INFRASTRUCTURE IMPROVEMENT FOR THE BUS STOP STATIONS

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Executive Summary

Windsor is a city in Ontario and southernmost city in Canada. The transport system of the city when accessed in terms of the comfort of the travellers and reliability, requires improvement. Fundamentally, one of the significant territories of the street transport system in Windsor that needs renovation is bus stop stations. Although the buses running through the city are well equipped and cover most of the city's areas, the bus's stop stations are basically underdeveloped. The chambers allocated for bus stops in various areas of the city are basically open and vulnerable to outer climate. To add to it, many bus stops don't even have chambers where the travellers could shelter themselves while waiting for their bus. The situation worsens when the climate is at the peak of its extremity during chilling winters and hot summer days. It becomes very difficult to wait for a long time for the bus when the climate is extremely freezing which is the case in winters and the same hold when the climate is severely hot during summers.

The following report outlines a proposal to improve and develop the current bus stop stations and or build new stations that could shelter people to support and assist individuals to have a decent and agreeable transportation framework, but as an improvement or change always comes at a price, the primary focus is looking for an economically viable solution. This proposed solution will encompass the heating/cooling system to regulate and maintain the temperature inside bus stops. The interior of the bus stop chamber will have a strong insulating fibreglass layer that can hold the temperature inside as per the requirement which will help the travellers to wait for their transport without any issues. Electronic panels or screens inside the station to show the buses routes, schedules and time for the bus to reach the station.

The total cost estimate for the construction of 100 bus stop shelters is $15,00,000. The installation heating and cooling systems are estimated to cost $81,200. This yields the total cost of the proposed solution to be $1,581,200. The solution will take around five months for fulfilling major milestones including proposal approval, construction of bus stops and installation of heating and cooling system.

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1. Introduction

The transport system of the city is extremely vital for the residents of the city to carry out their daily commutation. Hence it is imperative that the transport system should be well developed to take care of the comforts and needs of the travellers commuting through the bus. The proposal basically intends to address the problems faced by the travellers while waiting at bus stops.

Even though the routes of the city's bus system cover most of the 10 wards [2] of the region, the bus stops are fundamentally undeveloped and, in most locations, not occupied with shelters where the travellers could protect themselves while waiting for the bus. The chambers allotted for the bus stop locations in different regions of the city are essentially open and defenceless against the external atmosphere. The circumstance turns out to be much more dreadful when the atmosphere is at the pinnacle of its furthest point amid chilling winters and sweltering summer days, therefore a legitimate solution for this issue is required to help residents, students and attract outside business and investors, as it will ease the way of using bus transportation system in the city.

The following report considers the benefits, costs, and timeline of constructing shelters at the bus stop locations and how it's important to all people that live in the city to have such improvements. The solution introduces the most economic design that could use green energy like solar panels to power those proposed shelters.

2. Background and Literature Review

As the city of Windsor divided into 10 wards [2], it’s very important to investigate the busiest routes and locate the bus stations for those routes. The most engaging areas fall under wards number 1,2,3 and 4. The reason being that the students prefer to reside near their educational institute. As the University lies under ward 2, most of the university students reside. Furthermore, another reason for being the engaging area is the busiest US-Canada border [3], the Ambassador Bridge. It can be called one of the populated wards of the city Windsor. Similar scenarios are observed for Ward 1 because of the St. Clair College.

Another busy location that has been recognized is the city downtown. As the downtown has occupied with many restaurants and other places of entertainment, the bus routes going through the downtown are the busiest as compared to others. Apart from that, most of the grocery stores lie under ward 3 and 4, so both the domestic people and the students use these routes for their daily communication. As the above-mentioned wards are the most engaging areas of Windsor, the bus routes in these areas are most frequently used. Thus, the bus stops in these areas need to be developed to take care of the comfort of the residents and students commuting via bus transport.

It is tough for the people to wait for the bus at the bus stop that is not properly sheltered during extreme climates. The bus stops chambers are not insulated, and it doesn’t have any heating/cooling system like other cities. The most affected travellers are kids and senior citizens that have very less tolerance against severe weather. Additionally, there are no electronic panels for observing the live bus schedules. Hence many travellers get stuck on the bus stops unable to track their buses precisely.

Bus Terminals:

The city of Windsor has a couple of bus terminals and stations those are used most frequently. But among those none of them are covered with closed insulated chambers. As shown in the figures below are the bus stops located at the busiest bus routes of the city that are unsheltered. These bus stops are located at Transit Windsor Terminal (Figure 1), College ave. at community center (Figure 2), Tecumseh Mall (Figure 3) and University of Windsor (Figure 5).

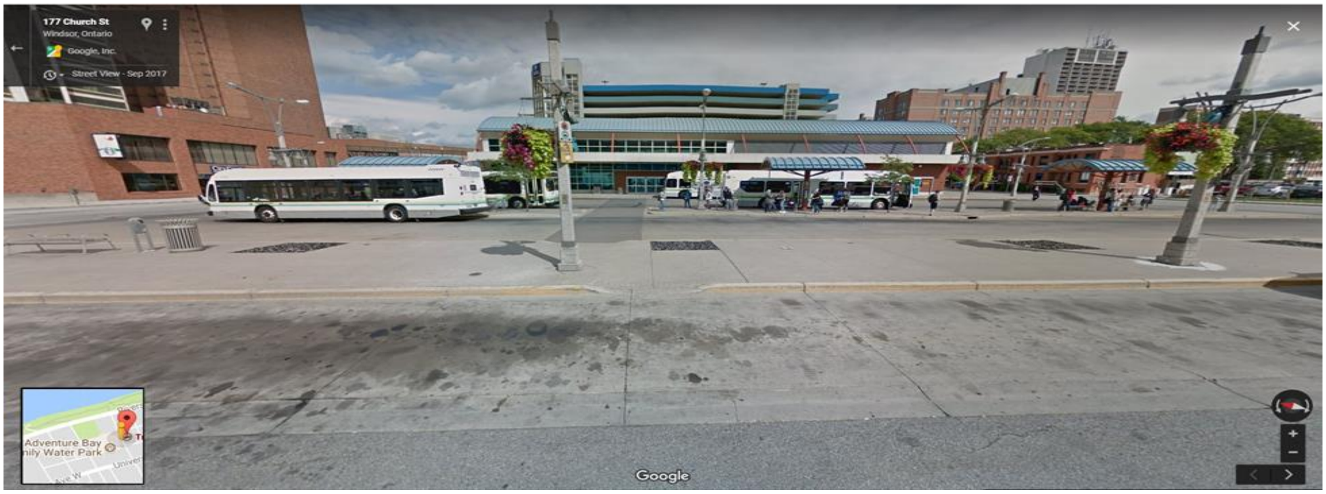

Figure 1: Transit Windsor Terminal [12].

Figure 2: College Ave. at Community Centre [13].

Figure 3: Tecumseh Mall (East) [14].

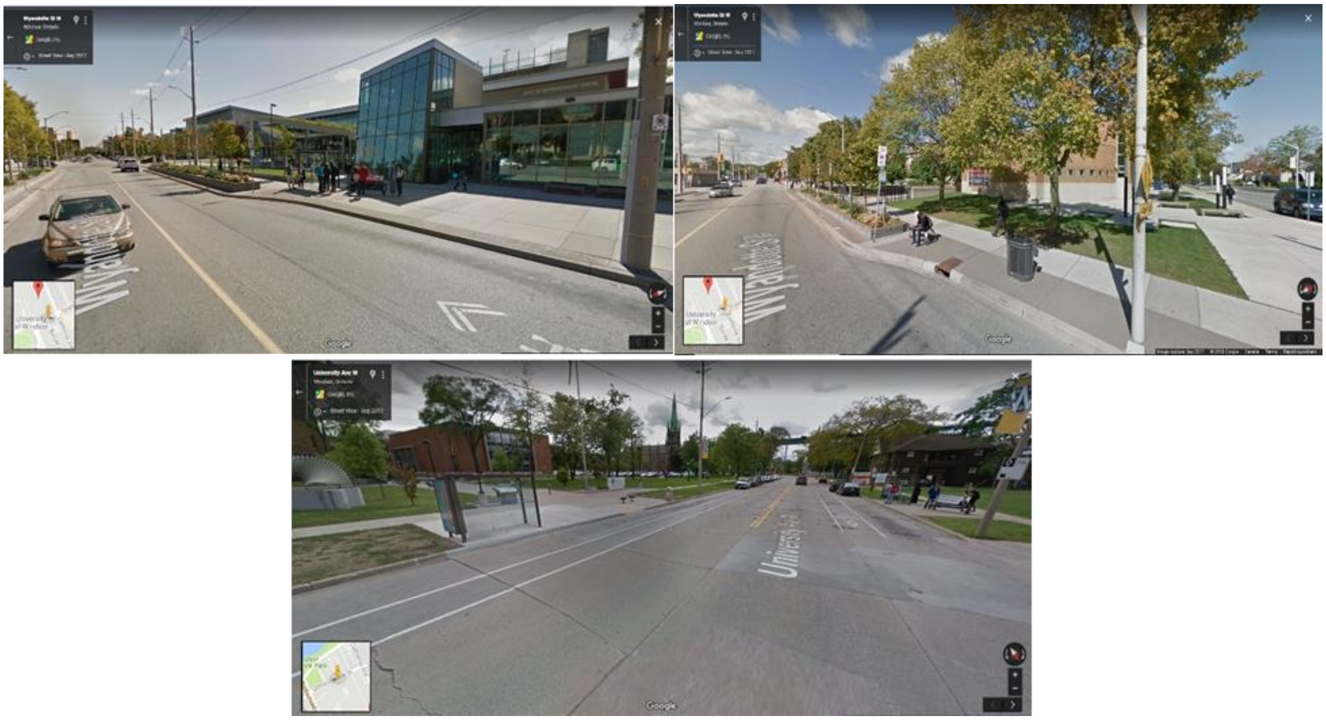

Figure 4: Bus Stop stations at the University of Windsor [15].

Figure 5: St. Clair College Bus Stop Station [16].

There is a lot of buses stops like these without proper shelter in front of workplaces, grocery store, entertainment centers and many more which requires insulated chambers for the easy communication of the travelers. Bus routes towards the downtown, university, college, grocery stores and malls are the most frequently used by the of Windsor. Especially the route of Transway 1C and Crosstown 2 passes through ward 2 and 3 [3]. These wards lie under the most engaging areas of Windsor, the routes are also used most frequently. The map below (Figure 6: Terminal locations) highlights the bus routes for 1C and 2 with the bus terminals that are unsheltered and require proper renovation.

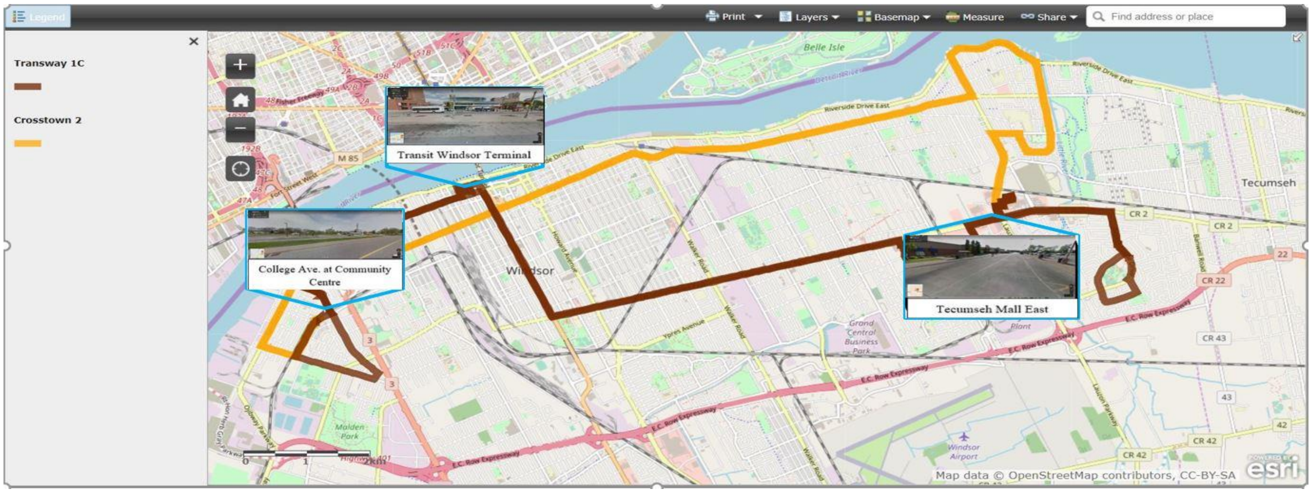

Figure 6: Terminal locations [2].

Location	Bus No.	Ward No.
University of Windsor	1C, 2	2
St. Clair College	7, 5	1
Devonshire Mall	1A, 7, 14	9
Tecumseh Mall	1C, 2, 4, 10	8
Transit Windsor Terminal	1A, 1C, 4, 5, 6, Tunnel Bus	3
Downtown	1C, 2, 3, 4, 5, 6, 8, Tunnel Bus	3, 4
College Ave. at Community Center	1C, 3, 7, 2	2

Table 1: Locations and bus routes.

2.1. Proposed models for bus station shelter, its environmental impact and benefits

It is essential for the structure of the bus stop chamber to be designed in a way that it supports the heating and cooling system embedded inside the chamber. Taking this into account, the materials used to renovate or build the structure from scratch should provide thermal insulation and maintain the comfort level of the people waiting inside at the same time. After rigorous search and comparison, we found out some good examples of the bus station models that combined the cost efficiency, utilizing the latest technology and uses green energy to supply the power for the heating and cooling system inside the station. By using solar panels, we will eliminate the need for connecting the proposed bus station to the local power grid which will save time and money, and at the same time the results of our proposal will have noticeable impact on the environment as more people will use the buses which will reduce the number of cars used for transportation and at the needless Carbone monoxide will be released to the air.

For our proposal, and after we spent a great deal of time finding the best models for the new bus stations, we selected the ones designed and fabricated by True form, a pioneering technology and manufacturing company, provide leading products, specialist engineering solutions and field support services for all modes of passenger transport. The following pictures show the types of station shelters that could be considered for the transportation improvements at the City of Windsor. Figure 7 shows the bus shelters that are available in various configurations and sizes. They are properly insulated and air-conditioned with modern amenities like CCTV, audio

PA and others. Figure 8 and Figure 9, on the other hand, shows the shelters that are solar powered with LCD displays indicating the bus timings.

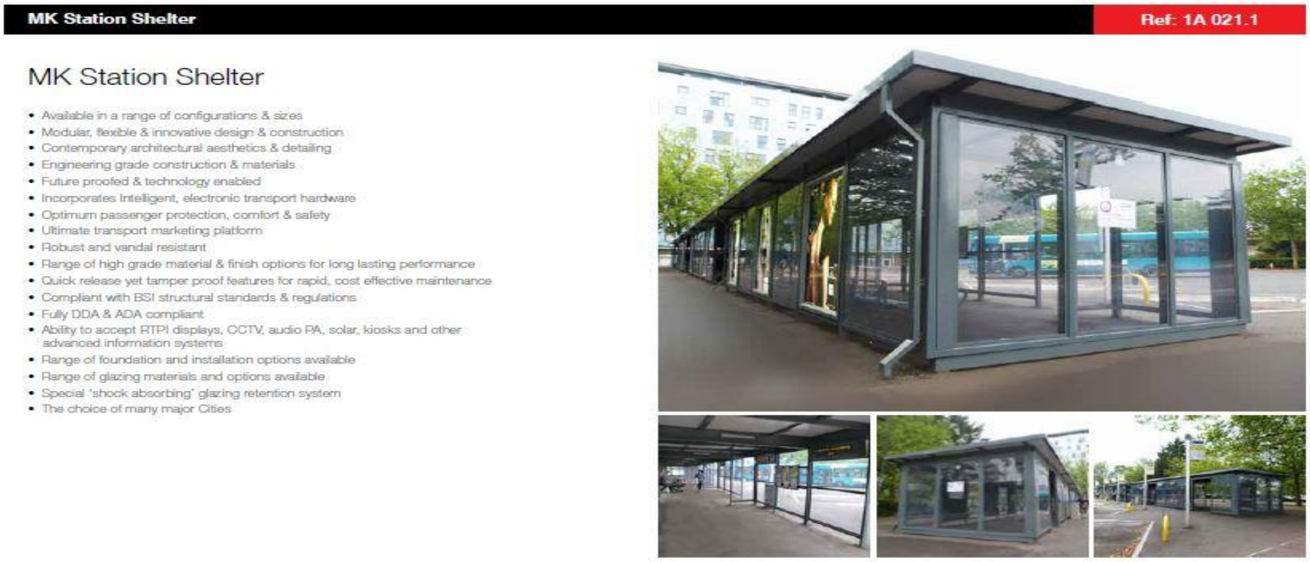

Figure 7: Big size station shelter for main and busy terminals [17].

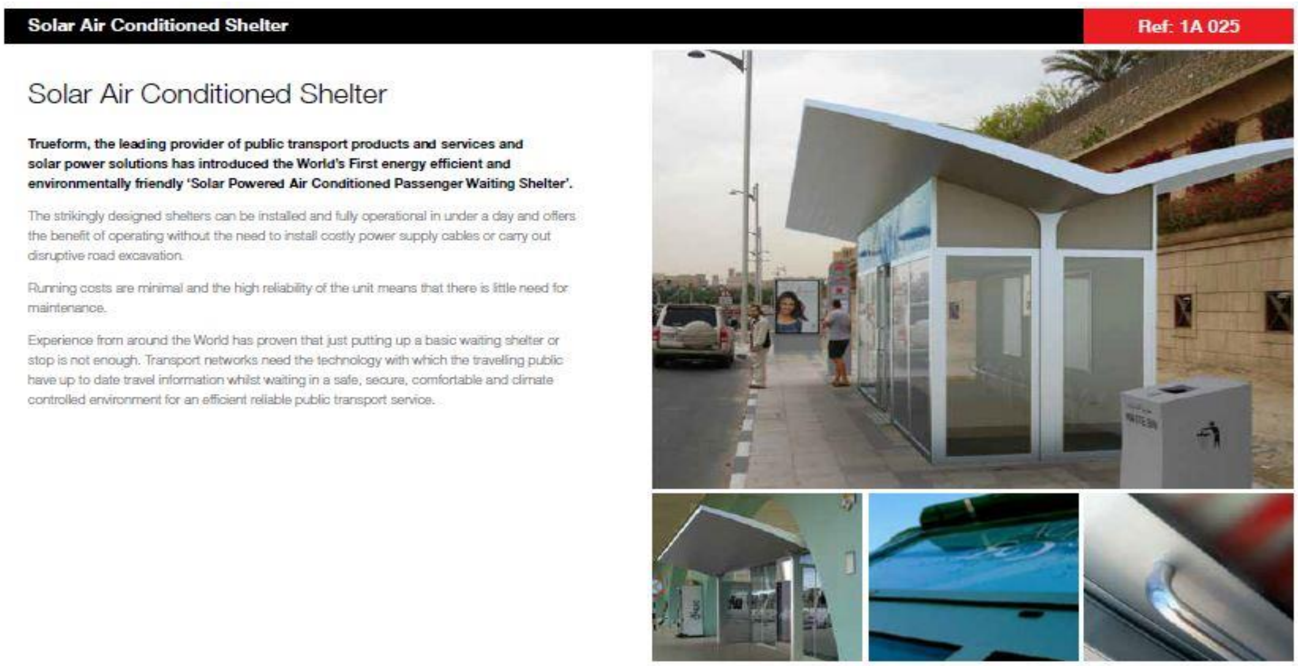

Figure 8: Normal size station shelter for typical station [18].

Figure 9: Solar panels for bus stop stations [20].

3. Requirements and Criteria

The proposed solution should satisfy the below requirements to achieve the desired outcomes

1. Cost effective: The solution proposed should be economically viable for implementation. This is a major aspect as it determines if the proposal could be implemented in a practical scenario. These can be achieved by creating a shelter with low infrastructure cost and high operating efficiency.

2. Energy Efficient: The bus stops should be energy efficient in its operations. It should consume minimum energy but maintain the comfort level of the travellers at the same time. These can be achieved by using energy efficient heating and cooling systems.

3. Robust: The bus stops should be robust so that it can withstand climate changes and age with time. It can be accomplished by using materials that can enhance the strength of the infrastructure of bus stops.

4. Low Maintenance: The bus stops should have a low maintenance cost. This will help in reducing the operating cost further.

5. Environment-friendly: The proposed bus stop model should be environment-friendly and should use green energy for its most of operations.

6. Comfort: The bus stops should maintain the comfort level of the travellers waiting for their buses.

The proposed solution considers the above requirements and ensures that each of them is met in an optimally not compromising the comfort of the travelers.

4. Methodology

4.1 Components and materials

It is essential for the structure of the bus stop chamber to be designed in a way that it supports the heating and cooling system embedded inside the chamber. Taking this into account, the components and materials used to renovate or build the structure from scratch should provide thermal insulation and maintain the comfort level of the people waiting inside at the same time. In addition to these, the materials used should be cost-effective, robust and efficient in the operations they will be used further. Our research led us to the below materials that will act as building blocks in the improved bus stop chamber structure.

Air conditioner:
Air conditioner with half ton capacity and heater with 500 watts will be mounted on the front wall from the entrance to maintain the desired temperature in the chamber.

Solar panel with charge controller:
Solar panels mounted on the roof of shelter will generate power depending upon the solar light density. Generated power in terms of the electron will be processed. The charge controller maintains the proper flow of power in varying sunlight condition.

Batteries with inverter:
Batteries will be used to store the power generated by solar panels. The inverter will be mounted along with the batteries for generating AC power from the batteries to run the heating/cooling system in the chamber.

Power grid:
The power grid will be connected to the chamber to provide additional power to maintain continuous operation of the heating/cooling system of the chamber.

Fibreglass:
The fibreglass will be embedded in the walls of the chamber to provide insulation from the changes in external temperature.

Solar and low power displays:
The low power displays will run on the solar power. This display will indicate the bus schedule, arrival and departure information.

4.2 Design, theory and analysis

4.2.1 Air cooling arrangement

Max temperature noticed in Ontario region during July month in summer is around 28 degrees Celsius which is equal 82 Fahrenheit. [4] Additionally, the effect of heat gets worse in a humid area like Windsor and nearby region.

Cooling procedure for any room or closed area is to remove heat for maintaining desired temperature and humidity level. Generally, the temperature and humidity maintained are 24 degrees Celsius and 55% relative humidity. Heat is measured in terms of BTU/HR. (1 BTU/HR heat is required to increase 1 Fahrenheit temperature of 1-pound water.

4.2.1.1 Air cooling calculation using thumb rule:

The volume of bus stop shelter can be required as following. Size of shelter in terms of length, width and height are 10 feet, 4 feet, 10 feet respectively. These all three parameters are utilised in following equation, [5]

Volume = Width X Length X Height

Volume = 4 X 10 X 10 Cubic feet

Volume = 400 Cubic feet

This volume is multiplied by constant 6.

C1 = 6 X Volume

C1 = 2400 BTU/HR

Number of maximum people utilise bus stop at a time are taken as 8. One person normally omits 500 BTU/HR* heat. Second parameter is C2 and calculated as,

C2 = 8 X 500 BTU/HR

C2 = 4000 BTU/HR

These both parameters are added together to find cooling capacity needed.

Cooling capacity estimated = C1 + C2

Cooling capacity estimated = 6400 (BTU/HR)

A half ton Air conditioner is capable 0f cooling 4900 BTU/HR heat.

4.2.2 Heating arrangement

The lowest temperature found in Windsor region is -7 degrees Celsius which is equal to -1-degree Fahrenheit during winter in January. [4]

4.2.2.1 Heating requirement calculation:

Floor area is calculated using formula, [6]

Floor area = length X Width
Floor area = 10 X 4
Floor area = 40 square feet

Required heater watts is determined by multiplying floor area by 10.

Watt rating of heater = Floor are X 10
= 400 watts*

These watts rating is multiplied by factor 1.25 as per thumb rule because ceiling height is more than standard height 8 feet.

Watt rating of heater = 400 X 1.25
= 500 watts

500 watts is equal to 500X3.412142 = 1706.071 BTU/HR heat is required by heater to provide adequate heating to bus stop shelter.

4.2.3 Solar panels

Solar panels could be used as an additional source of energy to power up the conditioning system in bus stop chambers. Solar panels could be installed on the roof of the bus stop chambers to generate necessary power during days with clear sky and sunshine.

Windsor has a wide temperature variation throughout the year during different seasons. Solar panels would fail to function particularly when they are covered with snow during winter. This can be taken care of by installing the panels at a vertical inclination so that the snow could slide off on its own accord as shown in figure 10 below.

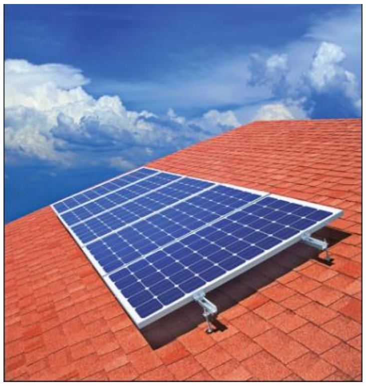

Figure 10: Solar Panel mounted on the roof at an inclination [19].

The efficiency of the solar panel can depend on the power generated by the panel per unit area.

The efficiency can be calculated by the equation as below [7]:

$$\eta_{max}\,(\text{maximum efficiency}) = \frac{P_{max}(\text{maximum power output})}{(E_{S,\gamma}^{SW}(\text{incident radiation flux}) * A_c(\text{area of collector}))}$$

The incident radiation flux is the amount of the sunlight energy that hits the earth's surface in W/m^2. It is usually assumed as 1000 W/m^2 under standard test conditions. For a solar panel of 400 Watts with and area of 30 ft^2. The calculations are as shown:

The total area in meters will be:

$$A_{m^2} = \frac{A_{ft^2}}{10.76}$$

This gives the area as 2.79 m^2.

Taking Pmax (400W), incident radiation flux as 1000 W/m^2 and Ac = 2.79 m^2. Efficiency can be calculated as,

$$\eta_{max} \; = \frac{400\,W}{(1000\,\frac{W}{m^2} * 2.79m^2)} = 0.143 \text{ x } 100\,\% = 14.3\,\%$$

The above efficiency can be taken as average efficiency taking different weather conditions and manufacturers into account. Also, it is found that the efficiency increases during snow if the panels are not covered with snow. These are due to snow additionally reflects sunlight on the panels increasing the incident solar power.

4.2.4 Power supply

The arrangement of the power supply can be explained as in the below block diagram:

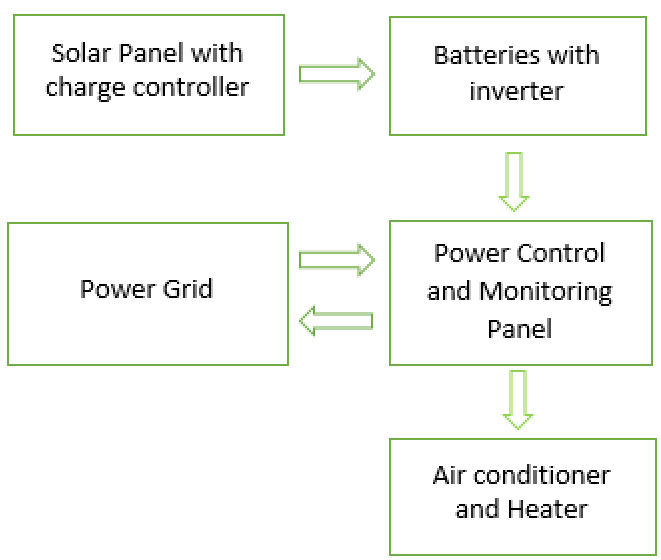

Figure 11: Block diagram of power supply.

The power generated from the solar panels will be stored in batteries. The power from the batteries via inverter will be monitored by the power control and monitoring panel. It will extract additional power from the power from the power grid if needed. The required power will be interfaced to the air conditioning and heating system in the chamber.

4.2.5 Fibreglass insulation

Fibreglass is a material that is made up of plastic and reinforced by tiny glass fibres. The composition of glass fibre provides additional strength to plastic and also enhances its insulation capacity [8]. Hence the use of fibreglass will slow down the spread of heat, cold and sound in structures. This task is carried out by trapping pockets of air that helps to keep rooms warm in winter and cooler in summer. Also according to some estimates carried out, these thermal insulation conserves 12 times as much as it is lost in the production using power generators. This could reduce the power consumption required for heating and cooling. It is estimated that the residential energy costs may reduce up to 40% according to the International Association of Certified Home Inspectors (InterNACHI) [9].

Performance Evaluation R – Value:
R value is an objective measure of a fibreglass to resist the heat flow. Thus, higher the R value will imply higher insulating power of the material. The R value can be calculated by the formula below:

$R = l/\lambda$ where,
l is the thickness of the material (in meters)
λ is the thermal conductivity* of the material (W/mk).

4.2.6 Final design

When we look at bus stop chambers around the world we can find these chambers are air-conditioned to maintain the desired temperature inside them. One such bus stop is as below located in London Europe designed and fabricated by True form – a pioneering technology and manufacturing company [8].

The final proposed bus shelter with fibre glass walls would look like shelter given in figure 12 below. The proposed designed bus stops will have air conditioners as well as heaters mounted on the walls. Solar panels will be installed on the roofs. Additionally, Low power LCD displays will be connected above the shelters. The power displays that will indicate the bus schedules, arrival and departure information are as shown below in figure 13.

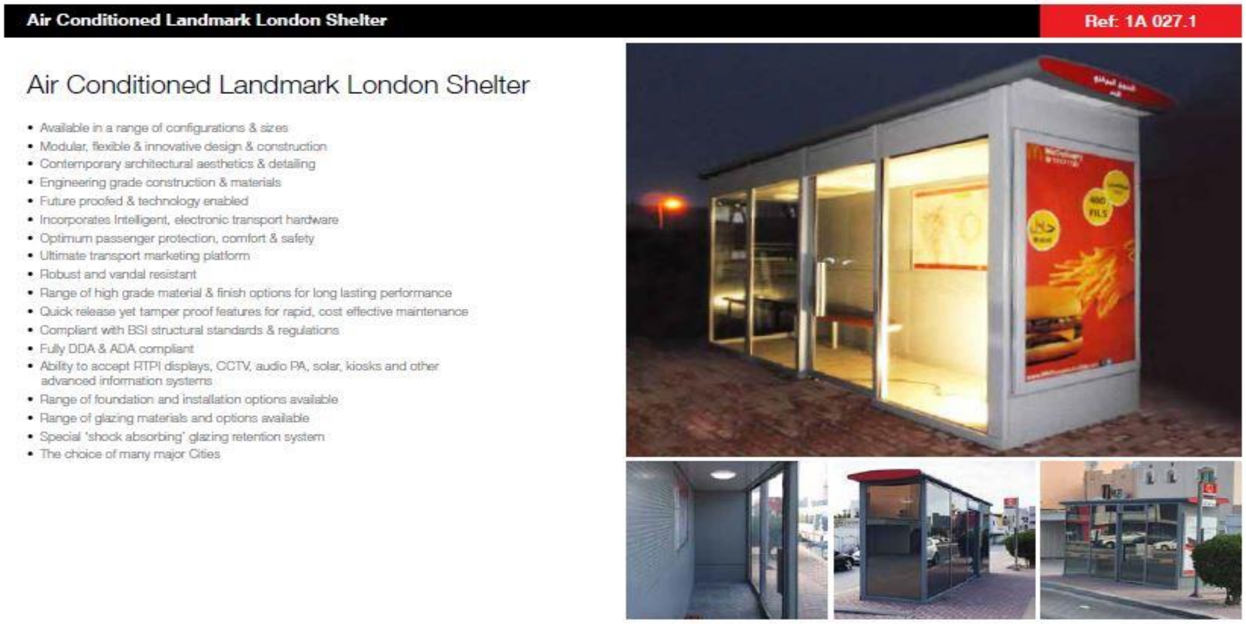

Figure 12: Air-conditioned Bus Stops [21].

Figure 13: Low power display for tracking bus schedules [22].

4.3 Cost analysis

Considering the design equations and the power requirements, the total cost estimate can be done as tabulated below:

The busiest bus routes are 1C and 2 for Windsor bus transit. There are total 90 bus stops on the 1C transit route and 83 bus stops on 2 transit routes. Among these 173 bus stops, 100 are most frequently used which are selected for project implementation [10].

Particular	Cost	Total cost
Bus stop shelter	$ 15000 /unit	$15,00,000
Air conditioner	$ 238 /unit	$23,800
Heater	$ 70 /unit	$7000
Solarpanel(650 watt)	$ 350 /unit	$35,000
Inverter	$ 100 /unit	$10,000
Batteries	$ 40 /unit	$400
Power control panel	$ 50 /unit	$5000
Grand Total		$1,581,200

Table 2: Cost Analysis.

4.4 Timeline:

The total timeline for implementation is of five months which are divided into six major milestones. Initially, legal documentation and final approval from the government will take approximately one-month time duration. Two-month time is required for constructing 100 bus stops with fibreglass having the robust structure. Installation of air conditioners and heaters along with solar panels on the roof of the shelter will require around one month. Finally, powering the bus stations and the connection of all equipment with control panels including lower power LCD displays will take one month.

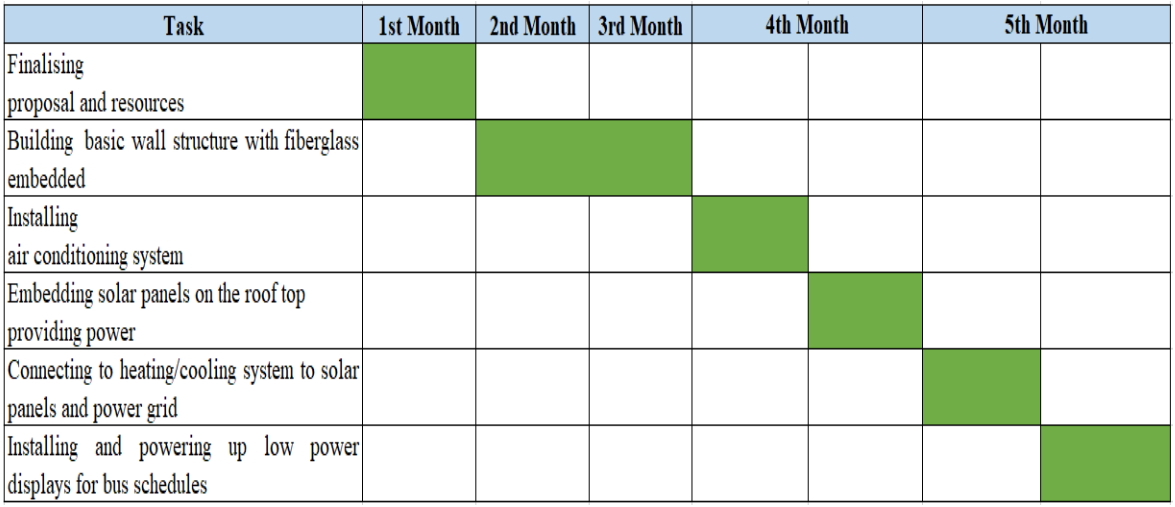

Figure 14: Timeline.

4.5 Structure evaluation and discussion

The proposal includes detail analysis of bus routes and busy bus stops located across the city. Keeping in mind the busy bus stops and variable climate of Windsor city, we have proposed an improved design of Bus stop chambers that will address the necessity to protect the bus travellers from harsh climate of the city. The new bus stop design proposed by us can be evaluated by listing major strengths and possible vulnerabilities as below:

Strengths of the proposed bus chamber design:

1. The structure will provide proper protection to bus travellers during harsh climates.
2. The design is made cost-effective in the long run by utilizing components like fibreglass and solar panels.
3. The solar panels will act as a green source of energy. Also, fibreglass will provide a powerful insulation. These two factors together will increase the energy efficiency and reduce the power consumption from the power grid by many folds.
4. The structure is robust and has low maintenance.
5. The implementation will get financial support from the federal government and province as the use of green energy is made.
6. The low power displays operating on solar power will help the travellers to track their buses and take appropriate actions.

Possible vulnerabilities:

1. The solar panels may work with very low efficiency if they are covered with snow for a long time. Hence periodic cleaning of the solar panels may be required during heavy snow periods.

2. The installation of fibreglass may cause injuries due to minute glass particles. Hence proper care must be taken during installation.

The new proposed structure addresses the needs of the residents of the city and adds to their travelling comfort. The proposed design will make the bus travel more comfortable for all the residents. Also, it will greatly assist the bus travel made by toddlers and people falling in old age groups that are more vulnerable to extreme climates encountered in the city. The new structure will further add proper tracking of the buses by displaying bus schedules and changes occurring in them due to external factors.

In the professional opinion, the structure is cost-effective, energy efficient and robust which can be seen from the analysis done.

5 Conclusions and recommendations

5.1 Conclusions

We discovered that the bus stops currently present in the city are vulnerable to external climate and hence add to the difficulties of the travellers during long waiting periods and uncertain schedule of the buses running through the city. After rigorous research, comparison and analysis we had proposed a bus stop chamber design that can protect the residents travelling by bus from the harsh climates of the city.

The challenge was to come up with a chamber structure that was embedded with heating/cooling system and was energy efficient, cost-efficient and reliable at the same time. We discovered that the use of solar panels could be used as a renewable energy source to provide a power supply for the heating/cooling system. The power grids will also be appropriately designed to provide additional power supply whenever required. Also, the structure can be strengthened and properly insulated by installing fibreglass in the walls of the chamber. This will help to maintain the temperature inside the chamber for long periods and further reduce the energy consumption. The low power displays operated through solar power will display accurate bus schedules to help the travellers track their bus and take appropriate actions.

Keeping in mind the difficulties faced by the residents of the city, majorly the ones falling in old age and toddlers during their normal bus travel, the report is focused on providing them protection from severe climates encountered in the city.

5.2 Recommendations

It is highly recommended that the proposed model for bus stop should be implemented in Windsor. The model will take care of the basic comfort of the travelers commuting through the bus on daily basis.

For successful implementation of the project we recommend the following measures:

1) We are primarily focused to renovate busy stops of the city. But we could further increase the scope of the project to all the bus stops of the city in near future. These further benefit people residing on the outskirts of the city. Also, it will assist people travelling from neighbouring cities or provinces.

2) One should ensure that the project runs as per time schedule and completed in the given timeline. Proper backup measures should be taken to handle unforeseen circumstances like power cuts, climate changes and other external factors.

3) The current bus stops of the city are open and made up of transparent hardened glass. To realize proper insulation and strength it is more advisable to construct these stops from scratch. This would help in building a robust and long durable structure.

4) During the implementation, proper detours should be made for the existing bus routes in a way that it causes minimum disturbance to the daily travellers. Also, if possible the bus could follow the same route if there is enough space for travellers to stand surrounding the previous bus stops. Care should be taken that proper planning is done to maintain the bus routes covering the busy and frequently visited areas of by city residents.

5) Proper care should be taken by installing the fibreglass, solar panels and power grids so that no causality occurs on site. Also, children and toddlers should be kept away from construction sites.

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7 Glossary

BTU/HR	British thermal unit per hour (A unit used to measure heat)
Watts	Entity to measure power
Thermal Conductivity	Entity measure of heat conducting capacity of a material
Unit	Entity to measure of power
Power Grid	A network used to distribute power from main power stations
Fibreglass	A material that is made up of plastic and reinforced by glass fibers