psychological human factors and universal design principles associated with the design were identified, and the interactions of the pedestrians with the design was described. Finally, the approximate cost of implementing the design includes $732,000 in capital and installation costs and $23,700 per year in operating and maintenance costs, falling under the budget of the city of Toronto.

The team looks forward to presenting the design to the client on April 25th, 2017.

1.0 Project Requirements

The West Bend Community Association (WBCA) is a group representing the concerns of permanent and temporary occupants in the area confined by the intersections: Keele-Dundas, Keele-Bloor, Bloor-Dundas (Appendix 4)[1]. The project, introduced to University of Toronto undergraduate students by WBCA representative Jim Chisholm, is intended to address public safety at the Keele-Annette and Keele-Dundas intersections.

1.1 Problem Statement

There have been a total of 10 fatalities since 1990 in the target area due to vehicle-related accidents [2]. Keele St. between Annette St. and Dundas St. widens and serves as a gateway between the 401 highway and the Gardiner Expressway, thus hosting a denser and faster traffic flow than the immediate surrounding area; motor vehicle speeds increasing from the limit of 40 km/h at the south of Keele-Annette (Keele-Bloor) to 75 km/h at the Keele St. stretch [2,3]. Furthermore, Annette St.-Keele St. form a 120° turn upon intersection, which permits turns at higher speeds as shown by Figure 1.1 (Appendix 1, 5). In the hours between sunset and sunrise, the infrequent positioning of lights (approximately every 23 m), the low brightness of the lamps, and the proximity of the tall architecture to the road at Annette decrease the discernibility and visibility of pedestrians, cyclists and vehicles (Appendix 2, 6).

These circumstances create the need for a design that would ensure a decline in the fatal collisions rate. Although the region of Keele-Annette and Keele-Dundas have been provided with repainted lanes and various traffic signs, the fatalities have not subsided, the implementation of the latter causes confusion among drivers [2]. Thus, the current solution lacks the capability to maintain the safety of pedestrians. Therefore, the design needs to address the distribution of vehicles and pedestrians along the intersection to avoid collision, as well as convey information in accordance to the attention and comprehension span of an adult human outlined by the International Sign Association (ISA) (Appendix 7)[27].

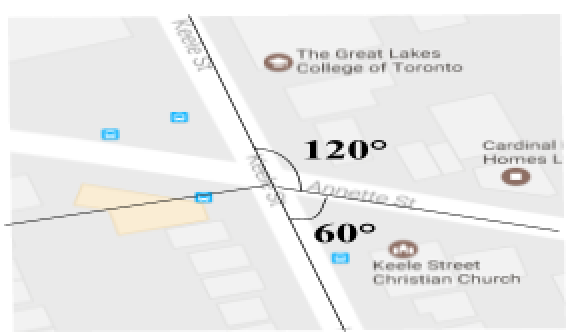


Figure 1.1 Annette-Keele Intersection Angle

1.2 Stakeholders

This section outlines stakeholders: companies, groups, and individuals who express interest in the consequences and implications of the design. Based on the interests of the stakeholders, limitations are imposed on any possible designs. Stakeholders are arranged based upon interests concerning the project. Connections between the design's functions (F#), objectives (O#), and constraints (C#) follow the preceding convention (most important first).

Table 1: Stakeholders

Stakeholders	Interests	Impact
Toronto Fire Station 423	Provide efficient and effective response to residents in the area near Keele and Dundas [4]	Design shall not obstruct the fire station vehicles from exiting or entering the fire station.
Toronto Community (The West Bend neighbourhood)	Improve aesthetics of neighbourhoods, ensure the public interests remain unharmed [5], desire safe and easy access to their residence, and absence of noise pollution [2]	Design shall not disrupt everyday activity for local residents (C1.5.2).
Cycle Toronto	Promote a safe and cycling-friendly environment for the stretch of Keele street from the railway tracks to Annette Ave [6]	Design should provide safe and accessible on and off road cycling infrastructure to ensure the safety of cyclists on the stretch (O1.4.1).
Toronto Transit Commission (TTC)	Provide a safe transit system to people living in Toronto including the Dundas-Keele area [7]	Design should maintain the safety of TTC users (O1.4.1).

1.3 Functions

The functions section refers to the design's purpose and ability. The primary functions were generated through the functional basis method: analyzing the project through mass, energy and information aspects. The design must control the movement of mass.

1.3.1 Primary Functions:

- Control the movement of vehicles, cyclists, and pedestrians

1.3.2 Secondary Functions:

- Reduce force of impact during collision
- Separate pedestrians, vehicles, and cyclists
- Ensure visibility for all objects of all objects
- Convey information about the appropriate movement within the target area in accordance to the attention and comprehension span of an adult human outlined by the ISA (Appendix 7)[27]

1.3.3 Unintended Functions:

- Increase cyclist and pedestrian traffic

1.4 Objectives

The objectives describe what the goal characteristics of the design should be. The objectives were generated through use of the client's and the West Bend's community expressed values and priorities, and are ordered in descending order of importance.

Table 2: Objectives

Objectives	Objective Goals
1.4.1 Safe	• Should bring down the average vehicle speed to 48 km/h since this speed has the likelihood of fatality at 10% [35] • Should ensure space and time for pedestrian crossing; space for two 1m wide people to pass, and time for a person walking a minimal speed of 2.8 km/h [59]
1.4.2 Durable	• Should withstand temperatures ranging from -25 °C to 35 °C [36] • Should withstand wind speeds up to 85 km/h [12] • Should withstand rainfall ranging from 11.5 mm to 76.2 mm [13] • Should withstand snowfall ranging from 0 cm to 37 cm [11]
1.4.3 Accessibility to lack of vision and hearing	• Should convey information to legally blind pedestrians: vision exceeding 20/200 with visual aid and/or field view of less than 20 degrees horizontal diameter [8] • Should convey information to people lacking the ability to hear less than 95 dB [9]

1.4.4 Aesthetically pleasing	• Alternating rounded weakly defined shapes and strongly accented shapes [30] • Utilisation of symmetry [31] • Accommodation of both green space and architecture [31] • Large mono coloured surfaces (larger than 5 m x 60 m) should have architectural components such as windows or murals [2]
1.4.5 Low cost	• Less than CAD$4.9 Billion per year in construction and maintenance [21]
1.4.6 Minimal construction time	• Should be constructed within 10 years [2]

1.5 Constraints

The absolute restrictions the design must satisfy in order for it to be considered as solution. The interests of the client and the stakeholders were used to generate the following constraints.

1.5.1 Ethics:

- Must abide by the Code of Ethics for engineers (Appendix 8)[17]

1.5.2 Structure, Location and Design:

- Must be on public property according to the City of Toronto [2]
- Must abide the Toronto Municipal Code for Streets and Sidewalks [22, 23]
- Must follow the Building Code Act of 1992 [18]

1.5.3 Resources:

- Must be available in Toronto
- Must have labour usage in accordance to Ministry of Labour Employment Standards [24]

1.6 Service Environment

The area of study is the stretch of Keele Street to the south of Annette Avenue in Toronto, Canada. The service environment section describes all of the physical, living, and virtual environmental conditions that exist at the Keele-Annette and Keele-Dundas intersections.

1.6.1 Physical Environment:

- Average temperature ranges from -13 °C to 31 °C, depending on the time of year
- Average rainfall ranges from 11.5 mm to 76.2 mm [13]
- Average snowfall ranges from 0 cm to 37 cm [11]
- Vehicles and traffic
- Intensity of sound of traffic is approximately 80 decibels [15]
- Sidewalk, buildings, shops, stores, and restaurants
- Traffic lights, pedestrian crossing lights, and push-to-walk buttons
- Intersections form 60° angles (Appendix 1)

1.6.2 Living Environment:

- People including drivers, bikers, and pedestrians that could pose a hazard for drivers
- Organisms that could pose a hazard for drivers including trees and small mammals
- Students who attend the Great Lakes of Toronto College during daytime whom drivers must be aware of
- Residents including children, youth, mature adults, and seniors, whom drivers must be aware of (Appendix 3)

1.6.3 Virtual Environment:

- Traffic lights and push-to-walk buttons are powered by electricity
- Mobile phone networks and Wi-Fi connection

1.7 Client Ethics and Values

The directive of the West Bend Community Association is to participate in neighbourhood projects and “improve the community” [1]. The concern of the client, Jim Chisholm, about the fatal accidents demonstrates that he prioritizes the safety of the people accessing the location of interest. Also, the client wants to enhance the visual appeal of the area [2]. This demonstrates that he cares about the appearance of the community. The purpose of this organization is to represent the interests of the community, to create a sense of community, and to “promote a healthy, happy, and safe living environment”[1].

2.0 Detailed Design

The pedestrian safety concern in the area encompassed by Keele-Dundas and Keele-Annette intersection is the main incentive for an engineering solution. The proposed solution to the design problem is the Boundary Sensor (Fig.2.0). It targets the two main issues that endanger people: the absence of adequate visibility for drivers and pedestrians and the high vehicle speeds. Furthermore, the design improves the streetscape and reinforces the historical background of the West Bend Community.

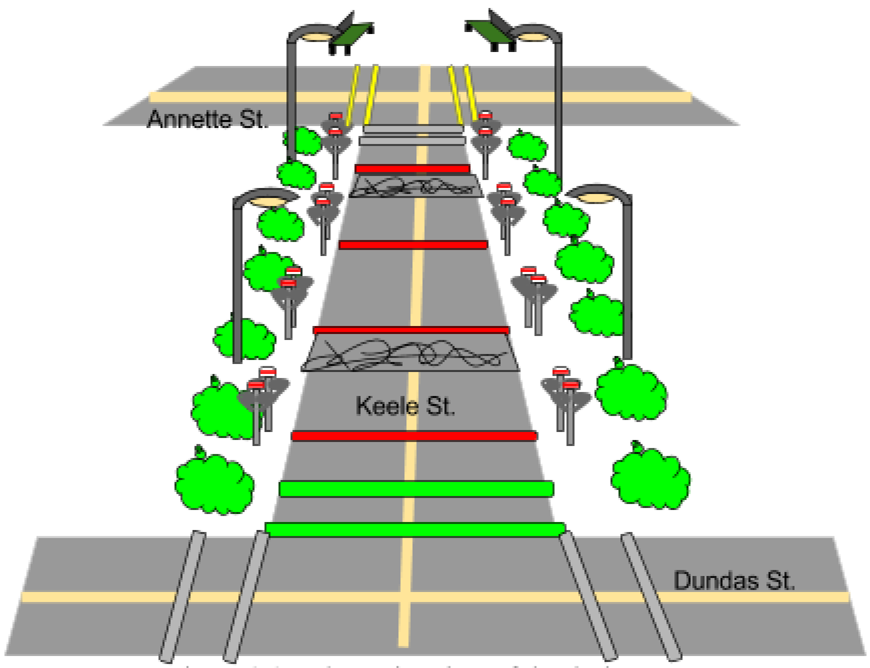


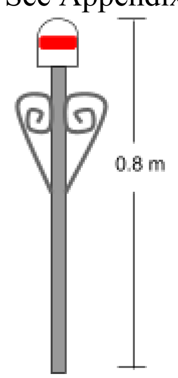
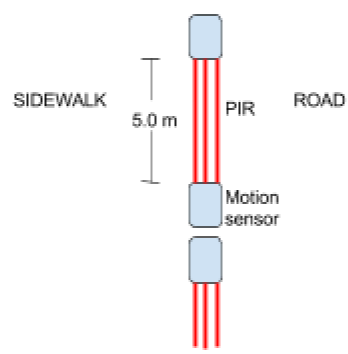
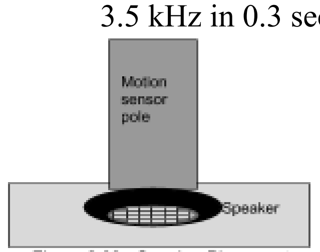
Figure 2.0 - The entire view of the design

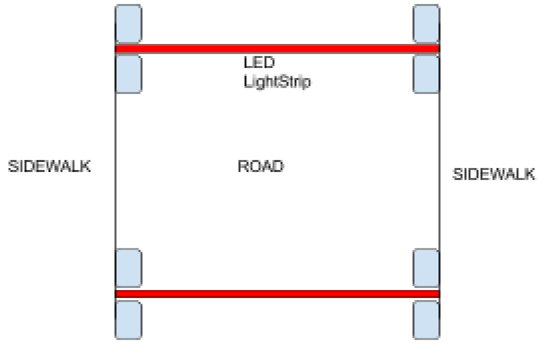
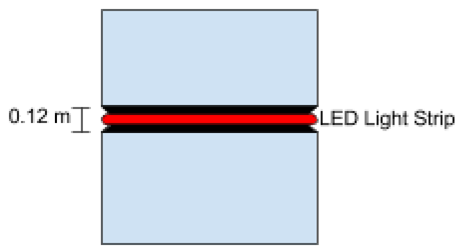
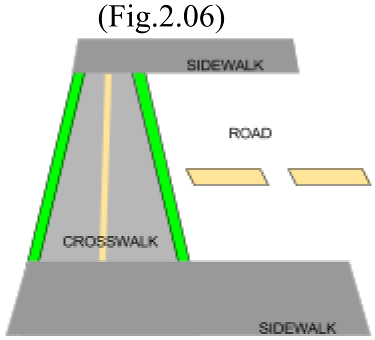
2.0.1 Design Details

The following tables demonstrate the technological, infrastructural, and streetscaping changes that are planned to be made to the target area as well as the impact it has in terms of Functions and Objectives.

The technological design component incorporates an alarm system, an LED crosswalk, and a modification to the current stoplight. These elements are an important aspect of the safety design, since they ensure the pedestrians visibility to the vehicle drivers as well as forcing the pedestrians to be self-aware and follow road regulations. The following table further delves into the specs of each element.

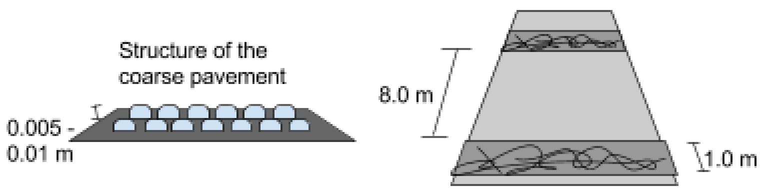
Table 3: Design Components - Technology

Design Component	**Details**	**Impact** **(⬢-function, ⬡-objective)**
Technology		
Boundary Motion Sensor	● The sensor will extend along the sidewalk and will be mounted on a 0.8m galvanized steel pole (Fig.2.01) ● Produce a several lines of IR lines therefore recognising the direction of motion ● Placed every 5m ● Polycarbonate PIR Bosch security OD850[32] ● Connected in series with the corresponding LED Alarm Light and sound System ● The presence of people on the road will start the corresponding alarm in the area enclosed by the pair of sensors (Fig.2.02) ● See Appendix 14 for execution code  Figure 2.01 - Motion Sensor  Figure 2.02 - Motion Sensor Placement	⬢ Separates the pedestrians from the vehicles ⬢ Prevents driver-pedestrian collisions through warning the drivers of pedestrians on road ⬢ The sound alarm would indicate to the pedestrian to leave the road ⬢ The LED path light will indicate the path a pedestrian needs to take and confine them to that path ⬢ The LED lights will increase the visibility of the pedestrians ⬡ The alarm system is composed of materials capable to withstand temperatures -25 °C to 35 °C and is waterproof (Appendix 15) ⬡ The capital cost is $85 980 which is significantly less than the goal cost of several billions (Appendix 11). ⬡ The light provides enough time for people to cross (Appendix 16)
Sound system	● Located in the small groove, 0.21mx0.16mx0.14 m in dimension, next to each boundary sensor (Fig.2.03) ● Polypropylene, stainless steel and aluminum Atrium Sat30 ● Producing intensity of 70-83 dB and frequency range 3.5 kHz in 0.3 second beeps (Appendix 9 and 10)[68]  Figure 2.03 - Speaker Placement	

Alarm light	• Located in the grooves across the road, connecting both sides of the boundary sensors (Fig.2.04) • Upon the triggering of the motion sensors, two lines, corresponding to each boundary sensor, will light up thus enclosing the area in which the person is located • 5050 Waterproof Flexible LED Strips placed into the grooves in the pavement (Fig.2.05)[67]  Figure 2.04 - Placement of LED strips  Figure 2.05 - Placement of LED strip in the pavement	
LED crosswalk	• The intersections of Annette-Keele and Dundas-Keele will be equipped with yellow and green LED lights • Green LED will illuminate the path • Once the countdown begins, the path will turn yellow (Fig.2.06)  Figure 2.06 - LED crosswalk lights	
Stoplight	• The stoplight time will be increased to 35 seconds (Appendix 16)	

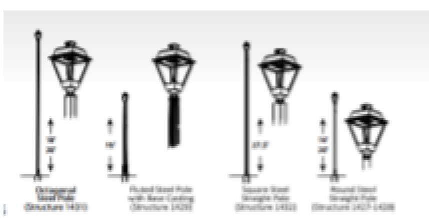
The infrastructure component of the design consists of lines of texture in the form of coarse pavement. This design will discourage drivers from going at high speeds therefore reducing the average speed which decreases the fatality rate upon collision.

Table 4: Design Components - Infrastructure

Design Component	**Details**	**Impact (⬢-function, ⬡-objective)**
Infrastructure		
Texture	• A texture in the form of coarse pavement will be introduced (Fig.2.07)(Appendix 17) • At speeds >50km/h the texture will cause uncomfortable vibration in the car[70]  Figure 2.07 - Coarse Pavement Specification	⬢ Reduce the force of impact during collision ⬡ The speed would be within 30 km/h-50 km/h thus meeting the objective goal

The Streetscape part of the design is composed of benches, streetlamps, bushes, and a mural. These changes will improve the visual appeal of the neighborhood as well as unintentionally improving the safety of the area by increasing the visibility through streetlamps.

Table 5: Design Components - Streetscape

Design Component	**Details**	**Impact (⬢-function, ⬡-objective)**
Streetscape		
Benches	• 2 benches in total are to be placed symmetrically on both sides of Keele south of Annette (Fig.2.08) [71]  Figure 2.08 - The Bench [71]	⬢ The lamps provide visibility of both the vehicles and pedestrians ⬢ The bushes provide a boundary between road and sidewalk ⬡ The elements provide a symmetrical layout of the street, incorporating architectural principles thus making the design aesthetically pleasing ⬡ Some of the elements are able to withstand the durability goals (Appendix 15)
Streetlamps	• Placed every 10 m and produce an equivalent of100 Watts of light • The model is Traditionaire (LED) (Fig.2.09)[40]  Figure 2.09 - Lamp Head Design [40]	
Bushes	• 0.5m high boxwood bushes are to be planted along the sidewalk from Dundas to Annette along both sides of Keele [72]	
Mural	• The mural is to be placed on the 5x60m wall of the storage building at North-West corner of Dundas-Keele (Appendix 18)	

As shown in the component specification tables, the design not only meets the FOCs, but exceeds them entirely. Moreover, it is a unique design that can enrich and greatly improve the West Bend Community.

2.1 Standards and Regulations

Safety and environmental regulations relating to the boundary sensor such as green space, noise, light pollution and material used are explored in the table below:

Table 6: Regulations

Category	**Regulation**
Green Space	Trees not designated for removal shall not be damaged and shall be protected from flooding and sediment deposits from construction operations[74].
Noise	Noise emissions to the environment needs to be controlled. The quasi-steady impulsive sound produced by the boundary sensor must be limited to 50 dBA from 7 to 23, and 45 from 23 to 7, received in the plane of windows in a residential area[75]
Light pollution	"All exterior light fixtures should be efficient while providing minimum illumination levels sufficient for personal safety and security in order to minimize glare and/or light trespass" taken directly from Lighting Regulations City of Toronto, 2011 [76]
Material	• All light posts (metal posts) shall be hot dip galvanized after fabrication [77] • Materials that will be used for the mural must be non-toxic and the procedures must be safe. "Some industrial paints and coatings emit toxic vapours and require precautions such as the use of personal protective equipment, e.g. organic vapour masks" as stated in "Creating a new mural" on Government of Canada website [78].

2.2 Testing

Methods to test various aspects of the design are explored in the subsections below:

2.2.1 Brightness of the Streetlamp

Brightness will be measured using a digital light meter pointing directly at the light bulb at ground level since the streetlamps are used to illuminate the sidewalk and road.

2.2.2 Loudness of the Speaker

Loudness of the speaker will be measured with a digital sound meter at 170cm above above ground level since it's the average height of Canadian[79], therefore it's the average distance the sound wave needs to travel before it reaches pedestrians ears

2.2.3 Aesthetically Pleasing

Model of the street lamp used is Traditionaire. It will be observed if it satisfies utilisation of symmetry[31]

2.3 Implementation Requirements

To implement the final design, the tasks needed are listed below to completed the implementation process:

- Notify people living around and passing through the Junction area about the new change over the target area (Keele St. between Dundas St. and Annette St.) with:
  - E-mail
  - Newspaper
- Components needed for the designed system:
  - LED lights
  - Street lamps
  - Sensors
  - Speakers
- Constructors for the preparation of installation of the system:
  - Removing asphalt before installation of the LED lights and cables
  - Recover the road to its original status after the installation of the system
- Electronic technicians for installation of the system:
  - Installation of cabling for power supply and the connection of components
  - Installation of LED lights, sensors, street lambs, and speakers
- Programmers for programming tasks:
  - Programming the LED lights system cooperating with the traffic light system
  - Programming the sensors, street lambs and speakers that they function as designed

2.4 Life Cycle and Environmental Impact

In this section, the diagram shows process from the creation of the design, to its application and its disassembly. The basic materials used and directly related to design are presented. The tables below highlight the environmental impacts from to aspects, mass and energy. Also, they present the way to minimize the potential harm.

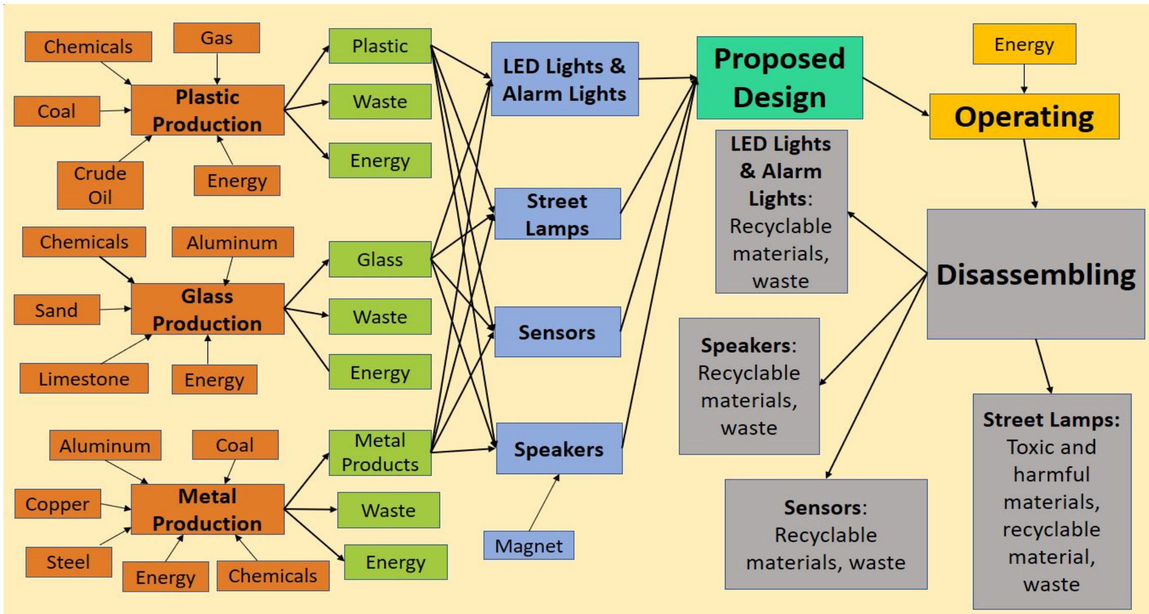


Figure 2.4.1: Life cycle diagram from-manufacturing to disassembling

Table 7: Mass Elimination while Producing

Type	Components	Impacts	Minimizing Impacts
Mass	Plastic	Negative: ● 6 kilogram of CO_2 per kilogram of plastic is produced[60]	● Following the standard of ISO 14040:2006[63]
	Glass	Negative: ● 1.2 tonnes of CO_2 produced per one tonne of glass[61] Positive: ● Glass is 100% recyclable [62]	
	Metal	Negative: ● 1.83 tonnes of CO_2 produced per one tonne of metal[64] ● 0.7 tonnes of solid waste produced per one tonne of metal[64]	● Concentrate the manufacture of metal ● Recycle the used metal

Table 8: Energy Consumption while Producing

Type	Components	Impacts	Minimizing Impacts
Energy	Plastic	Negative: ● 4.5×10^7 J of energy is used to produce one kilogram of plastics[65]	● Recycling the used plastics
	Glass	Negative: ● 18-35 MJ of energy is used to produce one kilogram of glass[66]	● Recycling the used glass
	Metal	Negative: ● 20-50 MJ of energy is used to produce one kilogram of steel[6] ● 60-125 MJ of energy is used to produce one kilogram of copper[66] ● 219 MJ of energy is used to produce one kilogram of Aluminum[66]	● Making improvement on the method of producing metal ● Maintenance of the devices

Table 9: Energy Consumption while Operating

Type	Components	Impacts	Minimizing Impacts
Energ y	LED lights & Alarm Lights	Negative: ● 36W[67]	● Programming the lights to be used only when it is necessary
	Sensors	Negative: ● 3W[68]	● Limiting the time that the speaker works
	Speakers	Negative: ● 100W[69]	● Programming the speakers to be used only when it is necessary
	Streetlamps	Negative: ● 100W[40]	● Using less energy-consuming streetlamps

2.5 Human Factors

This design focuses on the psychological level of human factors; it serves to meet one of the top objectives of this project which is to be accessible to both the visually and auditorily impaired. This design incorporates the basic principles of Universal Design, which serves to ensure the design is suitable for use by a wide range of users[80]. Furthermore this section discusses main interactions between the users and the design.

2.5.1 Psychological

- Design warns the user to exit the road by stimulating their auditory senses with the incorporated speakers; therefore is accessible to the visually impaired.
    - Speakers emit a sound with frequency of 3.5kHz, which is in the range of the greatest hearing sensitivity of humans (Appendix 9).
    - Speakers also produce a sound intensity of between 70 dB - 81d warning the user to get back onto the sidewalk (Appendix 10).
- Design warns users to exit the road by stimulating their visual senses with the incorporated strip of red LED lights in the grooves of the road; therefore accessible to the auditorily impaired.
    - Light emitted is 600 nm and is not focused as lasers are, which is within the the range of the wavelengths that are most sensitive to the human eye without damaging effects[82].
    - Light emitted is not focused as lasers are, therefore not damaging to the human eye

2.5.2 Universal Design

The Boundary Sensor was designed to address each principle of Universal Design as shown below.

Table 10: How the Design meets each principle of Universal Design

Universal Design Principles	How Design Addresses Principle
Equitable use	The alarm is activated for all users regardless of any disabilities.
Flexibility in use	Allows users to freely walk throughout the sidewalk, and does not impede traffic.
Simple and intuitive to use	The alarm evokes an intuitive sense for the user to get off the road and back onto the sidewalk (Appendix 10).
Perceptible information	The alarm is sensitive to the human's auditory and visually senses respectively[81,82].
Tolerance of error	Alarm disables in 5 minutes in the case of prolonged activation.
Low physical effort	The only physical effort required is for the pedestrian to enter back into the sidewalk.
Size and space for approach and use	Alarms are spaced apart 5m allowing sufficient space in the sidewalks for pedestrians.

2.5.3 Interactions of Pedestrians

The figures below describe the interaction of pedestrians with aspects of the design.

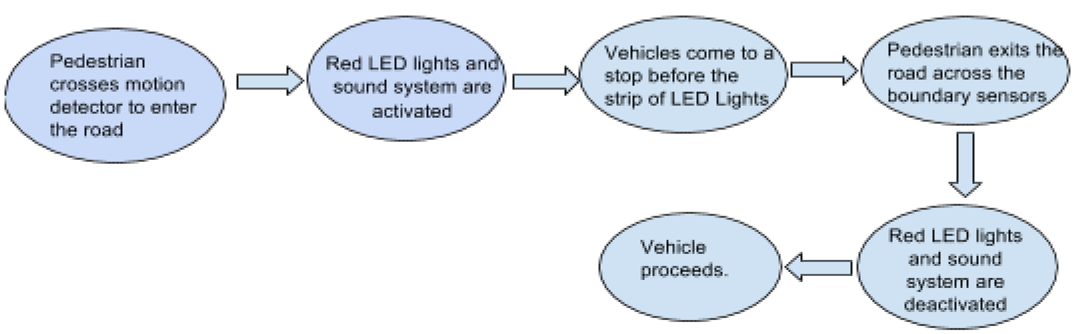


Figure 2.5.1 Flow chart describing the interaction of a pedestrian as they cross into the road across the motion sensor.

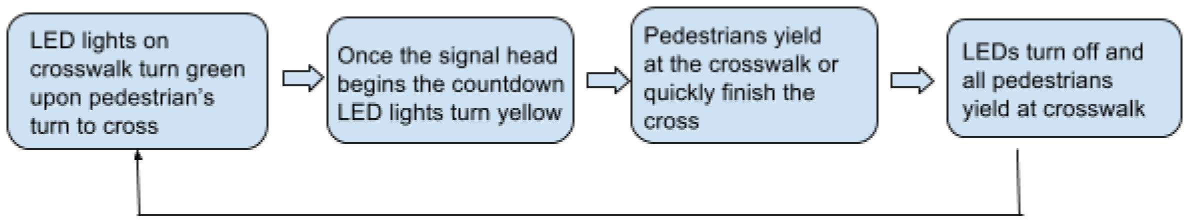


Figure 2.5.2 Flow chart describing the interaction of the pedestrian as they cross the crosswalk

2.6 Social Impact

The social impact of the design is to develop a more welcoming community for The West Bend Neighbourhood by influencing the people to act in a safer manner on the Keele stretch. This section discusses how the design balance stakeholder interests, affects human interactions, and impacts the immediate neighbourhood.

- Balancing Stakeholder Interests
    - Design leaves the route taken by the immediate fire station, Toronto Fire Station 423, unhindered.
    - Ensures that members of The West Bend Neighbourhood, cyclists, and TTC users experience a safe commute along the stretch.
- Effect on Interactions Between People
    - Collisions among drivers and pedestrians can result in confrontation; this design reduces collisions thus pedestrians are less inclined to participate in disputes
    - Aspects of the streetscape, such as the addition of benches in the sidewalks may increase social interactions between people on the Keele stretch.
- Impacts on The West Bend Neighbourhood
    - People will feel more safe to go out at night due to the increased visibility by the LEDs on the crosswalk and the additional street lights.
    - Improved streetscape of the design can evoke a better sense of community in the neighbourhood.

If the design is successful after implementation, safety practices experienced in the Keele stretch of interest due to the design can expand further into the city of Toronto by having the design implemented in other intersections, thus expanding this safer community to the rest of Toronto.

2.7 Economics

This section identifies approximations of the various costs associated with the implementation of the proposed design.

2.7.1 Capital Costs

Table 11 provides a list of the costs of each component required to construct the design. The prices were benchmarked using existing products.

Table 11: Capital Costs (Appendix 11)

Component	**Approximate Cost (CAD)**
LED lights [86]	$9500
Street lamps [87]	$303,240
Speakers [88]	$40,430
Motion sensors [89]	$31,310
Alarm lights [86]	$4740
Benches [90]	$1940
Bushes [91]	$18,000
Texture [92]	$52,000
Total	**$461,160**

2.7.2 Installation Costs

Table 12 provides the costs of installing each design component.

Table 12: Installation Costs (Appendix 12)

Component	**Approximate Cost (CAD)**
LED lights [93]	$6060
Street lamps [94]	$212,800
Speakers [95]	$40,860
Motion sensors and alarm lights [96]	$5320
Benches [97]	$1650
Bushes [98]	$3600
Texture [99]	$440
Total	**$270,730**

2.7.3 Operation Costs

Table 13 provides the costs of operating and maintaining each design component, taking into consideration the cost of electricity in Toronto and the wattage of each component.

Table 13: Operation Costs (Appendix 13)

Component	**Approximate Cost per Year (CAD)**
LED lights [86,100]	$2200
Street lamps [100,101]	$12,170
Speakers [100,102]	$1530
Motion sensors [100,103]	$50
Alarm lights [86,100]	$550
Bushes [104]	$7200
Total	**$23,700**

2.7.4 Decommissioning Costs

This section describes the cost of decommissioning the design. To calculate the cost of decommissioning the design, it was assumed that a team of twenty workers would be hired to take down the design over twenty working days on an hourly rate, each working five hours a day. The approximate cost of decommissioning the design was calculated to be $35,940 (Appendix 19).

2.7.5 Summary

This design will cost approximately $732,000 to implement. Additionally, it will cost approximately $23,700 annually to operate the design. These amounts are reasonable as they fall in the budget of the City of Toronto [21].

3.0 Project Management Plan

This section provides an updated breakdown of the project for this month, including key events. A set of dates is given for events for which exact dates are yet to be confirmed.

Table 14: Project Management Plan

Events	**Time Range**
Submission of Final Design Specification to Client	April 17th - April 21st
Final Client Presentation	April 25th

4.0 Conclusion

The High mortality due to traffic related incidents at the Keele St intersections with Annette St. and Dundas St. have created an issue in the West Bend Community Association (WBCA). This document explores the problem and explains the details concerning the proposed design, especially the testing and implementation implications. The main function of the design is controlling the movement of vehicles and pedestrians. The proposed design is the Boundary Sensor which accomplishes this task. The chosen design consists of a system that recognises pedestrians on the road and alerts drivers, provides lighting, and reduces vehicular speeds. Through the approval of the client, the team may proceed with the construction of the design.

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Appendices:

Appendix 1 - Annette-Keele Intersection angle

This map provides the angle at which Annette and Keele streets meet.

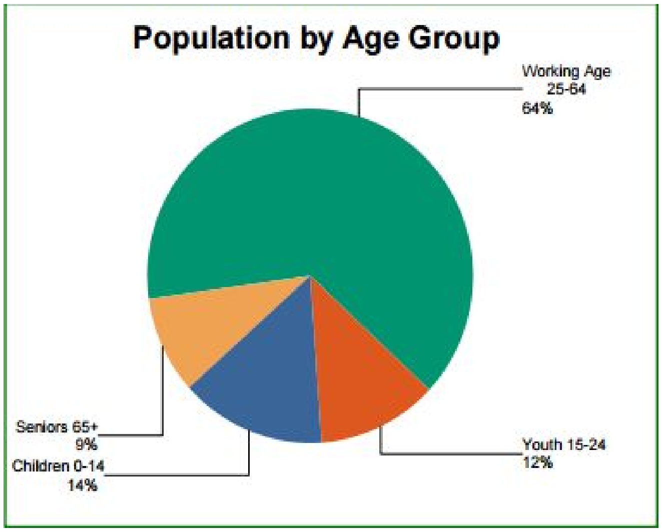
Appendix 2 - Visibility at Keele Street between Annette and Dundas

The following two photographs show low visibility in the target area. The nighttime photo shows the lack of light, and the daytime one shows the lack of visibility at turns at the intersection.

[20]

[20]

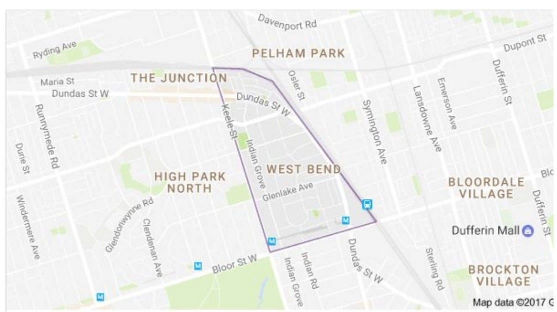
Appendix 3 - Demographics by Age in West Bend



[21]

Appendix 4 - West Bend Community area

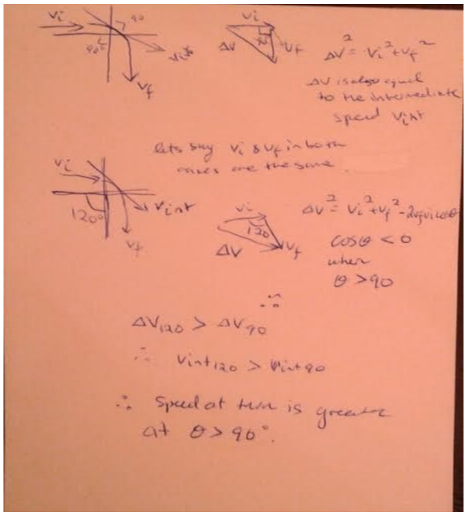
The image shows the boundary between the West Bend community and the rest of Toronto.



[25]

Appendix 5 - Calculation for turning speeds

The calculation shows that a greater turning speed is possible with increasing turning angle.



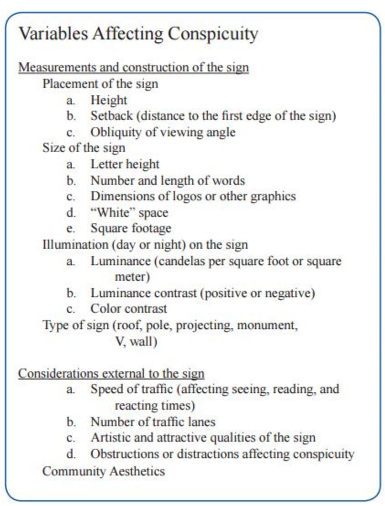
Appendix 6 - Spacing of Street Lamps

The image shows the infrequent placing of street lamps.

[26]

Appendix 7 - Sign Rules

The following several images are excerpts from the Sign Association describing the rules for creating and posting signs.



Variables Affecting Conspicuity

Measurements and construction of the sign

- Placement of the sign
  - a. Height
  - b. Setback (distance to the first edge of the sign)
  - c. Obliquity of viewing angle
- Size of the sign
  - a. Letter height
  - b. Number and length of words
  - c. Dimensions of logos or other graphics
  - d. "White" space
  - e. Square footage
- Illumination (day or night) on the sign
  - a. Luminance (candelas per square foot or square meter)
  - b. Luminance contrast (positive or negative)
  - c. Color contrast
- Type of sign (roof, pole, projecting, monument, V, wall)

Considerations external to the sign

- a. Speed of traffic (affecting seeing, reading, and reacting times)
- b. Number of traffic lanes
- c. Artistic and attractive qualities of the sign
- d. Obstructions or distractions affecting conspicuity
- Community Aesthetics

[27]

TABLE 1

The Standard Relationship Between Vehicle Speed and Legibility Distance In Feet and Meters

Vehicle Speed		MRLD
55 mph (88 kph)	81' /sec (25 m/sec)	440' (134 m)
50 mph (90 kph)	73' /sec (22.25 m/sec)	400' (122 m)
45 mph (72 kph)	66' /sec (20 m/sec)	360' (110 m)
40 mph (64 kph)	59' /sec (18 m/sec)	320' (98 m)
35 mph (56 kph)	51' /sec (15.5 m/sec)	280' (85 m)
30 mph (48 kph)	44' /sec (13.4 m/sec)	240' (73 m)
25 mph (40 kph)	37' /sec (11.3 m/sec)	200' (61 m)

Source: Schwab, Richard N.;[7] also, Garvey, P.M., et al, 1996.[8]

[27]

TABLE 2

Standard Letter Height Guidelines for On-Premise Signs

Speed Limit (mph)	Speed Limit (kph)	MRLD (Feet)	MRLD (meters)	Letter Height (Inches)	Letter Height (Centimeters)
25	40	200	61	7	18
35	55	280	85	9	23
45	70	360	110	12	30
55	90	445	136	15	38

[27]

TABLE 3

Readability Time per Number of Words

Number of Words	Normal Reader	Nonfluent or Dyslexic
1	0.7 seconds	3 to 13 seconds
2	1.4 seconds	6 to 16 seconds
3	2.1 seconds	9 to 19 seconds
4	2.8 seconds	12 to 22 seconds
5	3.5 seconds	15 to 25 seconds
6	4.2 seconds	18 to 28 seconds
7	4.9 seconds	21 to 31 seconds
8	5.6 seconds	24 to 34 seconds
9	6.3 seconds	27 to 37 seconds

[27]

Appendix 8 - Engineering Code of Ethics

i. fairness and loyalty to the practitioner's associates, employers, clients, subordinates and employees;

ii. fidelity to public needs;

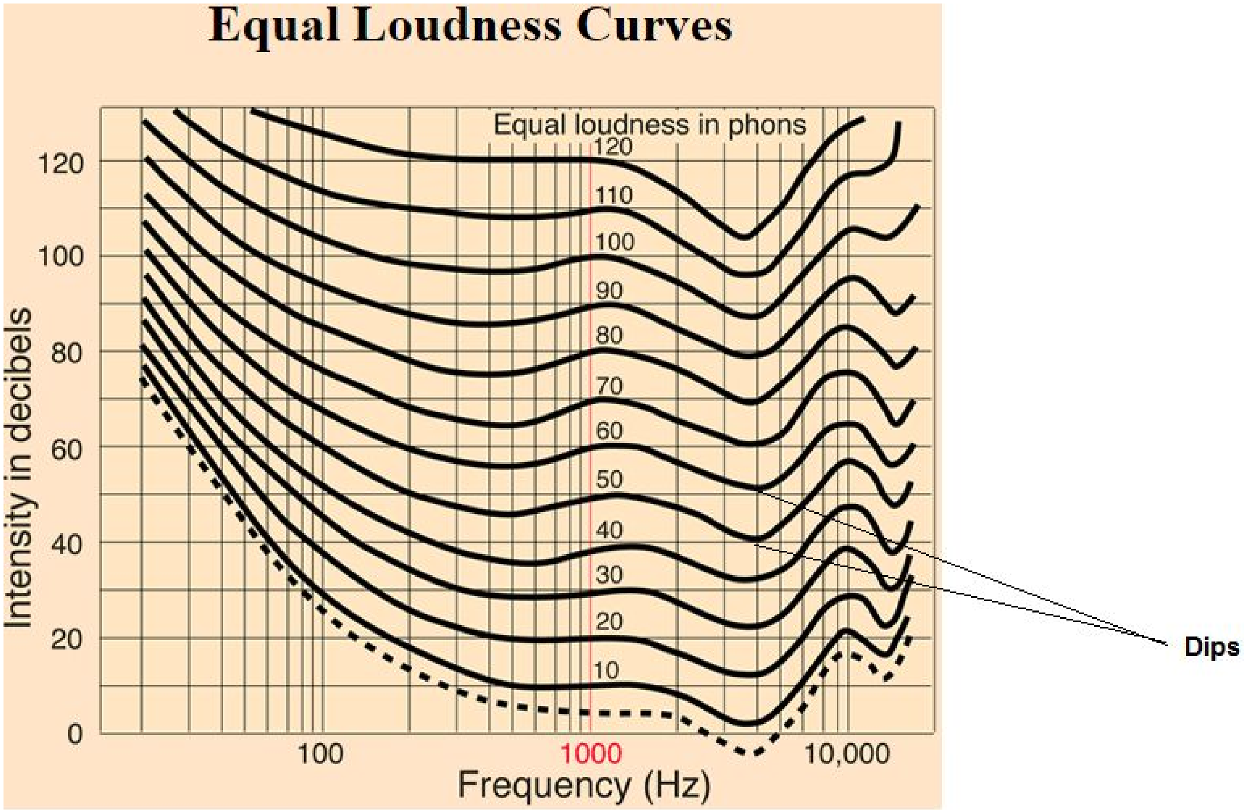
iii. devotion to high ideals of personal honour and professional integrity;

iv. knowledge of developments in the area of professional engineering relevant to any services that are undertaken; and

v. competence in the performance of any professional engineering services that are undertaken."

[17]

Appendix 9 - Explanation of the Chosen Frequency for the Speakers of the Design



[80]

This image shows the frequency in Hz plotted with intensity in dB. Each line represents equal loudness in phons, which is a measure of perceived loudness by humans. Each dip in the image corresponds to a frequency of 3 kHz - 4 kHz, hence it takes less sound intensity to produce the same perceived loudness if the frequency is between 3 kHz - 4 kHz [81]. Therefore the frequency which is most sensitive to humans lies between 3 kHz - 4 kHz.

Appendix 10 - Explanation of Why it is Intuitive for Users to get off the Road when the Sensor Alarm Sounds

When a human hears a sound of between 70dB - 100dB at frequencies between 500Hz - 4000Hz, such as the sound of the alarm in the design, an acoustic reflex occurs [83]. The middle ears' of the person contracts, as a result the intense sounds warns the person to protect from the sound to prevent long term damage of the organ of Corti [84] [85]. Hence to protect from against the sound the user responds to the stimulus by exiting the road.

Appendix 11 - Capital Cost Calculations

1. LED Light**s:** 80 reels x USD $89/light x CAD $1.33/USD $≈$9500 [86]
2. Street lamps: 40 street lamps x USD $5700/street lamp x CAD $1.33/USD $=$303,240 [87]
3. Speakers: 160 speakers x USD $189.98/speaker xCAD $1.33/USD $≈$40,430 [88]
4. Motion sensors: 160 motion sensors x CAD $195.67/motion sensor≈$31,310 [89]
5. Alarm lights: 40 reels x USD $89/reel x CAD $1.33/USD $≈$4740 [86]
6. Benches: 2 benches x USD $728.85/bench x CAD $1.33/USD $≈$1940[90]
7. Bushes: 600 bushes x CAD $29.99/bush≈$18,000 [91]
8. Texture: 400 m^2 x USD $130/m^2=$52,000 [92]
9. Total: $9500 + $303,240 + $40,430 + $31,310 + $4740 + $1940 + 18,000 + 52,000=$461,160

Appendix 12 - Installation Cost Calculations

1. LED Light**s:** 80 reels x USD $75/reel x CAD $1.01/AUD $=$6060 [93]
2. Street lamps: 40 street lamps x USD $4000/street lamp x CAD $1.33/USD $=$212,800 [94]
3. Speakers: 160 speakers x USD $192/speaker x CAD $1.33/USD $≈$40,860 [95]
4. Motion sensors and alarm lights: 40 sets x USD$ 100/set x CAD $1.33/USD $=$5320 [96]
5. Benches: 2 benches x CAD $(1550-728.85)/bench≈$1650 [97]
6. Bushes: 60 bushes x CAD $60/bush=$3600 [98]
7. Texture: 5 hr x USD $65.50/hr x CAD $1.33/USD $≈$440 [99]
8. Total: $7980 + $212,800 + $40,860 + $5320 + $1650 + 3600 + $440=$272650

Appendix 13 - Operating Cost Calculations

1. LED Light**s:** 80 reels x 0.036kW/light x 365 days/year x 24 hr/day x $0.087/kWhr≈$2200/year [86,100]
2. Street lamps: 40 street lamps x USD $200/street lamp/year x 1.33 CAD$/USD$ + 40 street lamps x 0.1kW/street lamp x 365 days/year x 12hr/day x 0.087 $/kWhr =$12,170/year [100,101]
3. Speakers: 40 speakers x 0.1kW/speaker x 365 days/year x 12hr/day x $0.087/kWhr≈$1530/year [100.102]
4. Motion sensors: 40 motion sensors x 0.003kW/motion sensor x 365 days/year x 12hr/day x $0.087/kWhr≈$50/year [100,103]
5. Alarm lights: 40 reels x 0.036kW/reel x 365 days/year x 12hr/day x $0.087/kWhr≈$550/year [86,100]
6. Bushes: 60 bushes x CAD $120/bush/year=$7200/year [104]
7. Total: $2200/year + $12,170/year +$1530/year + $50/year + $550/year + $7200/year=$23,700/year

Appendix 14 - Code Example
Alarm_on() is a function that turns on the alarm, person_count is the number of people on road, and alarm_direction is the direction in which the person crosses the alarm, -1 being from the road and 1 onto the road.

```
while person_count != 0:
   alarm_on(True)
   if alarm_direction == 1:
      person_count ++;
   else if alarm_direction == -1:
      person_count --;
```

Appendix 15 - Materials used in Designs
The following table shows materials used in the designs and their properties. Note that minimal temperatures are not mentioned. Since all of the materials are used in solid state, it can be assumed that their functionality only begins to become compromised in extreme colds (<-100℃), therefore the highest minimal working temperature is used for the entire design.

Material/Element	Properties
Aluminum [37]	• Metal • Corrosion-resistant (specific treated type) • Melting point of 660.3°C
Galvanized Steel [37]	• Melting point of 1370°C • Corrosion - resistant • Waterproof
Glass [37]	• Melting point of ~1400°C
Methyl Methacrylate (MMA) [37]	• Melting point of 160°C
Polycarbonate (solid) [37][38]	• Waterproof • Lower working temperature of -40°C • Glass transition phase of 147°C (solid to rubber) • Organic amorphous polymer
Passive Infrared Sensor (PIR)	• Able to operate within temperature

	range of -35°C to 54°C
Polypropylene [37]	• Melting point of 160°C

Table 15.1

Appendix 16 - Crossing time calculation

The following calculation uses the slowest speed of a person and the distance needed to cross and computes the time.

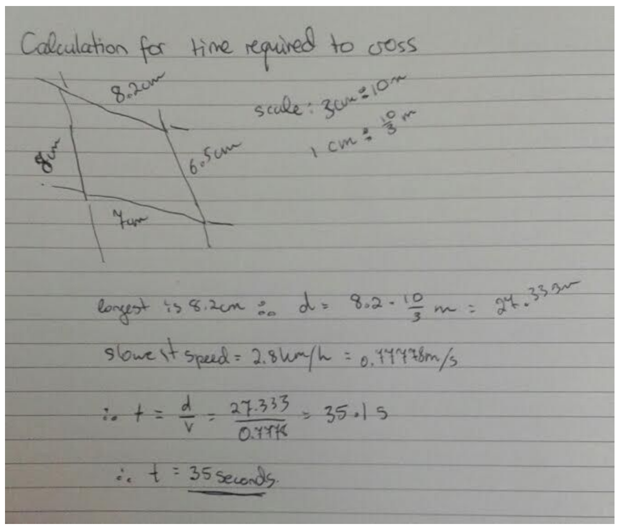


Figure 16.1

Appendix 17 - Coarse Texture Grain size estimation

The following diagram and calculation shows the estimation of grain size for coarse pavement.

Appendix 18 - Suggested Mural Painting - Van Gogh's Olive Trees

[107]

Appendix 19-Decommissioning Costs

20 men x $17.97/hr/man x 20 days x 5 hr/day=$35,940 [106]