CASE STUDY OF ACOUSTIC MAPPING OF INTERNATIONAL TRANSPORTATION ROUTE AND ITS EFFECT ON THE LOCAL COMMUNITY

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Introduction

The Windsor-Detroit border crossing is a gateway for North-American goods coming to and from Canada and the US. It is the largest border crossing in Canada and relies heavily on the smooth operation of the Ambassador Bridge. Huron Church Road is the main transportation route leading to the Ambassador Bridge, which sees on average 32, 000 vehicles cross daily and at times as many as 50 000 vehicles during peak times. The local area surrounding the Bridge and Huron Church consists mainly of residential areas where noise pollution can greatly affects the health and quality of life of the people living there. The issues are very evident and of concern to the local community and various solutions are being lobbied.

Windsor Environmental Noise Mapping Initiative (WENMI) is a unique project in North America first thought up as a 4th year design project for University of Windsor engineering students. Its purpose was to study the current condition of Huron Church and engineer a reliable noise contour of the local area. By providing the public an accurate and reliable analysis of the area it can potentially aid in the decision process towards a positive solution and create awareness about noise pollution.

The Essentials

Various terms specific to acoustical engineering must be understood to enable the interpretation of the results. Some local initiatives are also briefed to allow for a common understanding of the area.

Terminology

Decibel (dB)	A logarithmic unit of measurement that expresses the magnitude of a physical quantity (usually pressure, power or intensity) relative to a specified or implied reference level.
A- weighted scale	An adjusted decibel scale better representing the non-linear hearing capabilities of humans.
Noise Contour	Analogous to a thermal image, it allows the visualization of varying soundlevels

Local initiatives

The Green Corridor project is a groundbreaking initiative for generating a green redevelopment of the international bridge corridor linking Canada to the United States. It involves a 2km stretch of Huron Church Road leading south from the Detroit River. This development was created from an artistic perspective

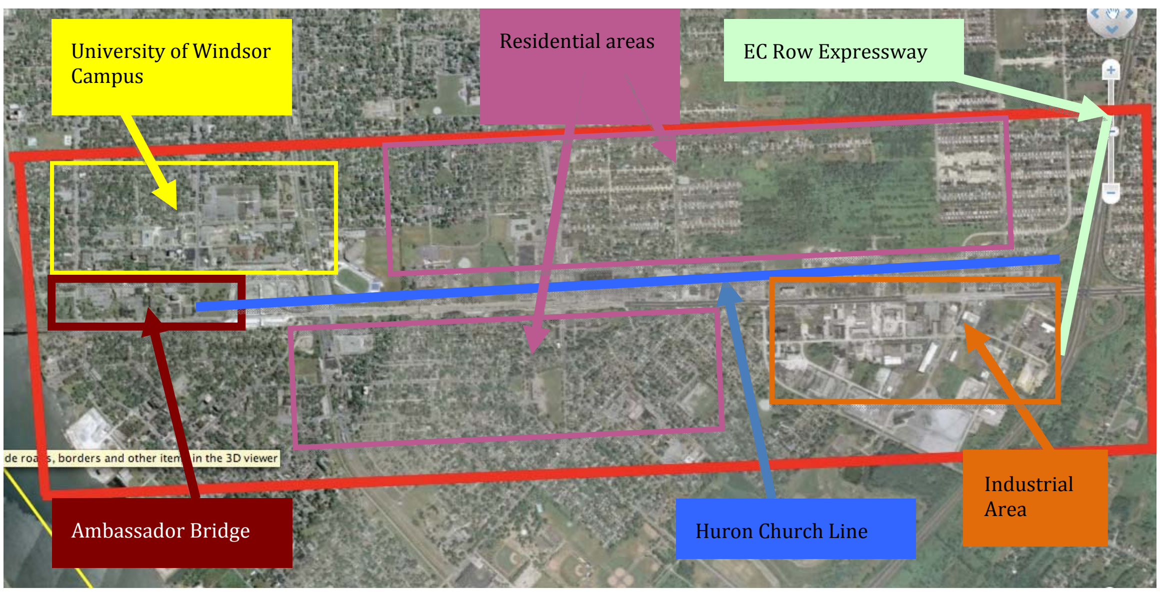
and did not contain any acoustical engineering consultation.

Legislation

Regulations in Ontario establish 55dBA during the day and 45dBA at night as the allowable guideline noise level in a residential zone. New residential areas surpassing the 55dBA level are required to employ noise mitigation measures to help suppress the noise levels to acceptable values. However, residences erected prior to the introduction of noise legislation are omitted despite the potential for adverse affect.

Area of Interest

Huron Church Road extends approximately 6.6 km (4 miles) in Windsor Ontario connecting the 401 Highway to the international river crossing. WENMI focused on the stretch extending from the Detroit River down to EC Row Expressway (5km). A width of 500m east and west of the road was included in the calculation area to ensure the effects of the noise pollution were sufficiently accounted for in the surrounding region.



This 5 square kilometer stretch of road was chosen due to the sensitive noise pollution issues associated with the area and the desire to analyze and better understand the problem. The area contains the University of Windsor campus, numerous residential areas, several local industrial plants, and numerous commercial businesses. It has been publically acknowledged that an issue regarding bridge traffic exists and several solutions are being considered. Studying this area would provide a good basis for the public and government to better understand the current situation and allow for the simulation of proposed ideas and their influence on noise levels.

Purpose

The goal for this project was to establish a reliable noise emissions contour and raise public awareness about environmental noise pollution. It is hoped that the results will be a stepping-stone in improving health and quality of life for the local residents. Providing a reliable and proven 3D acoustic model, including the consideration of various mitigation solutions, can be created through simulation techniques, this will ensure mitigation solutions are effective and engineered optimally.

Road to Success

Modeling program

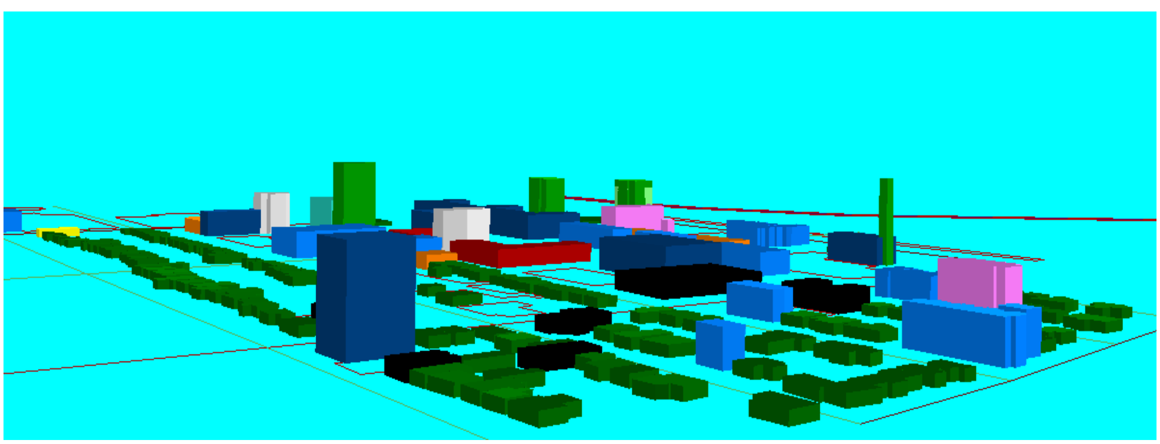
There were several programs available to WENMI for 3D modeling and simulation. After careful consideration Bruel & Kjaer's LimA software was chosen due to its extensive and detailed capabilities and excellent technical support. Some key features included 3D modeling, reverse engineering, soundscaping, and the ability to superimpose industrial noise sources with transportation noise. Even though the LimA program's capabilities are greater then what was required for this project, it will allow for further studies at the graduate level.

Bruel &Kjaer Support

Choosing such an advanced and capable modeling program like LimA also had the disadvantage of a large learning curve. To ease the difficulties of using a new program Bruel & Kjaer provided WENMI with excellent technical support and several web-ex sessions. The web-ex sessions were live-time interactive internet tutorials tailored by Bruel & Kjaer specifically for the WENMI group based on difficulties in learning the use of LimA. These sessions provided a great deal of knowledge and helped the progress of the project significantly.

Modeling process

The modeling process was subdivided into three stages; preprocessing, processing and post processing. The initial step in obtaining a noise contour was creating a 3D image of the area. This was achieved by creating numerous "polygons" each representing an object of interest. These mainly pertain to residential, industrial, commercial buildings, and roads. A bitmap containing real images was imported into LimA for visual aid and assisted in accurately modeling the polygons. The3D image below illustrates the model.

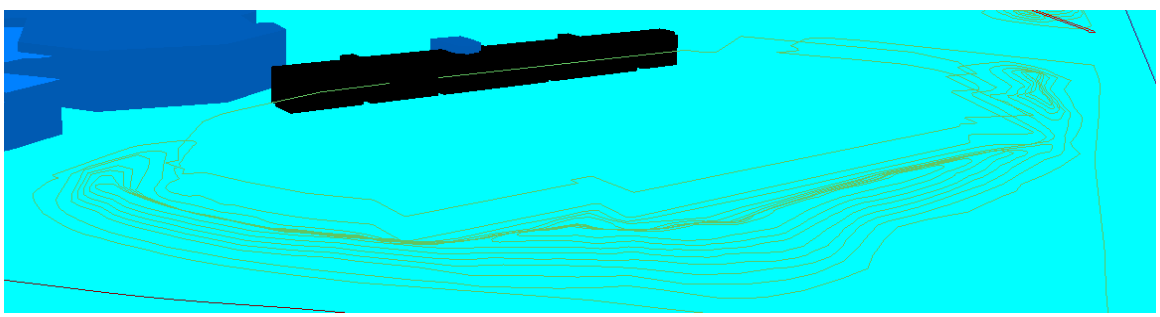


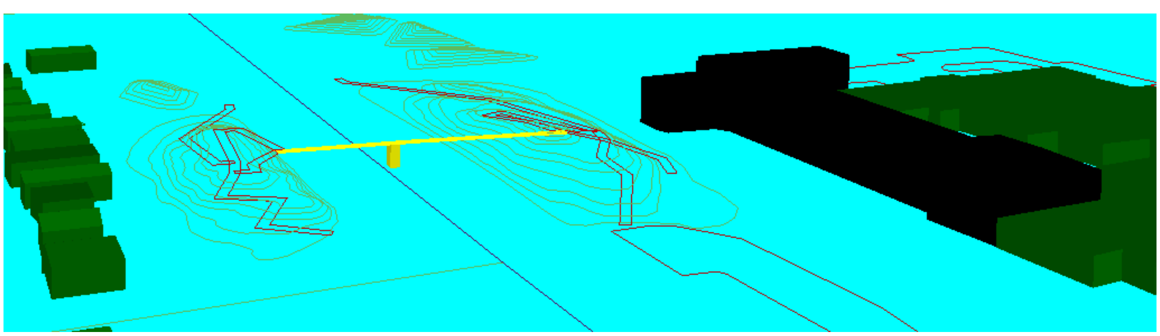
The shown green areas represent residential housing, the blue and white shapes represent the industrial and commercial properties and the green lines represent the area roads.

Several assumptions were made in order to establish a three dimensional model due to variances in residential dwelling designs and the topography of the region. Residential houses were assumed to have a mean height of 5 meters, while any larger structures like industrial plants or apartments had heights measured manually using a laser range finder to ensure accuracy. The topographical area was also assumed to be flat, as there are negligible elevation change throughout the region.

The most contributing components; the roads and their associated data were represented as "line polygons". This allowed for the implementation of data pertaining to every single road. Some attributes included the number of lanes, traffic volume figures for small and heavy vehicles, and reflectivity factors for road surfaces. Data pertaining to major roads was obtained from the City of Windsor while smaller roads were considered to be insignificant contributors due to their low trafficvolume. 15 roads were assigned traffic data and are represented in red and blue below

Certain structures in the area required additional attention to model. The Ambassador Bridge along with various walkways and berms along Huron Church Road needed to be implemented. Using dimensions obtained by field readings, aerial images, and LimA's3D modeling capabilities, area specific attributes were incorporated to ensure high accuracy of the model. From this, the Ambassador Bridge, several berms located around Alumni Field, an overhead walkway on Huron Church, and the EC Row Expressway overpass are all modeled. Illustrated below are close-up images of the Alumni Field berms and the nature bridge overpass located on Huron Church.





Industrial Noise sources

The majority of the environmental noise pollution is caused by auto and heavy truck traffic, although several industrial sites are also located within the area. To maintain accuracy of the model, significant industrial noise contributors were accounted for. Third octave Leq readings were logged to quantify the industrial sources. The length of data acquisition was dependent on the time taken for Leq readings to stabilize. Once collected, data was converted to the A-weighted sound power level and submitted into LimA as point sources. Industrial noise was represented as point sources due to their immobilized single point of origin, unlike a vehicle travelling on a road, which is represented as line sources.

When simulations are carried out point sources are measured separately from road emissions. Industrial and road emissions contours are calculated, and then are superimposed to provide a combined representative of both contours. The effect of the industrial source contributions will be covered in the simulation portion of this report.

Data acquisition

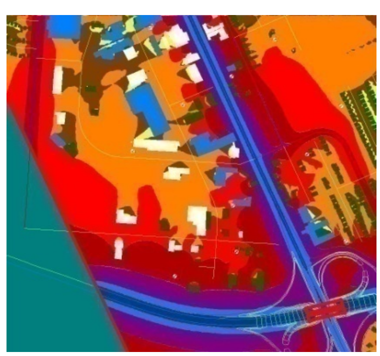
Readings were logged using Bruel & Kjaer Type 2238 and Type 2250 Sound Level Meters (SLMs). These meters provided great versatility with easy to use interfaces.

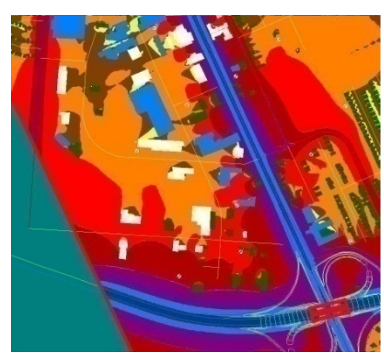
Simulation

The completion of a three dimensional model made way for the actual engineering work. The intent of the initial simulation was to make use of theoretical values to obtain a noise contour, then reverse engineer another contour using field data (discussed later), and finally compare the 2 simulations and optimize them.

For roadway noise, the model used the British Calculation of Road and Traffic Noise (CRTN) standard. Several incorporated European standards were available but unfortunately Canadian traffic models are not available yet within LimA. Creation of a custom standard is available in LimA but due to time constraints WENMI opted for CRTN which is somewhat similar to the Ontario Road Noise Analysis Method for Environment and Transportation (ORNAMENT) standards practiced in Ontario. Leq readings were divided into day and night outputs to enable the analysis of noise pollution during day and night periods. Calculations for day emissions were taken at a 1.5m height which represents the height of the residential backyards during the day and also provided uniformity. Night readings were simulated from a second story window, the equivalent of a 4.5 meter height.

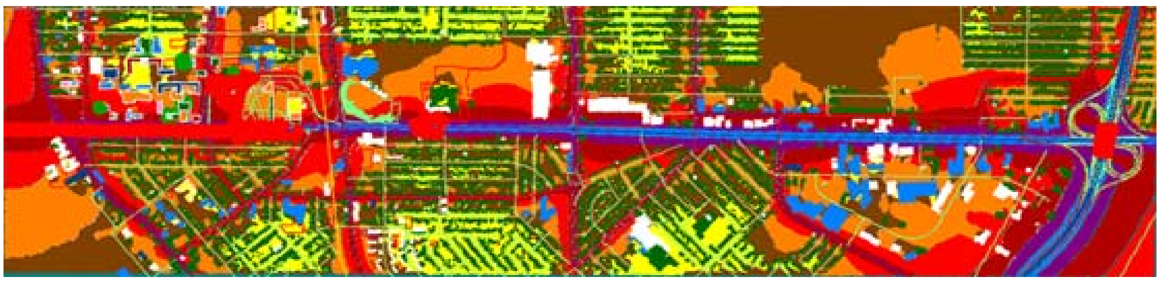
Initial simulations illustrated that the local industry noise contribution was insignificant. Shown below are the acoustic mappings for industrial noise, road emissions and the superimposing of both. It is clear that the most significant contributor is the traffic sources.



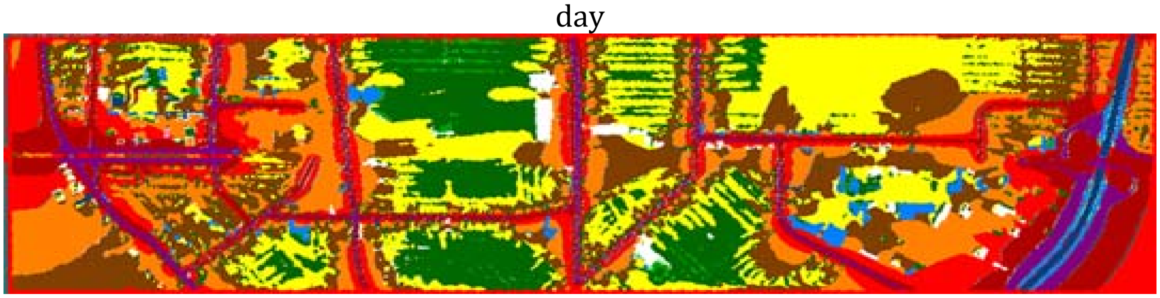


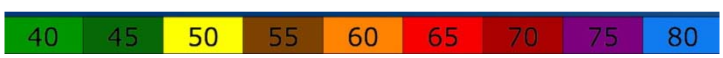
Further study was performed to better understand the effect Huron Church Road had on the traffic noise emissions. Sown are the day time noise calculations both considering and omitting Huron Church Road.

Huron Church emissions for day

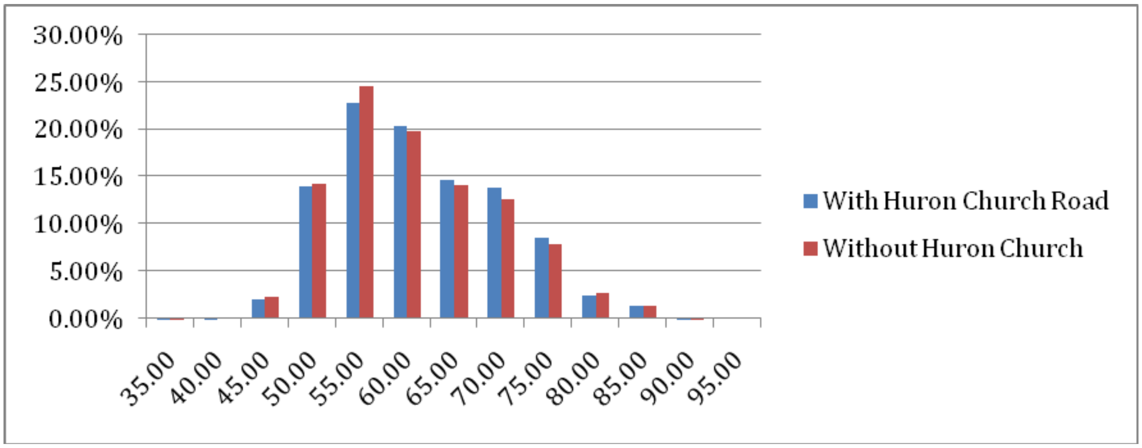


Huron Church omitted emission
day





Interpreting the images above it can be noted how greatly Huron Church contributes to the overall environmental noise pollution in the area. During the day time, Huron Church Road contributes to an increase of 3% for levels greater than 55 dBA. Further, 61 percent of the map achieves a sound level greater than 55 during the day. A summary of the results for day time noise calculations versus percent area is tabulated below.



REVERSE ENGINEERING

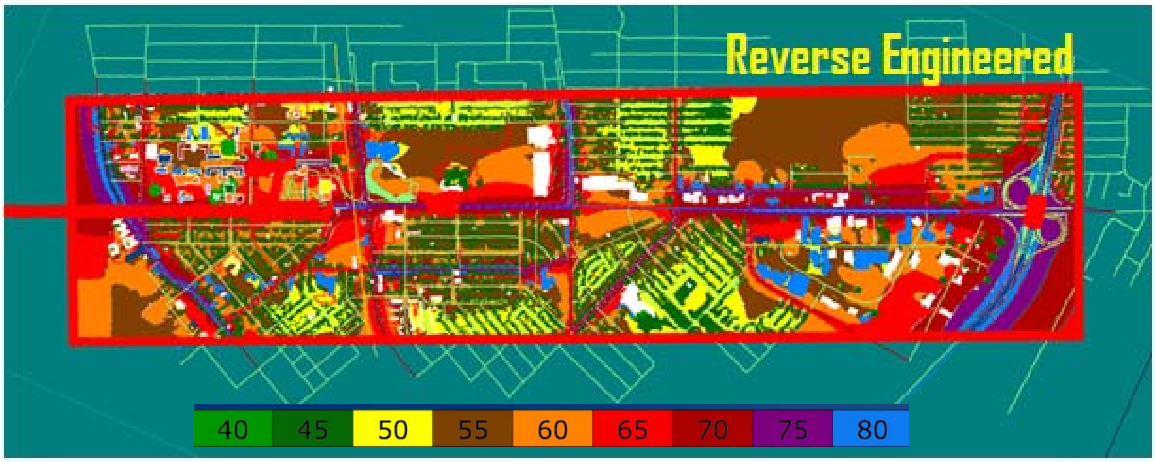
Once a reliable theoretical contour was produced the next step to engineer was a comparison of the modelled theoretical data against the actual data logged from field measurements.

Field Work

Strategic points of interest were selected to optimize the accuracy of the model. The image below displays the study area and details where the noise readings were taken.

The 24-hour readings were collected in seventy two 20-minute intervals. This allowed for the conversion of readings into day and night values which would later be used in reverse engineering the noise model. Once all the field data was collected, the same 3D model used for the theoretical simulations was utilized. This would provide a common base for both theoretical and field data to be compared.

The process taken to achieve the desired contour involved implementing "receptor points"into the model. The receptor points represented the location of where each individual reading was taken and the A-weighted noise levels recorded. To produce the desired noise contour, LimA uses powerful algorithms to reverse engineer the values. For the first simulation, road data is inputted and a noise contour is generated. The reverse engineering process of a map makes use of collected data points and simply reverses its calculations to obtain road values. The process taken with theoretical emission calculations is done backwards. Once Lima reverse calculates the road emissions, it produces a noise contour. Below is an image of the reverse engineered noise contour along with the



original noise contour for comparison.

While the images look fairly similar, small variances can be found in the modeled results. Utilizing LimA's statistical capabilities, a comparison of the two different maps yielded minimal differentiation in noise levels. A summary below compares the two models day time noise levels.

	Non_reversed Engineered		Reverse Engineered		
Reading (dBA)	Area of influence (m2)	%of area	Area of influence (m2)	% of area	%difference
35.00	300.00	0.00%	400.00	0.01%	0.00%
40.00	4375.00	0.07%	7950.00	0.13%	0.06%
45.00	120850.00	2.01%	142575.00	2.37%	0.36%
50.00	838100.00	13.95%	859250.00	14.30%	0.35%
55.00	1367250.00	22.75%	1476225.00	24.57%	1.81%

60.00	1223500.00	20.36%	1187475.00	19.76%	-0.60%
65.00	881075.00	14.66%	851400.00	14.17%	-0.49%
70.00	831900.00	13.84%	760475.00	12.66%	-1.19%
75.00	512650.00	8.53%	472400.00	7.86%	-0.67%
80.00	149325.00	2.49%	163725.00	2.72%	0.24%
85.00	78500.00	1.31%	85775.00	1.43%	0.12%
90.00	1025.00	0.02%	1300.00	0.02%	0.00%
95.00	0.00	0.00%	0.00	0.00%	0.00%
total	6008850.00	100.00%	6008950.00	100.00%	0

Although minor differences exist, the noise contours are largely similar. Several assumptions were required for the development of the model which provided potential sources of error. As stated previously, assumptions were made regarding residential building heights and traffic contributions from residential roads. Source of error located in the reverse engineering calculation regard the 24-hour Leq readings as they fail to account for variances in day-to-day traffic volume. These simulations provide a good representation of expected noise levels, but depending on daily traffic volumes, levels may increase or decrease. Overall, both modeled contours display similar readings thus demonstrating good accuracy of the model. It is also clearly demonstrated that the LimA produced model is effective in calculating the required environmental noise emissions and allows for accurate analysis of the results. The implementation and analysis of various mitigation solutions can also be executed with ease and peace of that mind accurate results will be generated.

Conclusion

Upon completion of all the initial calculations intended for this project, WENMI realized it could still design mitigation techniques and display them with LimA's modeling capabilities. The group utilized results obtained from reverse engineeringand progressed towards composing research papers,which discuss the incorporation of noise abatement solutions. Three papers are being submitted for publication:

1) An Approach to Generating and Calibrating an Environmental Noise Contour Map
2) The Green Corridor and its effect on noise levels and possible mitigations.
3) A Study of Modelling Pre-Existing Traffic Noise Mitigation

Along with the initial results, WENMI hopes awareness regarding noise pollution and its effects is increased. Also it is hopes the utilization of 3D modeling will be implemented in the optimization urban planning for environmental noise consideration. This project demonstrated that large-scale noise modeling is both feasible and accurate for environmental noise prediction of all common sources of community noise. With respect to Huron Church Road, there are large areas which exceed ministry guidelines for noise levels. It is hoped that the results obtained in this study will provide motivation for the public and government at all levels to take a proactive approach in mitigating the present problem.