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PRESIDENT'S MESSAGE / MESSAGE DU PRÉSIDENT

I am writing these editorial comments on the back of a very successful Acoustic Week in Canada (AWC) conference in Niagara-on-the-Lake this past October. The conference attracted some 125 contributed technical papers in all areas of acoustics and vibration, and featured four captivating plenary presentations on architectural acoustics by John Bradley, soundscaping and acoustical ecology by R. Murry Schafer, ecological psychoacoustics by John Neuhoff, and biomedical ultrasound imaging by Michael Kolios. We will also remember for a long time to come the full-packed multi-sensorial annual banquet, featuring the audio-tactile EmotiChair and Jazz concert.

I noted with excitement the exceptionally large contingent of about 50 student presenters or so at AWC 2009. We can conclude that AWC remains an event of choice for first-time student presenters and those wishing to put to test their latest thesis results. Above all, several students told me they particularly enjoyed meeting some of the most prominent acousticians in the country and discovering the large number of university and government institutions, consulting firms and manufacturers carrying out acoustical work in the country. It is the essence of our annual meeting of bringing all these people together. Many thanks to Ramani Ramakrishnan, the Conference Chair, and all members of the local Organizing Committee for such a great event.

AWC 2010 will be held in another beautiful setting in Victoria BC, October 13-15. The local Organizing Committee is led by our Past President, Stan Dosso, and two CAA Directors, Clair Wakefield and Roberto Racca. The last conference in Victoria, back in 1999, was a memorable event and we can look forward to a strong technical meeting with carefully selected social events again next year. Please mark it down immediately in your calendar and consult the current and future issues of Canadian Acoustics or the website for more information.

Many thanks to Vijay Parsa (UWO), who just completed his term as a CAA Director. I would like to welcome our newly elected Director, Hugues Nelisse, from "l'Institut de recherche Robert-Sauvé en santé et en sécurité du travail" (IRSST). Another Director, Sean Pecknold (DRDC Atlantic), has been assuming the role of CAA Webmaster since last Spring. We also have a new Executive Secretary in Brad Gover from the NRC Institute for Research in Construction, replacing David Quirt who served diligently for 7 years. Sadly, one of our most distinguished Canadian acoustician and CAA emeritus member, Edgar Shaw, passed away this October. We will forever remember him and his wife through the Edgar and Millicent Shaw Postdoctoral Prize in Acoustics.

Finally, as ever, the CAA constantly requires a fresh supply of members to volunteer on the various tasks and functions

J'écris ces quelques commentaires suite au franc succès de la Semaine canadienne d'acoustique à Niagara-sur-le-Lac en octobre dernier. Le congrès a attiré plus de 125 communications orales dans tous les champs de l'acoustique et des vibrations en plus de quatre présentations plénières des plus intéressantes en acoustique architecturale par John Bradley, en écologie du paysage sonore par R. Murry Schafer, en psychoacoustique écologique par John Neuhoff et en imagerie biomédicale par ultrasons par Michael Kolios. Nous allons longuement garder en mémoire le banquet annuel multi-sensoriel mettant en vedette le fauteuil audio-tactile EmotiChair et concert Jazz.

Pour ma part, j'ai constaté avec grand plaisir le nombre impressionnant de 50 étudiants et plus au congrès 2009. On peut en conclure que la Semaine canadienne d'acoustique demeure une occasion unique pour casser la glace et présenter ses tous premiers travaux lors d'un congrès scientifique ou mettre à l'épreuve ses tous derniers résultats de thèse. Avant tout, nombre d'étudiants m'ont indiqué qu'ils ont tout particulièrement apprécié dialoguer avec plusieurs acousticiens des plus connus au pays et découvrir l'éventail d'institutions universitaires et gouvernementales, de cabinets de consultants et de fabricants œuvrant dans le domaine de l'acoustique au pays. C'est l'essence même de la Semaine canadienne d'acoustique que de rassembler tous ces intervenants. Maints remerciements à Ramani Ramakrishnan, président du congrès 2009, et à toute son équipe pour un congrès des plus remarquables.

La Semaine canadienne d'acoustique 2010 se tiendra dans un endroit tout aussi charmant à Victoria en Colombie-Britannique du 13 au 15 octobre prochain. Le congrès sera dirigé par Stan Dosso, président sortant de l'ACA, et de deux directeurs de notre association, Clair Wakefield et Roberto Racca. Le dernier congrès tenu à Victoria en 1999 fut un franc succès et nous pouvons anticiper un congrès scientifique des plus stimulants encore l'an prochain et des activités sociales bien choisies. Veuillez inscrire cet événement dans votre agenda dès maintenant et consulter la présente et futures parutions de l'Acoustique canadienne pour plus de renseignements.

Je tiens à remercier Vijay Parsa (U. Western Ontario) qui vient de terminer son mandat de directeur au sein de l'ACA et j'en profite pour souhaiter la bienvenue à notre nouveau directeur élu, Hugues Nelisse de l'Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST). Un autre de nos directeurs, Sean Pecknold (RDDC Atlantique), assume le rôle de Webmestre depuis le printemps dernier. Nous avons aussi un nouveau Secrétaire exécutif, Brad Gover de l'Institut de recherche en construction du CNRC, remplaçant David Quirt qui a occupé ce poste durant les sept dernières années. C'est avec grands regrets que l'un de nos within the Association. Do not hesitate to contact members of the Executive or Board of Directors if you want to contribute more actively to the CAA, in any capacity.

Christian Giguère
CAA President

acousticiens canadiens les plus distingués et membre émérite de l'ACA, Edgar Shaw, est décédé en octobre dernier. Nous nous souviendrons tous de lui et de son épouse par le biais du Prix postdoctoral Edgar et Millicent Shaw en acoustique.

Enfin, comme toujours, l'ACA a besoin de sang neuf et de bénévoles pour accomplir diverses tâches et projets au sein de l'association. Alors, n'hésitez pas à communiquer avec un membre du comité exécutif ou du conseil d'administration si vous souhaitez contribuer plus activement à l'ACA, quelque soit la tâche.

Christian Giguère
Président de l'ACA

ACOUSTIC IMPACT OF THE GREEN CORRIDOR ACTION GROUP'S URBAN DESIGN USING ACOUSTIC MAPPING

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ABSTRACT

The Green Corridor is a not-for-profit organization which has proposed a green landscape concept along the roadway leading to the Ambassador Bridge, the major international crossing between Canada and the USA. In addition to improving the aesthetics of this mostly concrete and industrialized transportation route, the Green Corridor group had the added goal of wanting to improve the soundscape of the nearby neighbourhoods with innovated landscape designs. The high levels of traffic noise within the area are the result from this roadway being one of the busiest land trade corridors in the world. This study analyzed the changes proposed by the Green Corridor action group from an acoustic engineering perspective. The study first measured and modeled existing environmental noise conditions which included the implementation of a reverse engineering exercise to ensure an accurate acoustic map. This was followed by a second model to predict the expected noise levels with the implementation of the Green Corridor design proposals. As a result, this study was able to identify some areas where the proposed Green Corridor changes, if implemented, would be effective in reducing the local environmental noise levels. Other areas were identified where the proposed designs would have no positive acoustic benefit and would require additional abatement if the affected residential area were to meet provincial noise guidelines. A discussion of the benefits of good acoustic design, as well as improved noise legislation is also included. Finally, this study explored the possible physical and psychological health effects to residents living in those areas exposed to severe noise levels.

RESUME

"Green Corridor" est une association à but non lucratif qui propose un concept d'espace vert le long de la route qui mène au pond Ambassador, le principal pond international rejoignant le Canada et les Etats-Unis. En plus de vouloir améliorer l'esthétisme de cette route industrielle principalement faite de béton, le groupe « green corridor » souhaite améliorer le paysage sonore du voisinage avec leurs innovants aménagements paysagés. Le haut niveau sonore du trafic routier du quartier vient du fait que cette route est l'un des plus importants couloirs terrestres du commerce dans le monde. Cette étude analyse d'un point de vue acoustique les changements proposés par les actions du groupe « green corridor ». Dans un premier temps l'étude quantifie et modélise les conditions sonores existantes, incluant la mise en œuvre d'un exercice de retro-ingénierie pour assurer une carte acoustique précise. Dans un second temps l'étude est une prédiction des niveaux sonores suite à la mise place du projet de Green Corridor. L'analyse des résultats montrent qu'à certains endroits, le projet de Green Corridor serait efficace pour réduire le niveau sonore mais qu'à d'autres l'impact serait inexistant. Il faudrait alors mettre en œuvre d'autres mesures pour pouvoir arriver à atteindre les objectifs fixés par la province. Une discussion est jointe sur les bénéfices d'une bonne conception acoustique et sur l'amélioration de la législation. Pour finir, l'étude parle des possibles effets sur la santé physique et mentale des résidents des quartiers exposés à de hauts niveaux sonores.

1. INTRODUCTION

The issue of urban design is a complex one given that the tranquility and appeal of an area is determined by a subjective audience and that many factors come into play in whether or not an urban design will succeed. It has been shown that the quality of an urban area is a function of noise levels and visible natural features [1]. This study explored a proposed urban design for improvement from an acoustic perspective. While the overall success of a project is determined by many and sometimes very complex factors, noise is one that can be predicted and explored.

The work presented here was undertaken as an undergraduate studnet engineering design project given the name, "Windsor Environmental Noise Mapping Initiative (WENMI)". The group's goal was to create an environmental noise map of the present conditions of an area one kilometre in width and five kilometres in length.

This area is centered on Huron Church Road which is a major roadway accessing the Ambassador Bridge crossing between Windsor Canada, and Detroit, USA. Included in the study area are; the EC Row expressway, a railway line as well as well defined residential, commercial, and industrial areas.

The results obtained by the WENMI project were used to evaluate and compare the present acoustical conditions of the study area to a predicted model which includes the proposed environmental concept design developed by the Green Corridor Group (GC). The GC is a not-for-profit organization which has a focus on an environmentally favourable redevelopment of the area considered to be the gateway to Canada. This area is also the northern portion of the WENMI study area. Additional mandates of the GC group are aesthetics, artistic interpretation and education, and awareness of environmental issues. Their design concepts include the construction of berms and addition of vegetation with the purpose to improve air quality, mitigate noise and increase the beautification of the area. An additional goal of the concepts was also to specifically engage the public in considering the quality of the environment around them.

Further, the Green Corridors's design was not made with engineering acoustic principles in mind. As such, a fundamental goal of the WENMI study was to emphasize the importance of an engineering approach to noise abatement in consideration of an urban design. In doing so, it was also thought these outcomes would provide valuable information to the GC group and allow them to improve on the present artistic focused design.

2. DEVELOPMENT OF THE MODEL

Two acoustic propagation models were developed for the study; the first representing the present acoustic conditions and a second to predict the impact that the GC urban design would have on the area. Both were created using a commercial environmental noise calculation and mapping software package by Brüel & Kjær called Lima 7812. This software is primarily used throughout the European Union (EU) and was developed to fulfill the EU's directives and guidelines applicable to environmental noise computation. While the software is capable of predicting noise traffic noise using many standards, the traffic noise levels for this study were calculated using the British ministry of transport standard, *"Calculation of Road Traffic Noise"* (CRTN). This standard was selected since it meets all requirements of the EU Environmental Noise Directive and is somewhat similar to the Ontario Ministry of Environment calculation standard, *"Ontario Road Noise Analysis Method for Environment and Transportation"* (ORNAMENT). The Dutch RMR/SRM II and the ISO9613-2 standards were used for the rail and industrial noise calculations respectively. These standards are the generally representative approaches used in the EU for railway and industrial environmental noise modeling.

2.1 Noise Model of Present Conditions

The noise model representing the current conditions was created by first importing Geographic Information Systems (GIS) data into the noise mapping software. This data included most topographical details including roadways, however, the quality of the building footprint details was found to be out of date and lacking in sufficient detail. As such, a more laborious task was used to input each building into the model manually. To do this, a satellite image was first imported and calibrated to correlate to the size and orientation of the GIS roadway data. Major building heights were determined using field surveying techniques for each individual structure. For the many residential dwellings within the area, the heights were all assumed to have heights of 4.5 meters. From this, each building footprint was then digitized manually into the model.

Upon completion of the model topography and geographical details, the noise emission levels of the roadways were calculated using average annual daily traffic (AADT) count data provided by the City of Windsor. Such a prediction is only as good as the quality of traffic data inputted into the model. Given that the traffic data used was averaged over a 24 hour period, assumptions were required for the day and night time splits. To correct for this, actual noise measurements were made along the study area and used to calibrate, or reverse engineer the model, using the field measurement data. For this, 24 hour measurements of 20 minute equivalent noise levels (Leq) measurements were conducted at several representative locations. The locations, shown in Figure 1, were selected based on their proximity to the more significant noise sources which also have the most impact on the sensitive receptor areas. Once complete, the noise data was inputted into the software which has a reverse engineering algorithm used to calibrate the theoretical prediction. This process was iterated several times in order to improve the agreement between the CRTN results and the actual noise data. However, once complete, very little of the original noise model was altered in the final noise map, thus confirming the accuracy of the initial CRTN based model

Figure 1: Field Measurement Locations used for Reverse Engineering Calibration of the Noise Mapping Model

2.2 Noise Model of Green Corridor Concept

An acoustic map representing the Green Corridor urban concept was based initially on the model created for the current conditions but with modifications representing the specific details for the GC vision. These details included the creation of earthen berms along the Huron Church Road as well as the removal of some residential homes in order to create a buffer zone between the remaining houses and the transportation route. Other features included low density plantings of deciduous trees and the addition of low profile landscaped hills and swales. All of which were included in the updated noise prediction model. Some of these features are shown in Figure 2.

Figure 2: Artist's Concept showing many of the Proposed Green Corridor Features

3. PRESENTATION OF NOISE MAPS

A detailed look at the predicted impact of the proposed Green Corridor plan is discussed through presentation of the resulting acoustic maps. The noise contour maps provide an excellent visual representation of the noise impact that each of the respective scenarios would create on the study area. Presented first is an overview of the entire study area followed by a more detailed look at specific geographic sections which incorporate the most significant proposed changes by the Green Corridor plan.

3.1 Overall Model

Shown in Figures 3 and 4 are the noise contour models for the daytime conditions without and with the details of the GC plan respectively. It is shown that for the day time predictions, the noise levels in the near vicinity of the major roadways is reduce by at least 5 dB as a result of the earthen berms along the west side of Huron Church Road leading to the Ambassador Bridge. Given that these figures show the "big picture" of the predicted comparisons, a more detailed analysis which focuses on specific target areas on abatement concepts will be discussed further in this section.

The downside associated with visual noise mapping is that while informative, analysis of results is also somewhat subjective. For a more objective approach, a statistical analysis comparing the overall geographical area affected, for deviations of 5 dB, of the two scenarios without and with the GC plan is given in Tables 1 and 2. From these, it is evident that the implementation of the GC concept does improve the noise levels within the study area. For both the day and night time, implementation of the GC concept results in the most significant decrease in percent area affected by high noise levels within the 60 to 65dBA range. At the same time, the sound level range where the GC plan has a positive increase in percent affected area is in the more desirable 45 to 50dBA range. This statistically reinforces the fact that the proposed GC improvements caused the greatest area increase with lower sound levels at the bottom end of the noise level spectrum.

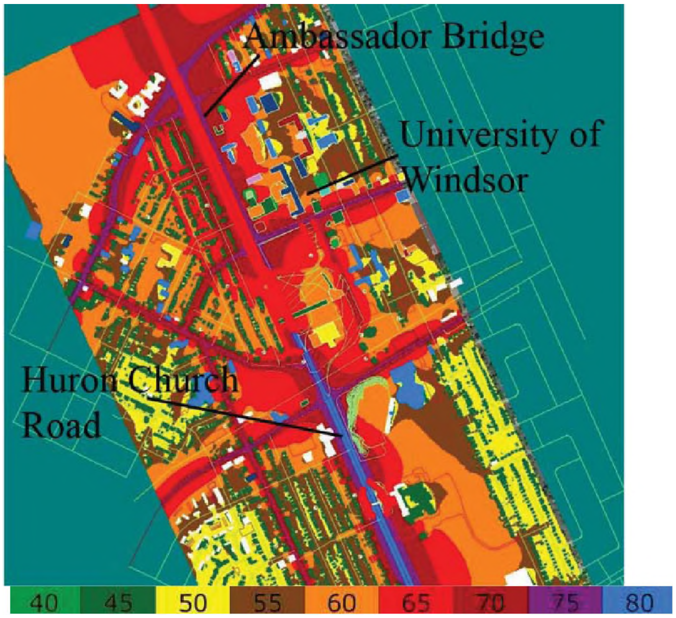

Figure 3: Noise Contour Map of the Study Area showing Present Daytime Noise (dBA) Conditions

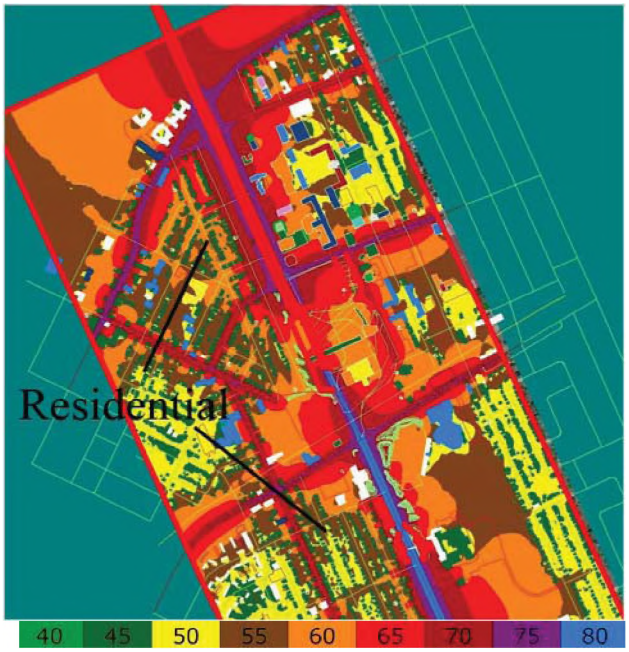

Figure 4: Noise Contour Map of the study area showing Predicted Green Corridor Daytime Noise (dBA) Conditions

Table 1 Daytime Percent Area Affected by Propsed Green Corridor Changes

dBA Range	Current Percent Area	GC Percent Area	Percent Area Change
40.1-45	2.01	2.71	0.7
45.1-50	13.95	14.37	0.42
50.1-55	22.75	22.73	-0.02
55.1-60	20.36	19.99	-0.37
60.1-65	14.66	14.2	-0.46
65.1-70	13.84	13.72	-0.12
70.1-75	8.53	8.43	-0.1
75.1-80	2.48	2.47	-0.01
80.1-85	1.31	1.25	-0.06

Table 2 Night time Percent Area Affected by Propsed Green Corridor Changes

dBA Range	Current Percent Area	GC Percent Area	Percent Area Change
40.1-45	1.26	1.35	0.09
45.1-50	14.65	15.57	0.92
50.1-55	28.21	28.03	-0.18
55.1-60	21.06	21.08	-0.02
60.1-65	15.47	14.99	-0.48
65.1-70	11.71	11.62	-0.09
70.1-75	4.8	4.65	-0.15
75.1-80	2.48	2.36	-0.12
80.1-85	0.28	0.25	-0.03

3.2 South East Sector (Area 1)

The south section of the study area on the east side of Huron Church Road is non residential but still of importance due to its usage. This area is the location of both a large high school and the University of Windsor's Human Kinetics and sports facilities. For this area, the green corridor plan is to make significant changes to the existing berms by breaking them up into several interlocking rolling hills with natural tall grasses as opposed to a single berm. A new berm is also proposed along the north end of the high school. The idea is to provide a more pleasing and natural looking landscape as opposed to a manicured grass covered noise earth berm.

For the noise map representing the current conditions, shown in Figure 5, much of the stadium playing field shows a noise level ranging between 55-65dBA for the daytime period. Similarly, the high school just south of the stadium has noise levels within the range of 55-70dBA during day. For the night time (not presented), the noise levels were similar to the day time levels, due mostly to the high night time truck traffic volumes which can be as high as 1000 heavy trucks per hour.

Figure 6 illustrates a realized drop in sound levels for this region with implementation of the modifications around the stadium and added barriers near the high school as specified by the Green Corridor action plan. These changes show a drop in both daytime and night time levels on the sports field from 55-65 dBA to the 55-60dBA range. Given that the new berms are not along the entire length between Huron Church Road and the high school, the realized noise attenuation here is less with a 5dBA drop on the north side of the school while the rest of the building remains unchanged.

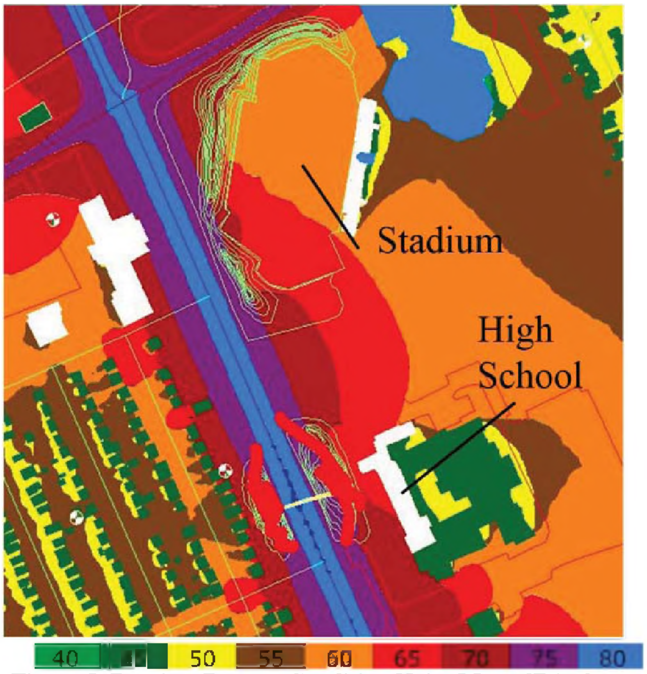

Figure 5: Daytime Present Condition Noise Map (dBA) for South East Sector around U of W Stadium and High School

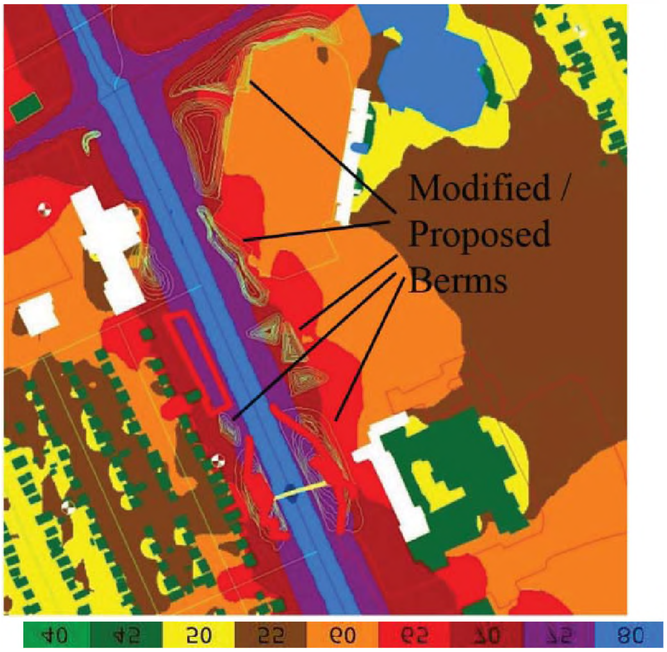

Figure 6: Daytime Green Corridor Noise Map (dBA) for South East Sector around U of W Stadium and High School

3.3 North West Sector (Area 2)

For the north west sector of the study area, a dense concentration of residential houses are located on the west side of the Ambassador Bridge and the roadway leading up to the bridge and Canadian Customs inspection booths. Immediately to the east side of the bridge are student residential housing buildings which are part of the University of Windsor campus. Along this area, the Ambassador Bridge is essentially an elevated roadway approximately five stories tall over top of the residential backyards and approximately 45 meters from the student housing building windows. The bridge has an average daily traffic count of 32,000 vehicles but can see peak volumes as high as 52,000 vehicles per day. This traffic accounts for 40% of the daily trade between the U.S.A and Canada for which a very large percentage is comprised of heavy trucks [5]. To make matters worse, depending on the direction of travel these trucks are either accelerating up or braking down the steep slope of the suspended bridge. Both of these actions produce excessive noise, particularly when the trucks use their engine brakes as they approach the Customs booths.

The Green Corridor action plan proposes the removal of the houses along the west side of the bridge and thus creating a buffer zone to separate the remaining residential dwellings west of the bridge. This proposed buffer zone is comprised of one row of residential lots approximately 30 meters deep which runs the length of the land based portion of the bridge. Within this buffer zone the Green Corridor group proposes to beautify the area by establishing trees, berms, and settling ponds in an attempt to improve the aesthetics and area quality of life. The resulting noise prediction maps for the present and proposed GC plan are illustrated in Figures 6 and 7 respectively for the day time conditions.

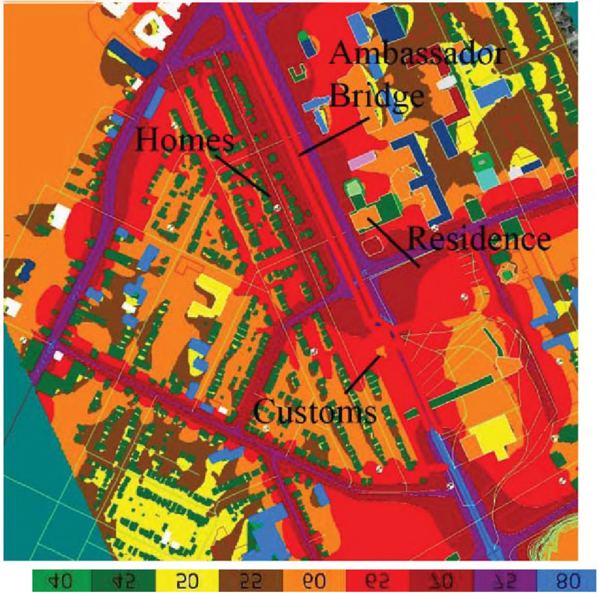

Figure 7: Daytime Present Condition Noise Map (dBA) for North West Sector along the Ambassador Bridge

While aesthetically appealing, inspection of Figures 7 and 8 demonstrates that the green Corridor concept plan does not result in an improvement from an acoustical perspective. According to the guidelines of the plan, the trees are not planted with sufficient density to yield significant attenuation and the settling ponds do not contribute at all to the areas acoustics. The recommended berms also have no appreciable effect given that they are far below the height of the deck of the bridge resulting in an unchanged path length difference between the residential homes and the noise source.

3.4 South West Sector (Area 3)

For this sector, the main receptors include the University of Windsor's Lebel Arts Building as well as a number of residential homes. The residential receptors are orientated with the backyard areas facing Huron Church Road. These homes were built long before the establishment of the present day Ontario Ministry of the Environment (MOE) guidelines for traffic noise were in place. This was also a time when Huron Church Road was only four lanes wide with much fewer vehicles than the divided eight lane roadway it is now. At some locations the houses are approximately 15 meters from the edge of this busy transportation route with no noise abatement.

Inspection of the noise contour map of the present daytime noise conditions given in Figure 9 shows that the noise levels in outdoor living areas of these receptors are in the 65-70 dBA range. This is far in excess of the MOE guidelines for a new residential development. Similarly, it is shown that the University of Windsor's Lebel building is exposed to noise levels within the range of 65-75 dBA during the daytime.

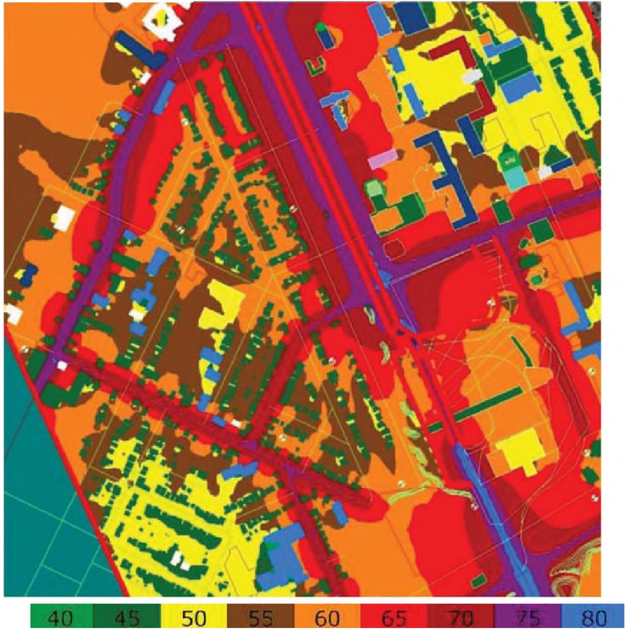

Figure 8: Daytime Green Corridor Noise Map (dBA) for North West Sector along the Ambassador Bridge

The predicted noise results of the Green Corridor concept are given in Figure 10. For here, the GC plan is to abate the traffic noise with low density vegetative plantings between the residential houses and Huron Church Road along with limited placement of berms. While the plantings have resulted in no improvement for the outdoor living areas of the nearest houses, the berms have resulted in minimal effect on the penetration of noise further into the neighbourhood with a 1 to 2 dB decrease in some very small areas resulting in contours dropping to the next lower range. For the Lebel Building, the GC plan is to erect a glass display wall along the length of the building. The predicted result is good protection on the east side of the building creating an area in the 50-60 dBA range along most of this facility which adequately protects it from the effects of the Huron Church traffic noise.

4. DISCUSSION

Ontario's Ministry of the Environment's (MOE) guidelines for acceptable noise levels for a new development are 55dBA during the daytime and 50 dBA during the night. If these noise guidelines are exceeded, then mitigation is required. This may include a warning clause within a purchase agreement of the home, the installation of air conditioning and upgraded windows or the design and installation of a noise barrier, depending on the degree of exceedance. The only circumstance in which a home may be built having outdoor sound levels over 60dBA with no mitigation is if abatement solutions are not feasible or in conflict with local bylaws. In such a case the house must be sold with a more stringent warning clause.

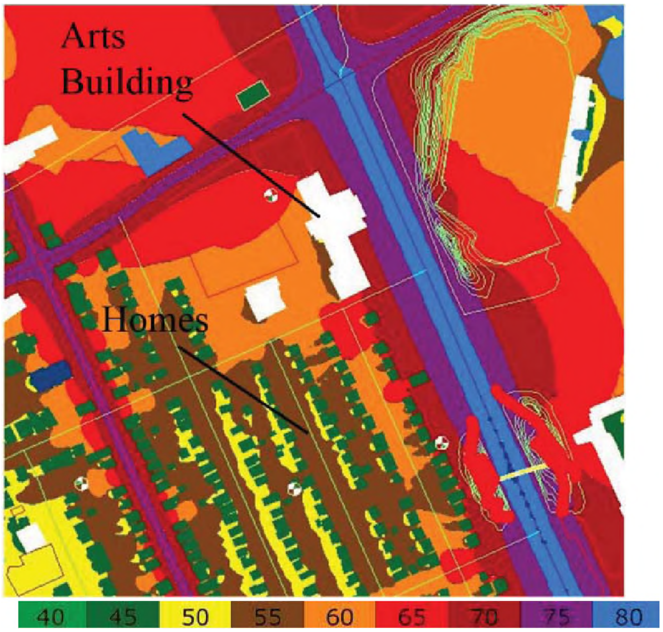

Figure 9: Daytime Present Condition Noise Map (dBA) for South West Sector along Huron Church Road

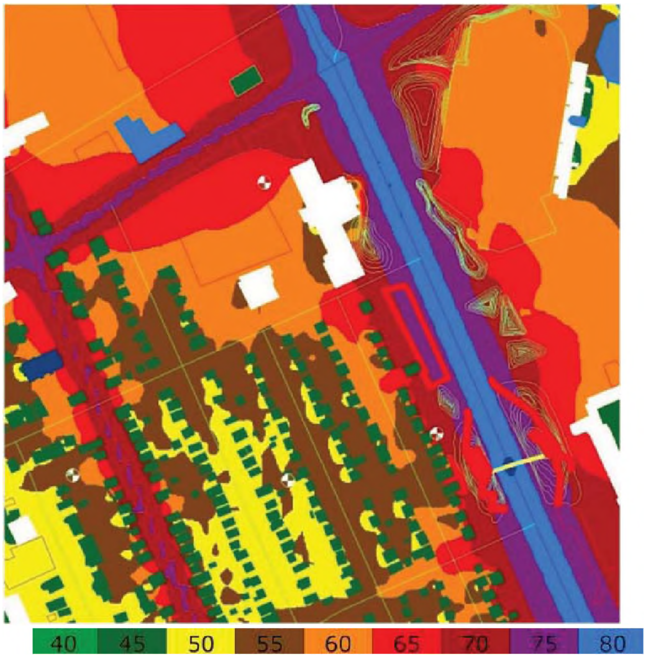

Figure 10: Daytime Green Corridor Noise Map (dBA) for South West Sector along the Huron church Road

From the presentation of the noise contours for the present day conditions, it has been illustrated that many of the homes nearest to Huron Church Road and the Ambassador Bridge are exposed to noise level which far exceed the MOE guidelines. Unfortunately, despite the best intentions of the Green Corridor Urban Action plan the same is true of the predicted noise levels if the plan were to come to fruition. However, the current MOE guidelines for retrofit of noise mitigation for existing residential areas have a number of exclusions, and as such, the residences within this study area are excluded from these guidelines [6]. The following sections are a more in depth look at how the proposed Green Corridor ideas failed to meet their noise attenuation goals as well as suggestions for improvement where possible.

4.1 Buffer Zone Next to Bridge

The proposed buffer zone along the west side of the bridge has resulted in very little effect for noise abatement except at the most southerly and lowest section of the bridge. At this location, any traffic noise propagation from the bridge is low enough in elevation such that the proposed berms will have some positive effect. Another aspect of the creation of the buffer zone is the removal of an arterial road which will result in a reduction of localized traffic noise.

Despite the above positive effects of the proposed buffer zone at the south end of the bridge, the same cannot be said along the remaining and majority of the bridge length. Here, the proposed installation of the berms, low density coniferous trees and the green space created through the removal of derelict residential buildings has little effect on the predicted noise levels. Given that the bridge is an elevated noise source, traffic noise will carry over the buffer zone and above the barrier berms resulting in no positive abatement. However, the removal of houses immediately adjacent to the bridge does remove residents out of the region of highest noise levels within the entire study area. It is also purported that the additional green space will have the effect of improved air and water quality.

Unfortunately, very little can be done to improve the environmental noise levels in this part of the study area. Given the technical and economical difficulties associated with abating a 90 year old suspension bridge with a highly elevated noise source, very little could be done to improve the GC's model.

4.2 Role of Trees in the Green Corridor Model

The stated intention of the Green Corridor's concept to use tree plantings extensively is to improve the aesthetics of the area, to improve the air quality and to abate noise emissions from the nearby Huron church Road and Ambassador Bridge. However, the proposed plantings are mostly low density deciduous trees which offer almost no noise attenuation characteristics. It is normally expected that 30 meters of dense bush will provide approximately 5 dB of noise attenuation. The available green space between source and receiver within the corridor area is 10 meters at the widest. Assuming a linear relationship between attenuation and thickness of planting, the GC's trees could provide no more than 1-1.5 dB attenuation. This may be counteracted by the effect that screening of a noise source often has on the perception of the noise. The work of G. Watts et al. [4] postulates a statistical relationship between the perceived noise level, the actual noise level and the amount of screening of the noise source. The relationship showed that the sensitivity to a noise increased with an increase in the screening of the source, meaning that for the same measured noise level, an observer perceived a higher level when the source was blocked from view. This suggests that the addition of vegetation in the fashion proposed by the GC plan may result in a rise in the perceived noise levels at the residents' homes. On the other hand, some suggest that the addition of trees as a natural feature will generally improve the subjective perception of an urban area.

While most standards completely disregard the attenuation of noise by vegetation belts of insignificant densities, proper plant selection can provide some attenuation. If vegetation is to be included for simple aesthetics, some advantage could be gained by designing the plantings in a dual role. Studies have shown that properly planted, a 6-10 meter wide strip can provide between 2 and 3 dB of attenuation [2, 3]. The most ideal design being a row of high density evergreen shrub plants followed immediately by a row of evergreen trees. This design maximizes density close to the ground while still providing height. If planted with the proper spacing to allow the plants to reach full maturity and density it has been suggested that it is possible to realize attenuations as high as 6 dB [2]. This small change to the GC concept would provide some residents in the immediate area an effective privacy screen and aesthetic improvement combined with a modest acoustic improvement.

4.3 Noise Attenuation Berms

The implementation of earthen berms to block roadway noise is a viable and cost effective solution in order to attenuate noise. Within the Green Corridor plan, berms are proposed along the west side of Huron Church Road from the Ambassador Bridge entrance to the southerly extent of the study area about 1.5 km away. Berm are also proposed within the suggested buffer zone adjacent to the Ambassador Bridge. The placement and heights of the berms were designed with aesthetics in mind and without considering acoustic engineering principles. Because of this the full degree of their effectiveness is unknown. This investigation offered the opportunity to analyze the current berm proposal and determine how effective the berms are in reducing the present noise levels.

The exact slope of the proposed barriers was not specified in the GC plan but a ratio of no more than 3:1 would be the most practical approach. It has been demonstrated that a slope of 1.5:1 or 2:1 can provide an additional 0.5 to 1 dB attenuation [7]. This is though often impractical as a steeper slope is more difficult to maintain and has the potential for soil erosion. To be effective, the berm height must be sufficient to break line between the road and receptor with each additional meter of height providing an additional noise reduction of 1.5 dB [7]. Unfortunately there are sections along Huron Church Road where there is not enough distance between the road and residence to install a berm. Also much of the proposed berm is located on the east side of the road which will protect the university stadium and high school whereas it may have been more appropriate had the model included berms on the other side of Huron church Road so as to protect the housing development. This would most likely provide a measurable improvement in the quality of life for those residing in the houses along this busy roadway.

The Green Corridor's implementation of berms within its plan do provide minimal noise attenuation, but with additional acoustic practices a more refined model could be achieved while maintaining the artistic integrity of the concept. With these concerns addressed an attractive and highly functional design can be coalesced.

4.4 Possible Concerns and Health Effects

The study area chosen was considered important to the community given the number of residential homes and major learning institutions located within the area. As part of this, it is important to consider the impact that noise has on the lives of those living and working in the study area. The EU adopted the Directive on Environmental Noise in 2002 (2002/49/EC) which in part requires that strategic noise contour maps be produced to identify regions which have ambient levels above 55 dBA so as to minimize annoyance and loss to quality of life. Such an exercise is very similar to the efforts and motivation taken in this study. While this investigation of the propose Green Corridor concept did not demonstrate a realized attenuation to levels below 55 dBA, it did show the merit of noise mapping in order to gain a better understanding of how communities are affected by major transportation routes such as Huron Church Road and the Ambassador Bridge.

One of the difficult components of studying noise related health effects is quantifying the resulting perception. The World Health Organization (WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” [8]. Unfortunately, most people associate the research of noise exposure with the physical effects of hearing loss without consideration of the other real non-auditory physiological effects which can include a possible increase in cardiovascular disease from elevated blood pressure [9]. “There is some evidence that suggests an increased risk of hypertension and ischaemic heart disease for people living in areas with road or air traffic noise at outdoor equivalent sound levels above 70 dB(A) based on exposure between 6:00 a.m. and 10:00 p.m.” [10]. With respect to this study, the reality is that there are areas of residences in near proximity to Huron Church Road where the noise does reach levels in excess of 70 dBA.

Perhaps the most common health affect which can result from excessive community noise is that of annoyance. A study which looked at noise annoyance in Canada revealed that nearly 8% of Canadians surveyed were either very or extremely bothered, disturbed or annoyed by noise in general for which traffic noise was identified as being the most annoying source [11]. Given the health concerns identified above this is a large percentage of the Canadian population, including a potentially much larger percentage within the study area considered here, which have not only self identified mental effects from community noise exposure but may also eventually suffer from other physiological diseases.

Another type of annoyance considered harmful to a persons well being is sleep disturbance. Sleep is essential to good health and noise has been reported to lessen both the quality and duration of sleep, and thus, quality of life [10]. The World Health Organisation suggests that for good sleeping conditions noise levels should not exceed 30 dBA in the sleeping area or 45 dBA for a single event [12]. As developed countries continue to grow in population, they are becoming more congested and noise levels are continuing to increase, leading to increased sleep disturbance. In a study of how traffic noise can effect sleep of young adults it was found that, “sleep disturbances are clearly related to noise levels, to the number of stimuli, to frequency spectra etc and people are less disturbed by continuous than by intermittent noises” [13]. As a result of these findings it is clear that the health of individuals exposed to excessive environmental noise is significantly reduced in all senses of the definition. This study demonstrated that the majority of the population within the study area are exposed to night-time levels well above this, with and without the proposed GC concepts.

5. CONCLUSIONS

The goal of this study was to measure, model and compare the current noise conditions along the Huron Church Road and the Ambassador Bridge to the predicted soundscape given the theoretical implementation of the Green Corridor’s concept of a better and healthier urban model. While it is not possible to predict the subjective visual effects of the design, this study has used the prediction of acoustic performance metrics to evaluate the outcome of this urban design.

While noise levels were shown to be reduced by the Green Corridor concept at some areas, it was not enough to bring the noise below the target 55 dBA at most receptors. However, it was also shown that the models could be improved with a number of simple changes. Better implementation of vegetative plantings and berm placements would reduce noise levels further along with the aesthetic effect of more greenery in the city. This study’s presentation of the possible negative health effects of excessive noise to the general public living in this area suggests that implementation of these suggestions would help to improve the quality of life for those living, working, and going to school within the study area.

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PREDICTION OF FLOW-INDUCED NOISE IN TRANSPORT VEHICLES: DEVELOPMENT AND VALIDATION OF A COUPLED STRUCTURAL-ACOUSTIC ANALYTICAL FRAMEWORK

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ABSTRACT

In this study, a complete analytical model framework able to accurately predict the flow-induced noise in the interior of a transport vehicle cabin is presented. The mathematical model framework presented represents a coupled structural-acoustic system, consisted by a plate subjected to a random excitation or to flow-induced noise, and an acoustic enclosure representing the transport vehicle cabin. The coupled analytical model is developed using the contribution of both structural and acoustic natural modes. It is shown that the analytical framework can be used for the prediction of flow-induced noise for different types of transport vehicles, by changing some of the parameters, as shown by the good agreement between the analytical results and several experimental studies. The results indicate that the analytical model is sensitive to the measurement location, with the change in position significantly affecting the predicted interior noise levels, as should be expected. Different sizes for the acoustic enclosure, as well as different types of panels were investigated. This study demonstrates the importance of including the acoustic receiving room (i.e., the vehicle cabin) contribution in the analytical formulation, in order to accurately predict the noise transmission and interior noise levels.

RESUME

Dans cette étude, un modèle analytique complet, capable de prédire avec précision le bruit à l'intérieur d'une cabine d'un véhicule de transport induite par l'écoulement externe, est présenté. Le modèle mathématique représente un système structurel-acoustique accouplé, qui consiste en une plaque avec une excitation aléatoire ou à l'excitation du écoulement turbulent, et une chambre acoustique qui représente la cabine du véhicule de transport. Le modèle analytique accouplé a été développé en considérant la contribution combinée des modes naturels de ces deux systèmes, structurel et acoustique. Il est démontré que le modèle analytique peut être utilisé pour prédire le bruit induit par l'écoulement externe dans différents types de véhicules de transport, en variant certains paramètres, tel que vérifié par la bonne concordance entre les resultants analytiques et les résultats des multiples études expérimentales. Les résultats indiquent que le modèle analytique est sensible à la variation du point de mesure, et que le changement de la position de mesure affecte significativement les niveaux de bruit intérieur prédit, comme cela était prévu. Différentes dimensions de chambres acoustiques, ainsi que différents types de panneaux ont été étudiés. Cette étude démontre l'importance d'inclure la contribution de la salle acoustique de reception (i.e., l'habitacle du véhicule) dans la formulation analytique, afin de prédire avec précision la transmission du bruit et les niveaux de bruit à l'intérieur.

INTRODUCTION

The interior noise and vibration in the cabin of an aircraft is mostly generated by the external flow excitation and engine noise. In opposition of what happens during takeoff, where the engine noise is the dominant cabin noise source, during cruise flight the airflow sources are the major contribution for the interior noise. Early measurements performed in jet transport aircraft by [1], have shown how the relative importance of engine and flow noise changes drastically during the course of a flight. This study concluded that, during takeoff and initial climb, the engine was the main source of cabin noise. However, during the climb to cruise flight altitude, the turbulent boundary layer (TBL) noise gradually increases and the engine noise decreases. Finally, when the cruise flight is reached, the TBL becomes the dominant source of interior noise, resulting from the increase of flight speed, and there is a reduction of engine noise, as the engine thrust is reduced to cruise setting. Furthermore, as referred in [2], turbulent boundary layer excitation is regarded as the most important noise source for jet powered aircraft at cruise speed, particularly, as new quieter jet engines are being developed. Similarly, automotive industry is progressively more concerned with passengers comfort. Since major advances have been made to the reduction of sound transmitted to the interior from the engine, transmission, and tires, the reduction of flow-induced noise is becoming more important. Additionally, as concluded by several studies for subsonic flight, e.g. [3-5], turbulent boundary layer pressure levels on the exterior of the fuselage increases with the flight Mach number.

Nowadays, reduced cabin interior noise is an important factor when considering the design of aircraft and transport vehicles in general, and it will even become a more important issue in the future transport vehicles. Reduced levels of interior cabin noise are desirable for both comfort and health-related reasons, and they are balanced with the cost, complexity, and physical constraints of noise control systems. Passive noise control (PNC) techniques are not effective in the low-frequency noise (LFN) range, where the active noise control techniques (ANC and ASAC) have demonstrated better results, showing the ability to decrease sound levels without a big penalty in terms of weight, compared with the PNC solutions [6-9]. However, the successful implementation of noise control techniques is a challenging problem, and is far from being a straightforward task. The complexity of the physics of the structural-acoustic coupled system itself, consisting of the fuselage structure together with the cabin interior, is already a major difficulty for solving the problem. To efficiently design a noise control system, a clear understanding of the mechanisms of sound radiation and transmission of the coupled structural-acoustic system is crucial. Furthermore, when considering the TBL excitation, the noise reduction problem turns into even more complicated, since the turbulent boundary layer induced pressure has a random and broadband nature.

Early experimental tests have been conducted as an effort to characterize the radiation of sound from single panels excited by turbulent boundary layers [4, 10-15]. The results illustrate that the TBL is a major source of exterior pressure fluctuations and provide knowledge about the shape of the spectrum, convection velocity and space-time correlation of the turbulent boundary layer pressure fluctuations on aircraft panels, as well as displacement and acceleration spectra of the vibrating aircraft panels. In addition, theoretical studies have been performed for the vibration and sound radiated by isolated panels (i.e., not coupled with an acoustic enclosure) excited by turbulent flows [16-20], and for random vibration of a plate coupled with acoustic enclosures [2, 21, 22]. In these studies, when the TBL excitation is object of study, it is usually described in terms of the statistical properties of the wall pressure fluctuations based on the Corcos formulation [23, 24]. A number of new models were developed after Corcos model for the TBL statistical description [25-29]. The main limitation of the Corcos formulation is the assumption that spanwise and streamwise correlations lengths do not depend on the boundary layer thickness parameter, unlike other methods. Despite not being the most accurate, the Corcos model is widely used to describe the induced TBL pressure field, since it captures the fundamental pressure tendency along the frequency and requires significantly reduced computational effort to employ. In the other hand, the Corcos-like formulation provides a good estimation for the TBL wall-pressure fluctuations levels at and near the convective peak, which is of fundamental importance for aircraft boundary layers (for high subsonic Mach numbers) [30]. Finally, with the Corcos model it is possible to obtain analytical expressions for the response of simply supported panel, which is fundamental in the present study. For all these reasons, the Corcos formulation is still being used in recent studies to describe the TBL wall-pressure fluctuations, e.g., [2, 30-36].

As a physical problem, the TBL-induced noise into a cabin can be simply explained as follows: (1) the turbulent boundary layer pressure fluctuations induce vibrations on the cabin structure, and (2) the vibrating structure radiates noise into the cabin. Mathematically, this physical problem can be simulated by the interaction of three different models: (1) an aerodynamic model, representing the TBL pressure fluctuations on the cabin structure; (2) a structural model, which characterize the vibration of the cabin structure; and (3) an acoustic model that represents the cabin interior sound pressure level.

The mains goal of the current investigation is the development of an accurate analytical framework for the prediction TBL-induced noise into transport vehicles cabins, and its validation. The knowledge of the characteristics of the turbulent boundary layer excitation, its induced vibration on the structure, and the noise radiated into the cabin space is essential for the accurate prediction of the interior noise levels. The effect of the receiving room space, i.e. the cabin space, is an important factor for the accurate interior noise prediction, as shown by the results shown in this study.

For the validation of the analytical framework, four studies were considered for comparison, more specifically the investigations by [2, 8, 22, 37]. The acoustic enclosure is of rectangular shape, filled with air, with five rigid walls and one wall completely or partially flexible. The flexible part of the enclosure wall is backed by the turbulent boundary layer or by normally impinging random noise. The analytical expressions obtained in this study, shown in the Appendices section, are able to predict overall values of interior SPL, overall values of plate vibration levels, as well as the SPL at a chosen point in the interior of the enclosure, and the level of structural vibration at a given point of the structure. The spectral quantities were obtained for frequencies up to 1000 Hz. The analytical framework here validated can be used to predict cabin noise for more complex cases, as the case shown [38].

The present article is organized as follows. First, the concepts and models used in the study are formally described. Section 2 presents the turbulent boundary layer wall pressure fluctuations model, Section 3 the structural model, Section 4 the acoustic model, and Section 5 the coupled structural-acoustic model. The method of solution for the prediction the spectral quantities is discussed in Section 6. Section 7 provides a discussion of the results obtained using the developed analytical framework, and their validation with the results from the literature. Finally, a summary of the results and concluding remarks are presented.

2. TURBULENT BOUNDARY LAYER WALL PRESSURE FIELD MODEL

The prediction of the vibration and sound of a flow-excited structure is dependent on a good description of the wall pressure field. Since numerical predictions are limited to low Reynolds number simple flow, one has to rely on semi-empirical models fitted to experimental data. Modeling the turbulent boundary layer wall pressure has been a subject of study for many years. As previously referred in this report, a large number of empirical models have been developed to describe the wall pressure fluctuations on a flat plate wall due to the TBL. The turbulent boundary layer wall pressure, p(x, y, t), is usually statistically described in terms of the pressure power spectral density, $S(s_1, s_2, \omega)$, where s_1 is the current position along the plate, and s_2 the separation vector between two measurement points.

In general, for a fully developed TBL, and for zero mean pressure gradient, the turbulent flow can be regarded as stationary and homogeneous in space, so that the s_1 dependence disappears in the $S(s_1, s_2, \omega)$ function. This way, for turbulent flow in the x-direction, the cross power spectral density (PSD) of the wall pressure over the (x, y) plane, can be defined as

$$S(\xi_x,\xi_y,\omega) = \langle\, p^*(x, y, \omega), p(x - \xi_x, y - \xi_y, \omega)\,\rangle\,, \tag{1}$$

in which $\xi_x = x - x'$ and $\xi_y = y - y'$ are the spatial separations in the streamwise and spanwise directions of the plate, respectively. Also, the cross PSD of a stationary random process can be expressed as the product of a reference PSD function, $S_{ref}(\omega)$, and a spatial correlation function, $\bar{S}(\xi_x,\xi_y,\omega)$, as

$$S(\xi_x,\xi_y,\omega) = S_{ref}(\omega)\, \bar{S}(\xi_x,\xi_y,\omega)\,. \tag{2}$$

Corcos [23, 24], proposed a model which considers the cross power spectral density of the stationary and homogeneous TBL wall pressure field in a separate form in the streamwise, x-, and spanwise, y-direction, as

$$S(\xi_x,\xi_y,\omega) = S_{ref}(\omega)\, f_1\!\left(\frac{\omega\,\xi_x}{U_c}\right) f_2\!\left(\frac{\omega\,\xi_y}{U_c}\right) e^{\frac{-i\,\omega\,\xi_x}{U_c}}\,, \tag{3}$$

where U_c is the TBL convective speed. Corcos found that measurements of particular forms of the cross PSD $S(\xi_x,0,\omega)$ and $S(0,\xi_y,\omega)$ could be well represented as functions of the variables $(\omega\xi_x/U_c)$ and $(\omega\xi_y/U_c)$, respectively. In practice, the functions $f_1(\omega\xi_x/U_c)$ and $f_2(\omega\xi_y/U_c)$ are frequently approximated by exponential decay functions, i.e.

$$S(\xi_x,\xi_y,\omega) = S_{ref}(\omega)\, e^{-\frac{\alpha_x\,\omega\,|\xi_x|}{U_c}}\, e^{-\frac{\alpha_y\,\omega\,|\xi_y|}{U_c}}\, e^{-\frac{i\,\omega\,\xi_x}{U_c}}\,, \tag{4}$$

where α_x and α_y are empirical parameters, chosen to yield the best agreement with the reality, which denote the loss of coherence in the longitudinal and transverse directions. Usually, $\alpha_x \in [0.1; 0.12]$ and $\alpha_y \in [0.7; 1.2]$. Recommended empirical values for aircraft boundary layers are $\alpha_x = 0.1$ and $\alpha_y = 0.77$ [39]. For the reference power spectrum, $S_{ref}(\omega)$, all the chosen studies for the validation of our model provide information about its value. However, in case of the absence of an adequate reference power spectrum function or value, the authors anticipate that the model proposed by Efimtsov [25] provides a good agreement with experimental data for the case of an aircraft in cruise flight [39, 40].

3. STRUCTURAL MODEL

Generally, an aircraft fuselage is a conventional skin-stringer-frame structure, with several panels connected between adjacent stringers and frames. Each individual panel can be assumed to vibrate independently of each other. As concluded in [13, 14], while jet noise induced vibration in aircraft is highly correlated over several aircraft panels, in both longitudinal and circumferential directions, the TBL induced vibration (in which the vibration correlation decays rapidly especially in the circumferential direction) is confined to one or two adjacent panels in the longitudinal direction.

The panels are considered to be flat and simply supported in all four boundaries. With these conditions, the vibration of an individual panel can be defined as [41, 42]

$$w(x,y,t) = \sum_{m_x=1}^{M_x} \sum_{m_y=1}^{M_y} \alpha_{m_x}(x)\, \beta_{m_y}(y)\, q_{m_x m_y}(t)\,, \tag{5}$$

in which $\alpha_{m_x}(x)$ and $\beta_{m_y}(y)$ are the spatial functions, defining the variation of w(x,y,t) with the variables x and y respectively, $q_{m_x m_y}(t)$ functions define the variation of w(x,y,t) with time, and $M = M_x \times M_y$ is the total number of plate modes (m_x, m_y) considered for the analysis. For simply supported plates, the spatial functions can be defined as:

$$\alpha_{m_x}(x) = \sqrt{\frac{2}{a}}\, \sin\left(\frac{m_x\, \pi\, x}{a}\right), \tag{6a}$$

$$\beta_{m_y}(y) = \sqrt{\frac{2}{b}}\, \sin\left(\frac{m_y\, \pi\, y}{b}\right), \tag{6b}$$

where a and b are the length and width of the plate, respectively. The natural frequencies of the simply supported panel are given by

$$\omega^{p}_{m_x m_y} = \sqrt{\frac{D_p}{\rho_p h_p}}\, \left[\left(\frac{m_x\, \pi}{a}\right)^2 + \left(\frac{m_y\, \pi}{b}\right)^2\right], \tag{7}$$

in which ρ_p is the density of the panel, h_p is its thickness, and $D_p = \frac{E_p\, h_p^3}{12\left(1 - \nu_p^2\right)}$ is the panel stiffness constant, with E_p being the panel Elasticity modulus and ν_p the Poisson ratio. The plate governing equation, for a given applied external pressure, is defined as

$$D_p \nabla^4 w + \rho_p\, h_p\, \dddot{w} + \zeta_p\, \dot{w} = p_{ext}(x,y,t)\,, \tag{8}$$

in which the term ζ_p was added to account for the damping of the plate.

4. ACOUSTIC MODEL

The acoustical physical system consists of a three-dimensional rectangular enclosure, with five fixed walls, and one totally or partially flexible wall. Similarly to the description of plate vibration in the structural model, the pressure field inside the acoustic enclosure can be defined through the acoustic modes, as following [43, 44]

$$p(x,y,z,t) = \sum_{n_x=1}^{N_x} \sum_{n_y=1}^{N_y} \sum_{n_z=1}^{N_z} \psi_{n_x}(x)\, \phi_{n_y}(y)\, \Gamma_{n_z}(z)\, r_{n_x n_y n_z}(t)\,, \tag{9}$$

in which $\psi_{n_x}(x)$, $\phi_{n_y}(y)$ and $\Gamma_{n_z}(z)$ are the spatial functions, defining the variation of p(x,y,z,t) with the variables x, y and z respectively, $r_{n_x n_y n_z}(t)$ functions define the variation of p(x,y,z,t) with time, and $N = N_x \times N_y \times N_z$ is the total number of plate modes (n_x, n_y, n_z) considered. The spatial functions are assumed to be orthogonal between each other, and are given by the rigid body enclosure modes [45, 46], i.e.:

$$\psi_{n_x}(x) = \frac{A_{n_x}}{\sqrt{L_x}} \cos\left(\frac{n_x \pi\, x}{L_x}\right), \tag{10a}$$

$$\phi_{n_y}(y) = \frac{A_{n_y}}{\sqrt{L_y}} \cos\left(\frac{n_y \pi\, y}{L_y}\right), \tag{10b}$$

$$\Gamma_{n_z}(z) = \frac{A_{n_z}}{\sqrt{L_z}} \cos\left(\frac{n_z \pi\, z}{L_z}\right), \tag{10c}$$

where L_x, L_y and L_z are the dimensions of the acoustic enclosure in the x-, y- and z- direction, respectively, and constants A_n were chosen in order to satisfy normalization. It can be shown that:

$$A_n = \begin{cases} \sqrt{2}, & \text{for } n \neq 0 \\ 1, & \text{for } n = 0. \end{cases} \tag{11}$$

The natural frequencies of a rectangular cavity can be determined using the following equation [45]

$$\omega^{ac}_{n_x n_y n_z} = c_0 \sqrt{\left(\frac{n_x\, \pi}{L_x}\right)^2 + \left(\frac{n_y\, \pi}{L_y}\right)^2 + \left(\frac{n_z\, \pi}{L_z}\right)^2}\,, \tag{12}$$

in which c_0 is the speed of sound inside the acoustic enclosure. The governing equation of this subsystem is the wave equation, defined by

$$\nabla^2 p - \frac{1}{c_0^2}\, \dddot{p} - \zeta_{ac}\, \dddot{p} = 0\,, \tag{13}$$

where the damping term ζ_{ac} was added to account for the acoustic damping in the enclosure.

5. STRUCTURAL-ACOUSTIC MODEL

The governing equations for the coupled structural acoustic system are obtained from the combination of the previously described governing equations for the individual uncoupled systems. To perform that combination, some mathematical manipulation is needed.

First, considering the plate governing equation, the right-hand side of Eq.(8) may be divided in two different contributions: (1) the external TBL excitation, $p_{tbl}(x, y, t)$, applied in the upper part of the panel, and (2) the pressure field, $p(x,y,z{=}L_z,t)$, applied in the panel due to the acoustic enclosure contribution. Considering this, Eq.(8) can be re-written as

$$D_p \nabla^4 w + \rho_p\, h_p\, \dddot{w} + \zeta_p\, \dot{w} = p(x,y,z{=}L_z,t) - p_{tbl}(x,y,t)\,. \tag{14}$$

Substituting w(x,y,t) in Eq.(14) by the expression defined in Eq.(5), expressing $p(x,y,z{=}L_z,t)$ in terms of Eqs.(9) and (10), making use of the orthogonality of the plate modes, and integrating the entire equation over the plate area, Eq.(14) becomes

$$\begin{aligned} &\rho_p h_p \left\{\ddot{q}_m(t) + 2\, \omega_m\, \xi_p\, \dot{q}_m(t) + \omega_m^2\, q_m(t)\right\} = \\ &\sum_{n=1}^{N} \frac{(-1)^{n_z} A_{n_z}}{\sqrt{L_z}} \int_{x_{p_i}}^{x_{p_f}} \alpha_{m_x}(x)\, \psi_{n_x}(x)dx \int_{y_{p_i}}^{y_{p_f}} \beta_{m_y}(y)\, \phi_{n_y}(y)dy\;\; r_n(t) \\ &- \int_{y_{p_i}}^{y_{p_f}} \int_{x_{p_i}}^{x_{p_f}} \alpha_{m_x}(x)\, \beta_{m_y}(y)\, p_{tbl}(x,y,z{=}L_z,t)\, dx\, dy\,, \end{aligned} \tag{15}$$

where $\zeta_p = 2\ \omega_m\ \xi_p$ is the structural modal damping; x_{p_i} and x_{p_f} are, respectively, the initial and last x-coordinates of the plate (corresponding to the plate length); y_{p_i} and y_{p_f} are, respectively, the initial and last y-coordinates of the plate (plate width); and $\omega^p_{m_x m_y}$, $q_{m_x m_y}(t)$, and $r_{n_x n_y n_z}(t)$ were substituted, respectively, by ω_m , $q_m(t)$ and $r_n(t)$, for notation simplicity.

Second, considering the rectangular acoustic enclosure governing equation, Eq.(13), the boundary conditions may be defined as follows: (1) normal component of the air particle velocity equal to zero at the enclosure rigid walls, and (2) equal to normal velocity of the panel, at the flexible wall, i.e.,

$$\frac{\partial p}{\partial u} = \begin{cases} -\rho_0\ \ddot{w}, & \text{at } z = L_z \\ 0, & \text{at rigid boundaries} \end{cases}, \tag{16}$$

in which u represents the direction normal to the boundary, and ρ_0 is the air density into the acoustic enclosure.

Substituting Eqs.(10) and (11) into Eq.(9), and then into Eq.(13), making use of the orthogonality condition of the acoustic modes, integrating over the volume of the rectangular enclosure, and, finally, applying the boundary conditions given by Eq.(16), the rectangular enclosure governing equation Eq.(13) becomes

$$\frac{1}{c_0^2}\left\{\ddot{r}_n(t) + 2\ \omega_n\ \xi_{ac}\ \dot{r}_n(t) + \omega_n^2\ r_n(t)\right\} =$$
$$-\rho_0 \frac{(-1)^{n_z} A_{n_z}}{\sqrt{L_z}} \sum_{m=1}^{M} \int_{x_{p_i}}^{x_{p_f}} \alpha_{m_x}(x)\psi_{n_x}(x)dx \int_{y_{p_i}}^{y_{p_f}} \beta_{m_y}(y)\phi_{n_y}(y)dy\ \ddot{q}_m(t) \tag{17}$$

where $\zeta_{ac} = 2\ \omega_n\ \xi_{ac}$ is the acoustic modal damping, and $\omega^{ac}_{n_x n_y n_z}$, $r_{n_x n_y n_z}(t)$, and $q_{m_x m_y}(t)$ were substituted, respectively, by ω_n , $r_n(t)$ and $q_m(t)$, for notation simplicity. Note that the term on the right-hand side of Eq.(17) and the first term on the right-hand side of Eq.(15) represent the coupling between the structural vibration and the enclosure acoustic pressure.

Third, it is convenient to write the couple system governing equations, Eqs.(15) and (17), together into the following matrix form:

$$\begin{bmatrix} \mathbf{M}_{pp} & \mathbf{0} \\ \mathbf{M}_{cp} & \mathbf{M}_{cc} \end{bmatrix} \begin{Bmatrix} \ddot{\mathbf{q}}(t) \\ \ddot{\mathbf{r}}(t) \end{Bmatrix} + \begin{bmatrix} \mathbf{D}_{pp} & \mathbf{0} \\ \mathbf{0} & \mathbf{D}_{cc} \end{bmatrix} \begin{Bmatrix} \dot{\mathbf{q}}(t) \\ \dot{\mathbf{r}}(t) \end{Bmatrix} + \begin{bmatrix} \mathbf{K}_{pp} & \mathbf{K}_{pc} \\ \mathbf{0} & \mathbf{K}_{cc} \end{bmatrix} \begin{Bmatrix} \mathbf{q}(t) \\ \mathbf{r}(t) \end{Bmatrix}$$
$$= \begin{Bmatrix} \mathbf{p}_{tbl}(t) \\ \mathbf{0} \end{Bmatrix}, \tag{18}$$

in which:

$$\mathbf{M}_{pp} = \text{diag}\left[\rho_p\ h_p\right] \quad \text{and} \quad \mathbf{M}_{cc} = \text{diag}\left[\frac{1}{c_0^2}\right], \tag{19a}$$

$$\mathbf{M}_{cp} = \rho_0 \left[\frac{(-1)^{n_z} A_{n_z}}{\sqrt{L_z}} \int_{x_{p_i}}^{x_{p_f}} \alpha_{m_x}(x)\psi_{n_x}(x)dx \int_{y_{p_i}}^{y_{p_f}} \beta_{m_y}(y)\phi_{n_y}(y)dy\right], \tag{19b}$$

$$\mathbf{D}_{pp} = \text{diag}\left[2\rho_p h_p \omega_m \xi_p\right] \quad \text{and} \quad \mathbf{D}_{cc} = \text{diag}\left[2\frac{1}{c_0^2}\omega_n \xi_{ac}\right], \tag{19c}$$

$$\mathbf{K}_{pp} = \text{diag}\left[\omega_m^2\ \rho_p\ h_p\right] \quad \text{and} \quad \mathbf{K}_{cc} = \text{diag}\left[\omega_n^2\ \frac{1}{c_0^2}\right], \tag{19d}$$

$$\mathbf{K}_{pc} = -\left[\frac{(-1)^{n_z} A_{n_z}}{\sqrt{L_z}} \int_{x_{p_i}}^{x_{p_f}} \alpha_{m_x}(x)\psi_{n_x}(x)dx \int_{y_{p_i}}^{y_{p_f}} \beta_{m_y}(y)\phi_{n_y}(y)dy\right], \tag{19e}$$

$$\mathbf{p}_{tbl}(t) = -\left[\int_{y_{p_i}}^{y_{p_f}} \int_{x_{p_i}}^{x_{p_f}} \alpha_{m_x}(x)\ \beta_{m_y}(y)\ p_{tbl}(x,y,z=L_z,t)\ dx\ dy\right]. \tag{19f}$$

In these equations, **M** corresponds to mass matrices, **D** to damping matrices, **K** to stiffness matrices, and subscripts *p* and *c* represent respectively *plate* and *cavity*, with: $\mathbf{M}_{pp}$, $\mathbf{D}_{pp}$, and $\mathbf{K}_{pp} \in \Re^{M\times M}$; $\mathbf{M}_{cc}$, $\mathbf{D}_{cc}$ and $\mathbf{K}_{cc} \in \Re^{N\times N}$; $\mathbf{M}_{cp} \in \Re^{N\times M}$; $\mathbf{K}_{pc} \in \Re^{M\times N}$; $\mathbf{q}(t)$ and $\mathbf{p}_{tbl}(t) \in \Re^{M\times 1}$; and $\mathbf{r}(t) \in \Re^{N\times 1}$. All matrices and vectors expressions were obtained analytically. Appendix A contains final analytical expressions derived for $\mathbf{M}_{cp}$ and $\mathbf{K}_{pc}$ matrices.

Since the TBL wall pressure field model, described in section 2 of this article, is expressed in the frequency domain, it is opportune to transform Eq.(18) from the time domain to the frequency domain. For this purpose, one may assume the components of the time functions defined as $q_m = Q_m\ e^{i\omega t}$ and $r_n = R_n\ e^{i\omega t}$. Using this form of the time function, Eq.(18) can be written in frequency domain as

$$\mathbf{Y}(\omega) = \mathbf{H}(\omega)\ \mathbf{X}(\omega)\ , \tag{19}$$

in which the $\mathbf{Y}(\omega)$ is the response of the system to the excitation $\mathbf{X}(\omega)$, and $\mathbf{H}(\omega)$ is the frequency response matrix of the system, and are defined, respectively, by:

$$\mathbf{Y}(\omega) = \begin{Bmatrix} \mathbf{W}(\omega) \\ \mathbf{P}(\omega) \end{Bmatrix} \quad \text{and} \quad \mathbf{X}(\omega) = \begin{Bmatrix} \mathbf{P}_{tbl}(\omega) \\ \mathbf{0} \end{Bmatrix}, \tag{20a}$$

$$\mathbf{H}(\omega) = \begin{bmatrix} -\omega^2\mathbf{M}_{pp} + i\omega\mathbf{D}_{pp} + \mathbf{K}_{pp} & \mathbf{K}_{pc} \\ -\omega^2\mathbf{M}_{cp} & -\omega^2\mathbf{M}_{cc} + i\omega\mathbf{D}_{cc} + \mathbf{K}_{cc} \end{bmatrix}^{-1}. \tag{20b}$$

In these equations, vectors $\mathbf{W}(\omega)$, $\mathbf{P}(\omega)$ and $\mathbf{P}_{tbl}(\omega)$ correspond to the frequency domain vectors of the previously defined time domain vectors $\mathbf{w}(t)$, $\mathbf{p}(t)$ and $\mathbf{p}_{tbl}(t)$, respectively.

6. METHOD FOR SOLUTION

One last step, needed to obtain a solution for the problem, is to transform the coupled system equations to PSD domain, as the TBL wall pressure model available is written in terms of the power spectral density of the wall pressure. This way, considering the TBL random excitation as a stationary and homogeneous function, the spectral density of the system response, $\mathbf{S_{YY}}(\omega)$, is defined by [47, 48]

$$\mathbf{S_{YY}}(\omega) = \mathbf{H}^*(\omega)\, \mathbf{S_{XX}}(\omega)\, \mathbf{H}^T(\omega)\ , \tag{21}$$

where $\mathbf{S_{XX}}(\omega)$ is the PSD matrix of the random excitation, $\mathbf{X}(\omega)$, $\mathbf{S_{YY}}(\omega)$ is the PSD matrix of the random response, $\mathbf{Y}(\omega)$, and superscripts * and T denote Hermitian conjugate and matrix transpose, respectively. It is convenient to write the system response matrix, $\mathbf{H}(\omega)$, defined by Eq.(20b), in the following form

$$\mathbf{H}(\omega) = \begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix}^{-1}\ , \tag{22}$$

with:

$$\mathbf{A} = -\,\omega^2\, \mathbf{M}_{pp} + i\,\omega\, \mathbf{D}_{pp} + \mathbf{K}_{pp}\ , \tag{23a}$$

$$\mathbf{B} = \mathbf{K}_{pc}\ , \tag{23b}$$

$$\mathbf{C} = -\,\omega^2\, \mathbf{M}_{cp}\ , \tag{23c}$$

$$\mathbf{D} = -\,\omega^2\, \mathbf{M}_{cc} + i\,\omega\, \mathbf{D}_{cc} + \mathbf{K}_{cc}\ . \tag{23d}$$

Also, for mathematical calculations, it is opportune to divide the matrix $\mathbf{S_{YY}}(\omega)$ into two matrices: (1) the PSD matrix of the coupled plate displacement, $\mathbf{S_{WW}}(\omega)$, and (2) the PSD matrix of the coupled acoustic pressure, $\mathbf{S_{PP}}(\omega)$. Similarly, the matrix $\mathbf{S_{XX}}(\omega)$ may be divided in two: (1) the PSD matrix of the TBL pressure, and (2) a null matrix. With this manipulation, Eq.(21) can be written in a separate form, defining matrices $\mathbf{S_{WW}}(\omega)$ and $\mathbf{S_{PP}}(\omega)$, independently, as functions of the PSD matrix of the TBL excitation, Stblω, respectively, as follows:

$$\mathbf{S_{WW}}(\omega) = \mathbf{H_W}^*(\omega)\, \mathbf{S_{tbl}}(\omega)\, \mathbf{H_W}^T(\omega)\ , \tag{24}$$

and

$$\mathbf{S_{PP}}(\omega) = \mathbf{H_P}^*(\omega)\, \mathbf{S_{tbl}}(\omega)\, \mathbf{H_P}^T(\omega)\ , \tag{25}$$

in which matrices the $\mathbf{H_W}(\omega)$ and $\mathbf{H_P}(\omega)$ are defined, respectively, by:

$$\mathbf{H_W}(\omega) = (\mathbf{A} - \mathbf{B}\, \mathbf{D}^{-1}\, \mathbf{C})^{-1}. \tag{26}$$

and

$$\mathbf{H_P}(\omega) = -\, \mathbf{D}^{-1}\, \mathbf{C}\, \mathbf{H_W}(\omega)\ . \tag{27}$$

The generalized PSD matrix of the TBL excitation, $\mathbf{S_{tbl}}(\omega) \in \Re^{M \times M}$, is defined as follows

$$\mathbf{S_{tbl}}(\omega) = \left[\iint_{y_{p_i}}^{y_{p_f}} \iint_{x_{p_i}}^{x_{p_f}} \alpha_{m_x}(x)\alpha_{m_{x'}}(x')\beta_{m_y}(y)\beta_{m_{y'}}(y')S(\xi_x,\xi_y,\omega)dxdx'dydy' \right]\ , \tag{28}$$

in which $S(\xi_x,\xi_y,\omega)$ is defined by Eq.(4). The analytically expression obtained for the matrix $\mathbf{S_{tbl}}(\omega)$ can be seen in Appendix B. Finally, the PSD functions of the plate displacement and acoustic enclosure pressure can be defined using the previously defined PSD matrices, respectively as:

$$S_{ww}(x_1, y_1, x_2, y_2, \omega) = \sum_{m_{x_1}, m_{x_2}=1}^{M_x^2} \sum_{m_{y_1}, m_{y_2}=1}^{M_y^2} \alpha_{m_{x_1}}(x_1)\alpha_{m_{x_2}}(x_2)\beta_{m_{y_1}}(y_1)\beta_{m_{y_2}}(y_2)\mathbf{S_{WW}}(\omega)_{m_1,m_2} \tag{29}$$

and

$$S_{pp}(x_1, y_1, z_1, x_2, y_2, z_2, \omega) = \sum_{n_{x_1}, n_{x_2}=1}^{N_x^2} \sum_{n_{y_1}, n_{y_2}=1}^{N_y^2} \sum_{n_{z_1}, n_{z_2}=1}^{N_z^2} \psi_{n_{x_1}}(x_1)\psi_{n_{x_2}}(x_2)\phi_{n_{y_1}}(y_1)\phi_{n_{y_2}}(y_2)\Gamma_{n_{z_1}}(z_1)\Gamma_{n_{z_2}}(z_2)\, \mathbf{S_{PP}}(\omega)_{n_1,n_2} \tag{30}$$

Eqs.(29) and (30) can be used, respectively, to calculate the displacement PSD at a certain point in the plate, and the pressure PSD at any given location of the acoustic enclosure. If one desires to predict the auto-spectral density solutions, for instance, at the location 1, it can be calculated by replacing x_2 by x_1, y_2 by y_1, and z_2 by z_1 in Eqs.(29) and (30). The overall PSD functions are calculated by integrating the individual PSD functions over the plate area and the cavity volume, respectively, as following:

$$S_{ww}(\omega) = \iint_{y_{p_i}}^{y_{p_f}} \iint_{x_{p_i}}^{x_{p_f}} S_{ww}(x_1, y_1, x_2, y_2, \omega)\, dx_1dx_2dy_1dy_2\ , \tag{31}$$

and

$$S_{pp}(\omega) = \iint_{z_{c_i}}^{z_{c_f}} \iint_{y_{c_i}}^{y_{c_f}} \iint_{x_{c_i}}^{x_{c_f}} S_{pp}(x_1,y_1,z_1,x_2,y_2,z_2,\omega)\, dx_1dx_2dy_1dy_2dz_1dz_2. \tag{32}$$

in which x_{c_i} and x_{c_f} are, respectively, the initial and last x-coordinates of the acoustic enclosure (corresponding to the enclosure length); y_{c_i} and y_{c_f} are, respectively, the initial and last y-coordinates of the enclosure (enclosure width); and z_{c_i} and z_{c_f} are, respectively, the initial and last z-coordinates of the enclosure (enclosure height). The final analytical expressions derived for $S_{ww}(\omega)$ and $S_{pp}(\omega)$ are shown in Appendix C.

7. VALIDATION OF THE MODEL

7.1 Validation Case 1

The study documented in [22] performed by NASA, presents an experimental and theoretical study with different panels in order to determine the noise transmission in a coupled panel-cavity system. The analytical model presented is a simple, one-dimensional model, providing a good fitting with the experimental results trend line. The noise sources considered were normally impinging sine waves (with an amplitude of 110 dB) and normally incident random noise (a white noise source providing 120 dB sound pressure level).

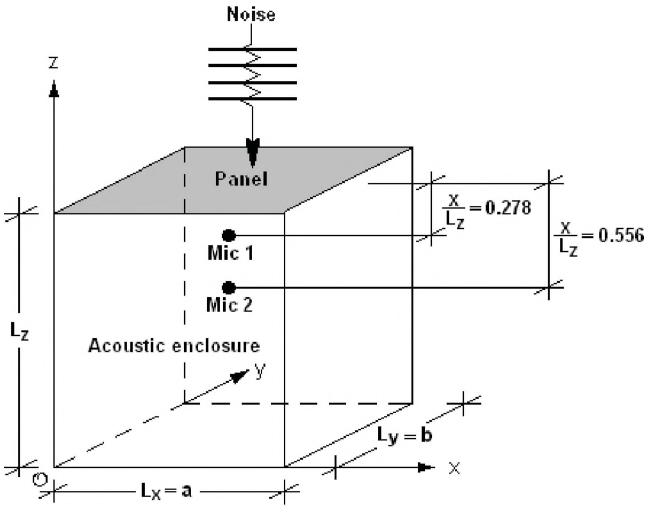

Figure 1. Details of the physical system of validation case 1.

Table 1. Parameters of the physical system for validation case 1.

Plate Properties (PVC)		
Variable	Description	Value
ρ_p	Density	1562.5 Kg m^{-3}
E_p	Elasticity Modulus	3.2×10^9 Pa^2
ν	Poisson's ratio	0.41
ξ_p	Damping ratio	0.02
h_p	Thickness	0.0016 m
a	Length	0.305 m
b	Width	0.381 m
Acoustic Enclosure Properties (Air)		
Variable	Description	Value
c_0	Speed of sound	348 m s^{-1}
ξ_{ac}	Damping ratio	0.001
L_x	Length	0.305 m
L_y	Width	0.381 m
L_z	Height	0.454 m

This study was considered as the validation case 1, and the system is composed by a PVC (Lead impregnated polyvinylchloride) panel coupled with a hard walled acoustic cavity, as shown in Fig. 1. The main properties of the system are displayed in Table 1. Two measurement microphones were located inside the cavity, directly behind the flexible panel, as shown in Fig. 1, in order to provide measurements of the interior sound pressure level. The noise reduction, NR, was obtained as following

$$NR = -10 \log_{10}\left(\frac{S_{pp}}{S_{ext}}\right) , \qquad (33)$$

in which, S_{pp} is the pressure PSD at the location of the interior microphone and S_{ext} is the external pressure PSD. Using our analytical framework, S_{pp} can be calculated from Eq.(30), while S_{ext} corresponds to S_{ref} expressed in Eqs. (2) to (4).

Figs. 2 and 3 show the noise reduction results obtained with our analytical model (part (a)), and the measured and theoretical results from [22] (part (b)), respectively, for the interior microphone locations 1 and 2, as shown in Fig. 1. Comparing these two figures, it is clear that changing the location of measurement also changes the noise reduction results, as should be expected. To obtain our analytical results, a total number of $M_x = 10$ and $M_y = 12$ plate modes, and $N_x = 3$, $N_y = 4$ and $N_z = 4$ acoustic modes, was necessary to achieve convergence of the results, for the maximum frequency of interest, i.e., 1000 Hz. It was found that, for the frequency range of interest, [0; 1000] Hz, it is necessary to include some non-resonant modes. A detailed explanation of criterion followed to determine the number of structural modes and acoustic modes required for convergence can be found in [38].

By comparison of parts (a) and (b) of Figs. 2 and 3, it can be concluded that our analytical model provides a good approximation to the experimental data from [22]. Comparing the analytical results in parts (a) and (b), it is clear that results from our framework confirm the existence of a more complex trend line, compared with the analytical results in [22]. This is explained by the fact that, in the present study, a much larger number of plate and acoustic modes were considered, compared with the number of modes used in [22]. An important conclusion from these results is that the number of modes, considered to obtain the analytical results, plays a crucial role in achieving an accurate prediction of the interior noise. However, some differences exist between our analytical results and the experimental results from [22]. As explained in [22], some acoustic leakage through the enclosure sides was observed during experiments, and those differences may be explained due to this factor.

7.2 Validation Case 2

The second case chosen for validation of our analytical model is based on the study described in [8]. It consists of a rectangular simply supported aluminum panel, which was flush mounted in the floor of a wind tunnel test section. An acoustically treated enclosure was mounted below the panel.

The sound pressure level, due to the noise radiated from the panel, was measured at various microphone locations inside the acoustic enclosure. Additionally, an accelerometer was located in the centre of the plate to evaluate the vibration levels. A schematic of the physical system is shown in Fig. 4.

The reference power spectral density of the external pressure field is approximately constant, as follows:

$$S_{ref} = 7.5 \times 10^{-5} \lambda^2 \rho^2 U_\infty^3 \delta^*, \qquad (34)$$

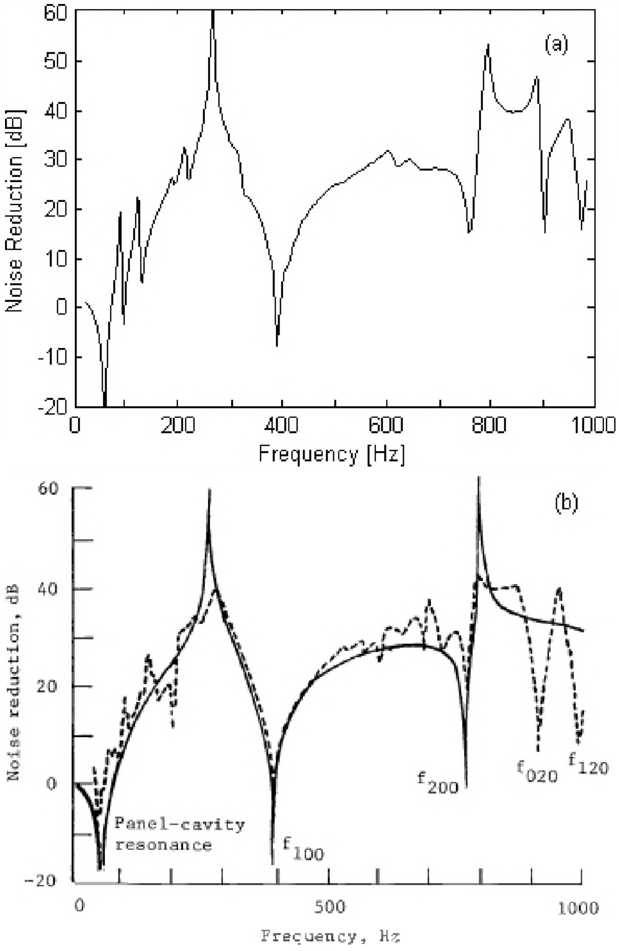

Figure 2. Noise reduction results for validation case 1, obtained for microphone location 1. (a) Obtained using our analytical model. (b) From [22]: ——, analytical results; – – –, experimental data.

in which $\lambda = 3$, ρ is the external air density, and δ^* is the boundary layer displacement thickness. As explained in [8], a displacement thickness of 12.8 cm gives a correct value for the pressure power spectra, and was used for the calculation of the turbulent excitation. The dimensions and characteristics of the panel and acoustic enclosure, and the properties of the external fluid are displayed in Table 2.

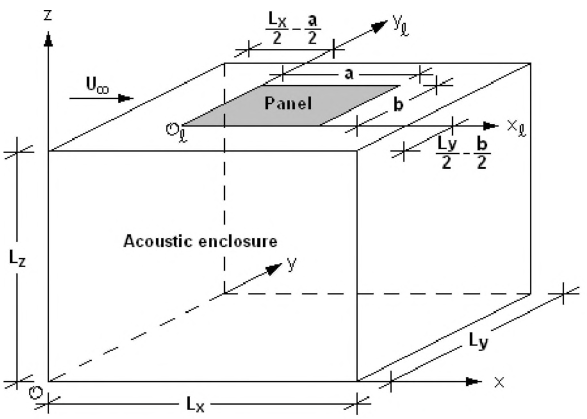

Figure 3. Schematic of physical system of validation case 2.

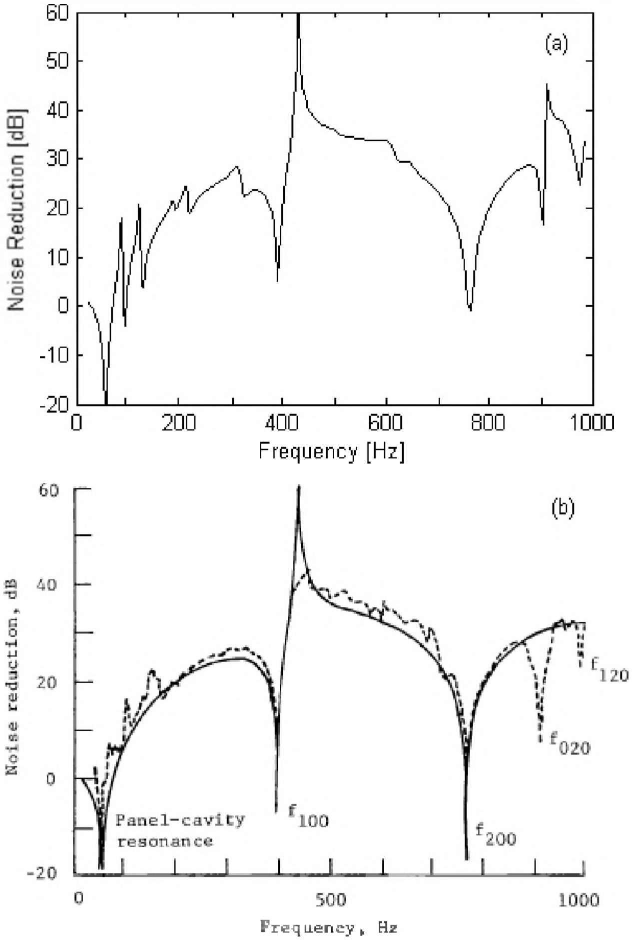

Figure 4. Noise reduction results for validation case 1, obtained for microphone location 2. (a) Obtained using our analytical model. (b) From [22]: ——, analytical results; – – –, experimental data.

The analytical results obtained using our framework are compared with the results from [8], as shown in Figs. 5 and 6. In Fig. 5, the response at higher frequencies is not accurately predicted by calculations in [8]. Both analytical results in parts (a) and (b) of Fig. 5 overpredict the acceleration level in the region from 900 Hz to 1000 Hz. However, our model is able to accurately predict the acceleration magnitude across the 700-900 Hz region. As stated in the validation case 1 section, this may be related with the number of structural and acoustic modes considered in the analysis. To accomplish convergence of the spectral quantities, a total number of $M_x = 5$ and $M_y = 4$ plate modes, and $N_x = 8$, $N_y = 6$ and $N_z = 5$ acoustic modes were used in our model. Again, not only resonant modes were considered in the analyses - a considerable number of non-resonant modes were necessary to achieve convergence of the results. The predicted SPL from our model is shown in Fig. 6 (a). The model accurately predicts the sound pressure levels obtained experimentally in [8], with the main differences observed for low frequencies.

Table 2. Parameters of the physical system for validation case 2.

External Flow Properties (Air)		
Variable	Description	Value
ρ	Density	1..225 Kg m^{-3}
U_∞	Free stream velocity	35.8 m s^{-1}
U_c	Convective velocity	0.65 U_∞
α_x / α_y	Empirical parameters	0.115/0.7
Plate Properties (Aluminum)		
Variable		
ρ_p	Density	2800 Kg m^{-3}
E_p	Elasticity Modulus	6.5×10^{10} Pa^2
ν	Poisson's ratio	0.3
ξ_p	Damping ratio	0.01
h_p	Thickness	0.0048 m
a / b	Length / Width	0.46 m/0.33 m
Acoustic Enclosure Properties (Air)		
Variable	Description	Value
c_0	Speed of sound	340 m s^{-1}
ξ_{ac}	Damping ratio	0.03
L_x	Length	1.05 m
L_y	Width	0.857 m
L_z	Height	0.635 m

7.3 Validation Case 3

The study chosen as the validation case 3, [2], investigates the modeling of an elastic panel coupled with an acoustic enclosure, with the plate occupying a portion of the cavity and subjected to a convected flow, as shown in Fig. 7. The system parameters can be seen in Table 3.

In this study, the model consists of four parts: (1) the external aerodynamic model, (2) the TBL model, (3) the plate model, and (4) the acoustic cavity model. Their model is based on the power balance equation, written in the frequency domain, with the transfer functions of the system of equations computed using MATLAB, and using 4 plate modes and 17 cavity modes (i.e., resonant modes for frequencies up to 1000 Hz). For this frequency range, the TBL point pressure power spectrum was taken to be constant, as follows

$$S_{ref}(\omega_{max}) = 3.84 \times 10^{-5} \frac{\left(\rho U_\infty^2\right)^2}{4\,\omega_{max}}, \tag{35}$$

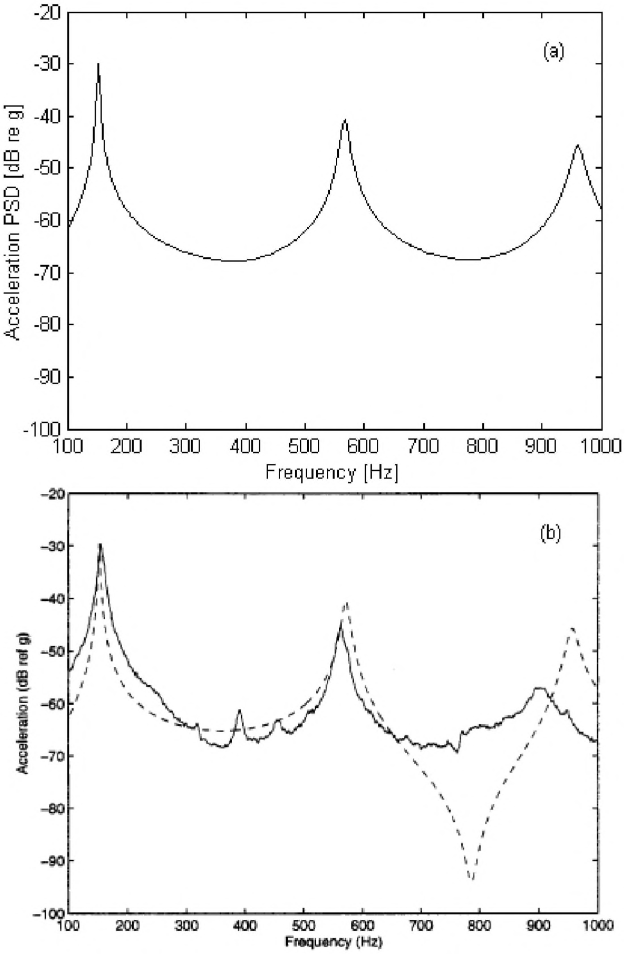

Figure 5. Validation case 2: acceleration power spectral density. (a) Analytical results obtained using our model. (b) From [8]:– – –, calculated;——, measured.

in which ω_{max} is the maximum frequency of interest. Assuming 4 plate modes and 17 cavity modes, the results for the cavity power spectrum are shown in Fig. 8. The cavity power spectrum was calculated through the acoustic pressure PSD, $S_{pp}(\omega)$, defined in Eq.(30), as following

$$E_{pp}(\omega) = \frac{L_x\, L_y\, L_z}{4\,\rho_0\, c_0^2}\,\omega\, S_{pp}(\omega). \tag{36}$$

Comparing results in parts (a) and (b) of Fig. 8, one can conclude that they in very good agreement, taking into account the entire frequency spectrum. One might now consider a more accurate result as a larger number of plate and cavity modes should be needed in the model. Again, aiming for convergence of calculated spectral quantities, one must consider a total number of $M_x = 5$ and $M_y = 5$ plate modes, and $N_x = 21$, $N_y = 3$ and $N_z = 3$ acoustic modes in the series expansion. With this number of system natural modes, the results become different, as shown in Fig. 9. As can be concluded by comparison of Figs. 8 and 9, a larger number of modes results in higher cavity power spectrum amplitudes, mainly for frequencies above 300 Hz. The bigger amount of spectral peaks above 300 Hz displayed in the more accurate results, shown in Fig. 9, is associated with the additional resonant modes considered. Results for lower frequencies remain essentially unaltered from Fig. 8 to Fig. 9.

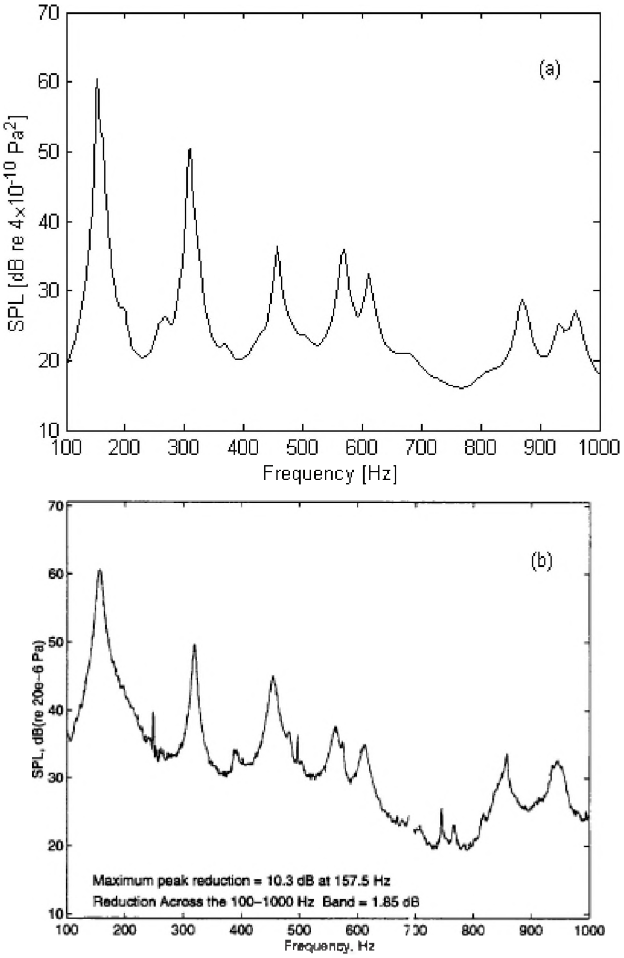

Figure 6. Validation case 2: Sound pressure level: (a) obtained using our analytical model; (b) experimental data from [8].

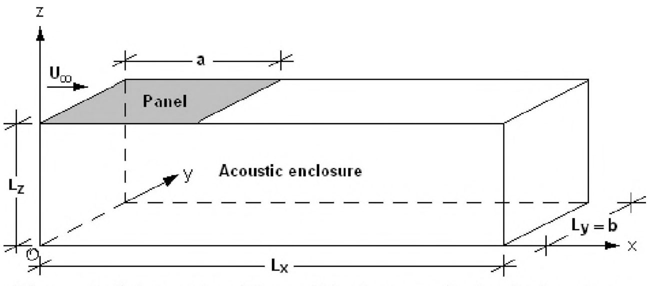

Figure 7. Schematic of the validation case 3 physical system.

Table 3. Properties of the system for the validation case 3.

External Flow Properties (Air)		
Variable	Description	Value
c_0	Speed of sound	310 m s^{-1}
ρ	Density	0.42 Kg m^{-3}
$U_{\infty 1}$	Free stream velocity 1	0.1 c_0
$U_{\infty 2}$	Free stream velocity 2	0.5 c_0
$U_{\infty 3}$	Free stream velocity 3	0.8 c_0
U_c	Convective velocity	0.6 U_∞
α_x	Empirical parameter	0.1
α_y	Empirical parameter	0.5
Plate Properties (Aluminum)		
Variable		
ρ_p	Density	2800 Kg m^{-3}
E_p	Elasticity Modulus	7.0×10^{10} Pa^2
ν	Poisson's ratio	0.3
ξ_{p1}	Damping ratio 1	0.01
ξ_{p2}	Damping ratio 2	0.02
ξ_{p3}	Damping ratio 3	0.03
h_p	Thickness	0.0018 m
a	Length	0.3 m
b	Width	0.3 m
Acoustic Enclosure Properties (Air)		
Variable	Description	Value
c_0	Speed of sound	310 m s^{-1}
ρ_0	Density	0.42 Kg m^{-3}
ξ_{ac}	Damping ratio	0.05
L_x	Length	3.0 m
L_y	Width	0.3 m
L_z	Height	0.3 m

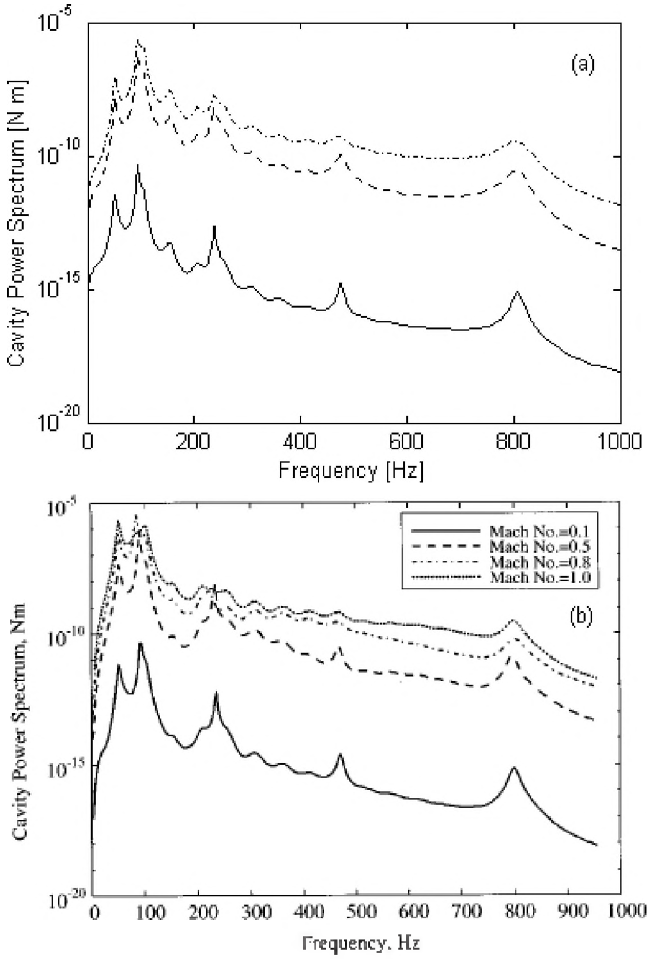

Figure 8. Validation case 3: cavity power spectrum results (using 4 plate modes and 17 cavity modes):——— , M=0.1; - - - , M=0.5; -·-·, M=0.8.
(a) From our analytical framework. (b) From [2].

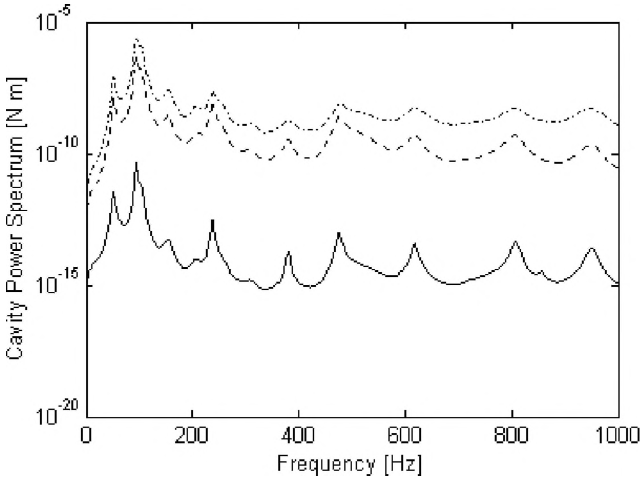

Figure 9. Validation case 3: cavity power spectrum results from our analytical framework (using a larger number of plate and cavity modes): ——, M=0.1; – – –, M=0.5; – · – ·, M=0.8.

7.4 Validation Case 4

The validation case 4 is the study by [37]. As in the previous validation case, this study investigates the model of a convected fluid loaded plate coupled with an acoustic enclosure. However, the dimensions are different from the previous case, and were chosen to reproduce a small commercial aircraft. The physical system schematic is shown in Fig. 10 and the main parameters of the system are displayed in Table 4.

Table 4. System parameter of validation case 4.

External Flow Properties (Air)		
Variable	Description	Value
c_0	Speed of sound	310 m s $^{-1}$
ρ	Density	0.42 Kg m^{-3}
U_∞	Free stream velocity	0.1 c_0
U_c	Convective velocity	0.6 U_∞
α_x	Empirical parameter	0.1
α_y	Empirical parameter	0.5
Plate Properties (Aluminum)		
Variable		
ρ_p	Density	2700 Kg m^{-3}
E_p	Elasticity Modulus	7.1×10^{10} Pa^2
ν	Poisson's ratio	0.3
ξ_p	Damping ratio	0.01
h_p	Thickness	0.0022 m
a	Length	0.6 m
b	Width	0.525 m
x_p	Plate x-coordinate	0.6 m
y_p	Plate y-coordinate	0.6 m
Acoustic Enclosure Properties (Air)		
Variable	Description	Value
c_0	Speed of sound	310 m s $^{-1}$
ρ_0	Density	0.42 Kg m^{-3}
ξ_{ac}	Damping ratio	0.05
L_x	Length	6.0 m
L_y	Width	1.8 m
L_z	Height	1.8 m

In [37], a total number of 50 acoustic modes and 20 plate modes were used to obtain the numerical results. For this number of natural modes, the results for the cavity acoustic potential energy are shown in Fig. 11. Fig. 12 shows the

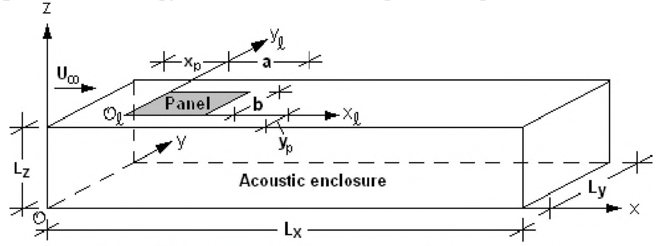

Figure 10. Physical system of validation case 4.

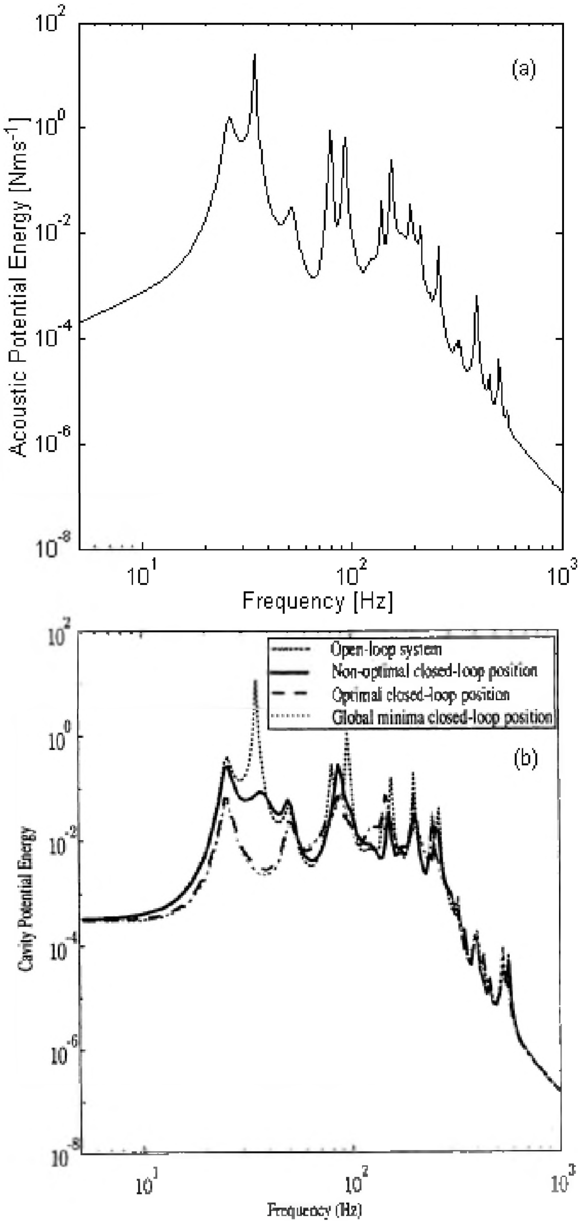

Figure 11. Validation case 4: acoustic potential energy results (using 20 plate modes and 50 cavity modes): (a) obtained using our analytical framework; (b) from [37].

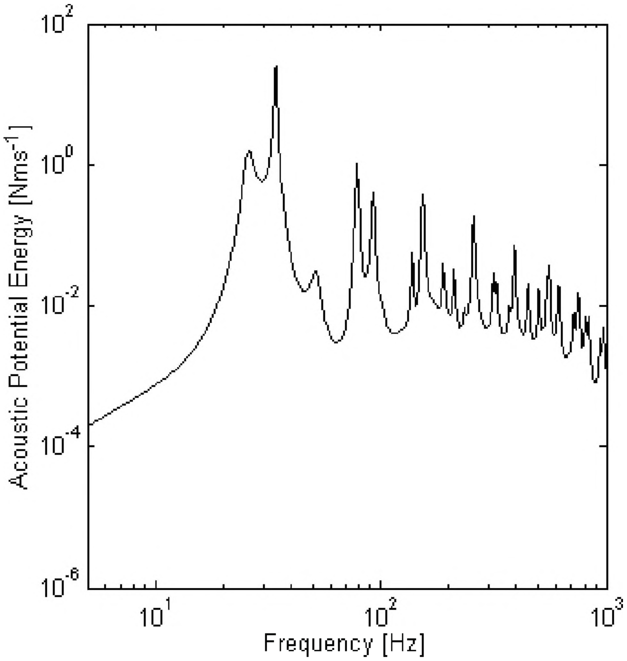

Figure 12. Validation case 4: acoustic potential energy results from our analytical framework (using a larger number of plate and acoustic modes).

results obtained with analytical results, but using a total number of $M_x = 9$ and $M_y = 7$ plate modes, and $N_x = 40$, $N_y = 7$ and $N_z = 7$ acoustic modes, in order to obtain accurate results in the bandwidth of interest. To calculate the cavity potential energy, in Figs. 11 and 12, the following equation was used

$$E_{pp}(\omega) = \frac{L_x\, L_y\, L_z}{4\, \rho_0\, c_0^2}\, \omega^2\, S_{pp}(\omega)\,, \tag{37}$$

in which $S_{pp}(\omega)$ is defined by Eq.(30). Comparing parts (a) and open-loop plot in part (b) of Fig. 11, one can conclude that results are in good agreement. However, when considering a larger number of natural modes, the results are very different, mainly for higher frequencies, as shown in Fig. 12. The consideration of the larger number of system modes results in an increase of acoustic energy for frequencies above 200 Hz.

8. CONCLUSIONS

The model validation is an essential part of the model development process in order to the models to be accepted and used as a predictive tool. Several independent experimental and numerical studies, with different physical properties and environment, were used for conducting the validation of our model. The analytical results from our model show an overall match with the data from the validation cases. This indicates that our model can be used for the prediction of noise levels, and applicable for different practical cases.

The analytical model has applied for the prediction of noise levels to 4 different cases. The analytical predictions of the plate vibration PSD and the enclosure pressure PSD were calculated in order to perform the comparative analysis with the experimental and numerical data from the validation cases. In all 4 analyses, the predicted values are in good agreement with the data from the validation chosen studies. Additionally, it was found that the number of plate and acoustic natural modes used in the analysis play an important role in the model accurate prediction. In fact, there is a minimum number of natural modes which needs to be used in the analysis, in order to accurately predict the noise and vibration levels up to a maximum frequency.

The analytical framework developed and here validated can be used for the noise and vibration levels prediction for physical systems with a rectangular shaped enclosure with one flexible wall. This framework presents a solid basis for further analyses, opening the doors for its use in the design and implementation of noise reduction techniques. As demonstrated, accurate analytical models can be used to solve the problem of cabin TBL-induced interior noise prediction. Moreover, being the cabin an acoustic enclosure, it is important to consider not only the structural natural modes associated with the structural panels, but also the cabin acoustic modes, as well. Even though the structural-acoustic coupling turns the analytical framework more complex, it can be a first alternative to the much more time consuming numerical solutions. Future work of the present research will aim for the prediction of TBL-induced noise into an acoustic enclosure with several flexible panels, and also the development of additional analytical frameworks for cylindrical and spherical acoustic enclosures.

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APPENDICES

A. Analytical expressions for $\mathbf{M}_{cp}$ and $\mathbf{K}_{pc}$ matrices

Matrices $\mathbf{M}_{cp}$ and $\mathbf{K}_{pc}$ are defined, respectively, by Eqs.(19b) and (19e). To derive the final analytical expressions for these matrices, the integrals over x_p and y_p on the equations need to be analytically obtained.
Starting by the derivation of the mass matrix, $\mathbf{M}_{cp}$, by substituting Eqs. (6) and (10) into Eq.(19b), it becomes

$$\mathbf{M}_{cp}=\frac{2\,\rho_0}{\sqrt{a\,b\,L_x\,L_y\,L_z}}\left[(-1)^{n_z}A_{n_x}A_{n_y}A_{n_z}\int_{x_{p_i}}^{x_{p_f}}\sin\left(\frac{m_x\pi\,(x-x_{p_i})}{a}\right)\cos\left(\frac{n_x\pi\,x}{L_x}\right)dx\int_{y_{p_i}}^{y_{p_f}}\sin\left(\frac{m_y\pi\,(y-y_{p_i})}{b}\right)\cos\left(\frac{n_y\pi\,y}{L_y}\right)dy\right], \quad (A.1)$$

where x and y correspond to the acoustic enclosure (global) coordinate system, and terms inside [ ] are developed to obtain a matrix, according with the n and m indexes. Note that, in Eq. (A.1), the plate spatial functions, defined in Eqs. (6a) and (6b), were modified in order to be expressed in the enclosure coordinate system. For convenience, one may consider Eq.(A.1) written as the an alternative form as

$$\mathbf{M}_{cp}=\frac{2\,\rho_0}{\sqrt{a\,b\,L_x\,L_y\,L_z}}\left[(-1)^{n_z}A_{n_x}A_{n_y}A_{n_z}B_{nm}(x)B_{nm}(y)\right], \quad (A.2)$$

with:

$$B_{nm}(x)=\int_{x_{p_i}}^{x_{p_f}}\sin\left(\frac{m_x\pi\,(x-x_{p_i})}{a}\right)\cos\left(\frac{n_x\pi\,x}{L_x}\right)dx\,, \qquad (A.3a)$$

$$B_{nm}(y)=\int_{y_{p_i}}^{y_{p_f}}\sin\left(\frac{m_y\pi\,(y-y_{p_i})}{b}\right)\cos\left(\frac{n_y\pi\,y}{L_y}\right)dy\,. \qquad (A.3b)$$

The analytical development of the functions $B_{nm}(x)$ and $B_{nm}(y)$ results in the following final expressions:

$$B_{nm}(x)=\begin{cases} f(x_{p_f})-f(x_{p_i}), & \left(\frac{m_x}{a}\neq\frac{n_x}{L_x}\right)\wedge\left(\frac{x_{p_i}}{a}\text{ even}\right)\\ f(x_{p_f})-f(x_{p_i}), & \left(\frac{m_x}{a}\neq\frac{n_x}{L_x}\right)\wedge\left(\frac{x_{p_i}}{a}\text{ odd}\right)\wedge(m_x\text{ even})\\ f(x_{p_i})-f(x_{p_f}), & \left(\frac{m_x}{a}\neq\frac{n_x}{L_x}\right)\wedge\left(\frac{x_{p_i}}{a}\text{ odd}\right)\wedge(m_x\text{ odd})\\ 0, & \left(\frac{m_x}{a}=\frac{n_x}{L_x}\right)\end{cases} \quad (A.4a)$$

and

$$B_{nm}(y)=\begin{cases} g(y_{p_f})-g(y_{p_i}), & \left(\frac{m_y}{b}\neq\frac{n_y}{L_y}\right)\wedge\left(\frac{y_{p_i}}{b}\text{ even}\right)\\ g(y_{p_f})-g(y_{p_i}), & \left(\frac{m_y}{b}\neq\frac{n_y}{L_y}\right)\wedge\left(\frac{y_{p_i}}{b}\text{ odd}\right)\wedge(m_y\text{ even})\\ g(y_{p_i})-g(y_{p_f}), & \left(\frac{m_y}{b}\neq\frac{n_y}{L_y}\right)\wedge\left(\frac{y_{p_i}}{b}\text{ odd}\right)\wedge(m_y\text{ odd})\\ 0, & \left(\frac{m_y}{b}=\frac{n_y}{L_y}\right)\end{cases} \quad (A.4b)$$

in which:

$$f(x)=\frac{\cos\left[\left(\frac{m_x}{a}+\frac{n_x}{L_x}\right)\pi x\right]}{2\left(\frac{m_x}{a}+\frac{n_x}{L_x}\right)\pi}+\frac{\cos\left[\left(\frac{m_x}{a}-\frac{n_x}{L_x}\right)\pi x\right]}{2\left(\frac{m_x}{a}-\frac{n_x}{L_x}\right)\pi}\,, \qquad (A.5a)$$

and

$$g(y) = \frac{\cos\left[\left(\frac{m_y}{b}+\frac{n_y}{L_y}\right)\pi y\right]}{2\left(\frac{m_y}{b}+\frac{n_y}{L_y}\right)\pi} + \frac{\cos\left[\left(\frac{m_y}{b}-\frac{n_y}{L_y}\right)\pi y\right]}{2\left(\frac{m_y}{b}-\frac{n_y}{L_y}\right)\pi}, \qquad \text{(A.5b)}$$

Similarly to mass matrix, the stiffness matrix, $\mathbf{K}_{pc}$, may be written in the following form

$$\mathbf{K}_{cp} = -\frac{2}{\sqrt{a\,b\,L_x L_y L_z}}\left[(-1)^{n_z} A_{n_x} A_{n_y} A_{n_z} B_{mn}(x) B_{mn}(y)\right], \qquad \text{(A.6)}$$

with functions $B_{mn}(x)$ and $B_{mn}(y)$ defined by Eqs.(A.4a) and (A.4b), respectively.

B. Analytical expression derived for $\mathbf{S}_{tbl}(\omega)$ matrix

Substituting Eqs.(4) and (6) into Eq.(28), $\mathbf{S}_{tbl}(\omega)$ matrix becomes defined as follows

$$\mathbf{S}_{tbl}(\omega) = \frac{4\,S_{ref}(\omega)}{a\,b}\left[\iint_{x_{p_i}}^{x_{p_f}} \sin\left(\frac{m_x \pi x}{a}\right) \sin\left(\frac{m'_x \pi x'}{a}\right) e^{-\frac{\alpha_x \omega |x-x'|}{U_c}} e^{-\frac{i\omega(x-x')}{U_c}} dx dx' \iint_{y_{p_i}}^{y_{p_f}} \sin\left(\frac{m_y \pi y}{b}\right) \sin\left(\frac{m'_y \pi y'}{b}\right) e^{-\frac{\alpha_y \omega |y-y'|}{U_c}} dy dy'\right] \qquad \text{(B.1)}$$

in which terms inside [ ] are developed to obtain a matrix, according with the m and m' indexes, and x and y correspond to plate (local) coordinate system. After some mathematical manipulation, Eq. (B.1) can be written as

$$\mathbf{S}_{tbl}(\omega) = \frac{4\,S_{ref}(\omega)}{a\,b}\left[\int_{x_{p_i}}^{x_{p_f}} \sin\left(\frac{m'_x \pi x'}{a}\right)\left\{e^{\frac{x'(-\alpha_x+i)\omega}{U_c}} \int_{x_{p_i}}^{x'} \sin\left(\frac{m_x \pi x}{a}\right) e^{\frac{x(\alpha_x - i)\omega}{U_c}} dx + e^{\frac{x'(\alpha_x+i)\omega}{U_c}} \int_{x'}^{x_{p_f}} \sin\left(\frac{m_x \pi x}{a}\right) e^{\frac{x(-\alpha_x - i)\omega}{U_c}} dx\right\} dx' \right.$$
$$\left. \int_{y_{p_i}}^{y_{p_f}} \sin\left(\frac{m_{y'} \pi y'}{b}\right)\left\{e^{-\frac{y'\alpha_y\omega}{U_c}} \int_{y_{p_i}}^{y'} \sin\left(\frac{m_y \pi y}{b}\right) e^{\frac{y\alpha_y\omega}{U_c}} dy + e^{\frac{y'\alpha_y\omega}{U_c}} \int_{y'}^{y_{p_f}} \sin\left(\frac{m_y \pi y}{b}\right) e^{-\frac{y\alpha_y\omega}{U_c}} dy\right\} dy'\right], \qquad \text{(B.2)}$$

Developing Eq.(B.2) analytically, one obtains the final analytical expression for the $\mathbf{S}_{tbl}(\omega)$ matrix components, which become defined as follows:

$$S_{tbl}(\omega)_{m,m'} = \frac{4\,S_{ref}(\omega)}{a\,b}\left\{\left[C_{x_1}(\omega,m)\,C_{x_5}(m,m') + C_{x_2}(\omega,m)\,C_{x_6}(m,m') + C_{x_3}(\omega,m)\,C_{x_7}(\omega,m') + C_{x_4}(\omega,m)\,C_{x_8}(\omega,m')\right]\right.$$
$$\left.\left[C_{y_1}(\omega,m)\,C_{y_5}(m,m') + C_{y_3}(\omega,m)\,C_{y_7}(\omega,m') + C_{y_4}(\omega,m)\,C_{y_8}(\omega,m')\right]\right., \qquad \text{(B.3)}$$

in which functions C's are defined by the following analytical expressions:

$$C_{x_1}(\omega,m) = \frac{2\alpha_x\omega}{U_c}\,\frac{\left(\frac{\omega}{U_c}\right)^2(\alpha_x^2+1)+\left(\frac{m_x\pi}{a}\right)^2}{\left[\left(\frac{\omega}{U_c}\right)^2(\alpha_x^2-1)+\left(\frac{m_x\pi}{a}\right)^2\right]^2+\left[2\alpha_x\left(\frac{\omega}{U_c}\right)^2\right]^2}, \qquad \text{(B.4)}$$

$$C_{x_2}(\omega,m) = -\frac{\left(\frac{m_x\pi}{a}\right)\left(\frac{4\alpha_x\omega^2}{U_c^2}\right)i}{\left[\left(\frac{\omega}{U_c}\right)^2(\alpha_x^2-1)+\left(\frac{m_x\pi}{a}\right)^2\right]^2+\left[2\alpha_x\left(\frac{\omega}{U_c}\right)^2\right]^2}, \qquad \text{(B.5)}$$

$$C_{x_3}(\omega,m) = -\frac{e^{\frac{x_{p_i}(\alpha_x-i)\omega}{U_c}}}{\left[\left(\frac{\omega}{U_c}\right)^2(\alpha_x^2-1)+\left(\frac{m_x\pi}{a}\right)^2\right]^2+\left[2\alpha_x\left(\frac{\omega}{U_c}\right)^2\right]^2}$$
$$\left\{\left[\left(\frac{\omega}{U_c}\right)^2(\alpha_x^2-1)+\left(\frac{m_x\pi}{a}\right)^2\right]+2\alpha_x\left(\frac{\omega}{U_c}\right)^2 i\right\}\left[\frac{(\alpha_x-i)\omega}{U_c}\sin\left(\frac{m_x\pi x_{p_i}}{a}\right)-\frac{m_x\pi}{a}\cos\left(\frac{m_x\pi x_{p_i}}{a}\right)\right], \qquad \text{(B.6)}$$

$$C_{x_4}(\omega,m) = -\frac{e^{-\frac{(x_{p_i}+a)(\alpha_x+i)\omega}{U_c}}\cos(m_x\pi)}{\left[\left(\frac{\omega}{U_c}\right)^2(\alpha_x^2-1)+\left(\frac{m_x\pi}{a}\right)^2\right]^2+\left[2\alpha_x\left(\frac{\omega}{U_c}\right)^2\right]^2}$$
$$\left\{\left[\left(\frac{\omega}{U_c}\right)^2(\alpha_x^2-1)+\left(\frac{m_x\pi}{a}\right)^2\right]-2\alpha_x\left(\frac{\omega}{U_c}\right)^2 i\right\}\left[\frac{(\alpha_x+i)\omega}{U_c}\sin\left(\frac{m_x\pi x_{p_i}}{a}\right)+\frac{m_x\pi}{a}\cos\left(\frac{m_x\pi x_{p_i}}{a}\right)\right], \qquad \text{(B.7)}$$

$$C_{x_5}(m,m') = \begin{cases} \frac{a}{2}, & \text{for } m_x = m'_x \\ \text{Const.}_{x_5}, & \text{for } m_x \neq m'_x \end{cases} \qquad \text{(B.8a)}$$

with:

$$\text{Const.}_{x_5} = \frac{-\sin\left[(m'_x+m_x)\frac{\pi}{a}(x_{p_i}+a)\right]+\sin\left[(m'_x+m_x)\frac{\pi}{a}x_{p_i}\right]}{2(m'_x+m_x)\frac{\pi}{a}} + \frac{\sin\left[(m'_x-m_x)\frac{\pi}{a}(x_{p_i}+a)\right]-\sin\left[(m'_x-m_x)\frac{\pi}{a}x_{p_i}\right]}{2(m'_x-m_x)\frac{\pi}{a}}, \qquad \text{(B.8b)}$$

$$C_{x_5}(m,m') = \begin{cases} 0, & \text{for } m_x = m'_x \\ \text{Const.}_{x_6}, & \text{for } m_x \neq m'_x \end{cases} \qquad \text{(B.9a)}$$

$$\mathrm{Const.}_{x_6}=\frac{-\cos\left[(m'_x+m_x)\frac{\pi}{a}(x_{p_i}+a)\right]+\cos\left[(m'_x+m_x)\frac{\pi}{a}x_{p_i}\right]}{2(m'_x+m_x)\frac{\pi}{a}}+\frac{-\cos\left[(m'_x-m_x)\frac{\pi}{a}(x_{p_i}+a)\right]+\cos\left[(m'_x-m_x)\frac{\pi}{a}x_{p_i}\right]}{2(m'_x-m_x)\frac{\pi}{a}}, \quad \text{(B.9b)}$$

$$C_{x_7}(\omega,m')=\frac{e^{\frac{(x_{p_i}+a)(-\alpha_x+i)\omega}{U_c}}}{\left[\frac{(-\alpha_x+i)\omega}{U_c}\right]^2+\left(\frac{m'_x\pi}{a}\right)^2}\left\{\frac{(-\alpha_x+i)\omega}{U_c}\sin\left[\frac{m'_x\pi(x_{p_i}+a)}{a}\right]-\frac{m'_x\pi}{a}\cos\left[\frac{m'_x\pi(x_{p_i}+a)}{a}\right]\right\}-\frac{e^{\frac{x_{p_i}(-\alpha_x+i)\omega}{U_c}}}{\left[\frac{(-\alpha_x+i)\omega}{U_c}\right]^2+\left(\frac{m'_x\pi}{a}\right)^2}\left[\frac{(-\alpha_x+i)\omega}{U_c}\sin\left(\frac{m'_x\pi x_{p_i}}{a}\right)-\frac{m'_x\pi}{a}\cos\left(\frac{m'_x\pi x_{p_i}}{a}\right)\right], \quad \text{(B.10)}$$

$$C_{x_8}(\omega,m')=\frac{e^{\frac{(x_{p_i}+a)(\alpha_x+i)\omega}{U_c}}}{\left[\frac{(\alpha_x+i)\omega}{U_c}\right]^2+\left(\frac{m'_x\pi}{a}\right)^2}\left\{\frac{(\alpha_x+i)\omega}{U_c}\sin\left[\frac{m'_x\pi(x_{p_i}+a)}{a}\right]-\frac{m'_x\pi}{a}\cos\left[\frac{m'_x\pi(x_{p_i}+a)}{a}\right]\right\}-\frac{e^{\frac{x_{p_i}(\alpha_x+i)\omega}{U_c}}}{\left[\frac{(\alpha_x+i)\omega}{U_c}\right]^2+\left(\frac{m'_x\pi}{a}\right)^2}\left[\frac{(\alpha_x+i)\omega}{U_c}\sin\left(\frac{m'_x\pi x_{p_i}}{a}\right)-\frac{m'_x\pi}{a}\cos\left(\frac{m'_x\pi x_{p_i}}{a}\right)\right], \quad \text{(B.11)}$$

and

$$C_{y_1}(\omega,m)=\frac{\frac{2\alpha_y\omega}{U_c}}{\left(\frac{\alpha_y\omega}{U_c}\right)^2+\left(\frac{m_y\pi}{b}\right)^2}, \quad \text{(B.12)}$$

$$C_{y_3}(\omega,m)=-\frac{e^{\frac{y_{p_i}\alpha_y\omega}{U_c}}}{\left(\frac{\alpha_y\omega}{U_c}\right)^2+\left(\frac{m_y\pi}{b}\right)^2}\left[\frac{\alpha_y\omega}{U_c}\sin\left(\frac{m_y\pi y_{p_i}}{b}\right)-\frac{m_y\pi}{b}\cos\left(\frac{m_y\pi y_{p_i}}{b}\right)\right], \quad \text{(B.13)}$$

$$C_{y_4}(\omega,m)=-\frac{e^{-\frac{(y_{p_i}+b)\alpha_y\omega}{U_c}}}{\left(\frac{\alpha_y\omega}{U_c}\right)^2+\left(\frac{m_y\pi}{b}\right)^2}\left[\frac{\alpha_y\omega}{U_c}\sin\left(\frac{m_y\pi(y_{p_i}+b)}{b}\right)+\frac{m_y\pi}{b}\cos\left(\frac{m_y\pi(y_{p_i}+b)}{b}\right)\right], \quad \text{(B.14)}$$

$$C_{y_5}(m,m')=\begin{cases}\frac{b}{2}, & \text{for } m_y=m'_y\\ \mathrm{Const.}_{y_5}, & \text{for } m_y\neq m'_y\end{cases} \quad \text{(B.15a)}$$

with:

$$\mathrm{Const.}_{y_5}=\frac{-\sin\left[(m'_y+m_y)\frac{\pi}{b}(y_{p_i}+b)\right]+\sin\left[(m'_y+m_y)\frac{\pi}{b}y_{p_i}\right]}{2(m'_y+m_y)\frac{\pi}{b}}+\frac{\sin\left[(m'_y-m_y)\frac{\pi}{b}(y_{p_i}+b)\right]-\sin\left[(m'_y-m_y)\frac{\pi}{b}y_{p_i}\right]}{2(m'_y-m_y)\frac{\pi}{b}}, \quad \text{(B.15b)}$$

$$C_{y_7}(\omega,m')=\frac{e^{-\frac{(y_{p_i}+b)\alpha_y\omega}{U_c}}}{\left(\frac{\alpha_y\omega}{U_c}\right)^2+\left(\frac{m'_y\pi}{b}\right)^2}\left\{-\frac{\alpha_y\omega}{U_c}\sin\left[\frac{m'_y\pi(y_{p_i}+b)}{b}\right]-\frac{m'_y\pi}{b}\cos\left[\frac{m'_y\pi(y_{p_i}+b)}{b}\right]\right\}+\frac{e^{-\frac{y_{p_i}\alpha_y\omega}{U_c}}}{\left(\frac{\alpha_y\omega}{U_c}\right)^2+\left(\frac{m'_y\pi}{b}\right)^2}\left[\frac{\alpha_y\omega}{U_c}\sin\left(\frac{m'_y\pi y_{p_i}}{b}\right)+\frac{m'_y\pi}{b}\cos\left(\frac{m'_y\pi y_{p_i}}{b}\right)\right], \quad \text{(B.16)}$$

$$C_{y_8}(\omega,m')=\frac{e^{\frac{(y_{p_i}+b)\alpha_y\omega}{U_c}}}{\left(\frac{\alpha_y\omega}{U_c}\right)^2+\left(\frac{m'_y\pi}{b}\right)^2}\left\{\frac{\alpha_y\omega}{U_c}\sin\left[\frac{m'_y\pi(y_{p_i}+b)}{b}\right]-\frac{m'_y\pi}{b}\cos\left[\frac{m'_y\pi(y_{p_i}+b)}{b}\right]\right\}-\frac{e^{\frac{y_{p_i}\alpha_y\omega}{U_c}}}{\left(\frac{\alpha_y\omega}{U_c}\right)^2+\left(\frac{m'_y\pi}{b}\right)^2}\left[\frac{\alpha_y\omega}{U_c}\sin\left(\frac{m'_y\pi y_{p_i}}{b}\right)-\frac{m'_y\pi}{b}\cos\left(\frac{m'_y\pi y_{p_i}}{b}\right)\right]. \quad \text{(B.17)}$$

For random incident white noise, the external PSD excitation may be defined as

$$S_{ext}=\frac{4\,S_{ref}}{a\,b}\left[\iint_{x_{p_i}}^{x_{p_f}}\sin\left(\frac{m_x\pi\,x}{a}\right)\sin\left(\frac{m'_x\pi\,x'}{a}\right)dx\,dx'\iint_{y_{p_i}}^{y_{p_f}}\sin\left(\frac{m_y\pi\,y}{b}\right)\sin\left(\frac{m'_y\pi\,y'}{b}\right)dy\,dy'\right], \quad \text{(B.18)}$$

which analytically developed results in the following expression

$$S_{ext}=\left[\frac{4\,a\,b\,S_{ref}}{m_x\,m'_x\,m_y\,m'_y\,\pi^4}\left\{\cos\left(\frac{m_x\pi(x_{p_i}+a)}{a}\right)-\cos\left(\frac{m_x\pi\,x_{p_i}}{a}\right)\right\}\left\{\cos\left(\frac{m'_x\pi\,(x_{p_i}+a)}{a}\right)-\cos\left(\frac{m'_x\pi\,x_{p_i}}{a}\right)\right\}\left\{\cos\left(\frac{m_y\pi\,(y_{p_i}+b)}{b}\right)-\cos\left(\frac{m_y\pi\,y_{p_i}}{b}\right)\right\}\left\{\cos\left(\frac{m'_y\pi\,(y_{p_i}+b)}{b}\right)-\cos\left(\frac{m'_y\pi\,y_{p_i}}{b}\right)\right\}\right], \quad \text{(B.19)}$$

where S_{ref} is the constant PSD amplitude of the normally impinging noise on the plate.

C. Analytical expressions for $S_{ww}(\omega)$ and $S_{pp}(\omega)$ functions

The plate overall displacement PSD function, $S_{ww}(\omega)$, was previously defined by Eq. (31). In order to obtain the final analytical expression for this function, one must substitute Eqs. (6) into Eq. (29), and then integrate over the plate area, as shown in Eq. (31). Doing this, the final expression for $S_{ww}(\omega)$ is

$$S_{ww}(\omega)=\frac{4ab}{\pi^4}\sum_{m_{x_1},m_{x_2}=1}^{M_x^2}\sum_{m_{y_1},m_{y_2}=1}^{M_y^2}\frac{\mathbf{S_{WW}}(\omega)_{m_1,m_2}}{m_{x_1}m_{x_2}m_{y_1}m_{y_2}}\cos\left(\frac{m_{x_1}\pi x_{p_i}}{a}\right)\cos\left(\frac{m_{x_2}\pi x_{p_i}}{a}\right)\cos\left(\frac{m_{y_1}\pi y_{p_i}}{b}\right)\cos\left(\frac{m_{y_1}\pi y_{p_i}}{b}\right)[\cos(m_{x_1}\pi)-1][\cos(m_{x_2}\pi)-1][\cos(m_{y_1}\pi)-1][\cos(m_{y_2}\pi)-1]\,. \tag{C.1}$$

with each matrix component $\mathbf{S_{WW}}(\omega)_{m_1,m_2}$ corresponding to the respective element of the matrix previously defined in Eq. (24).

Similarly, the analytical expression for the enclosure overall pressure PSD function, $S_{pp}(\omega)$, may be obtained by replacing Eqs. (10) into Eq. (30), and then integrating over the enclosure volume, as shown in Eq. (32). It can be shown that the final analytical expression for $S_{pp}(\omega)$ is

$$S_{pp}(\omega)=\frac{L_xL_yL_z}{8}\sum_{n_{x_1},n_{x_1}=1}^{N_x^2}\sum_{n_{y_1},n_{y_1}=1}^{N_y^2}\sum_{n_{z_1},n_{z_1}=1}^{N_z^2}A_{n_{x_1}}^2A_{n_{y_1}}^2A_{n_{z_1}}^2\mathbf{S_{PP}}(\omega)_{n_1,n_2} \tag{C.2}$$

with each matrix component $\mathbf{S_{PP}}(\omega)_{n_1,n_2}$ corresponding to the respective element of the matrix previously defined in Eq. (25).


GOAL:
✓ REDUCE NOISE
✓ REDUCE WEIGHT
✓ REDUCE COST
✓ INCREASE CUSTOMER PROFITS

ACOUSTICS STANDARDS ACTIVITY IN CANADA - 2009

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ABSTRACT

2009/2010 will be a critical year for Acoustical Standards activity in Canada. Traditionally organised under the auspices of the CSA Z107 Technical Committee, these activities may have to find a new home due to budget constraints, either within an expanded Z94.2 committee devoted to hearing conservation or within a reformed Canadian Committee on Standards within the CAA. The final form of this change will become clear in the first few months of 2010.

1. INTRODUCTION

For over 30 years the Canadian Standards Association (CSA) Technical Committee Z107 – Acoustics and Noise Control and its subcommittees have looked after all but one of the 10 Canadian Acoustics Standards (the exception is Z94.2 Hearing Protection Devices, which has its own technical committee) and coordinated other acoustical standards activities. This year, due to budget constraints, the Environment group of CSA has informed the Z107 committee that they can no longer support its activities. Since there is no "White Knight" available to fund its activities, we are looking with CSA at what can be done to find new homes to those activities which can be preserved and decide what standards must be dropped.

At present, CSA is looking at the possibility that Z94.2, the hearing protection committee, can be expanded to encompass Hearing Conservation standards under its Strategic Steering Committee for Occupational Health and Safety Standards. This would expand this group to include three Canadian standards:

Z94.2 – Hearing Protection Devices – Performance, Selection Care and Use, the best selling CSA acoustics standard, referred to in many provincial health and safety regulations, this standard sets out the unique A, B, C designations for hearing protectors.

Z107.56 – Guidelines for Measurement of Occupational Noise Exposure, Z107's top selling standard, again referred to in Federal and Provincial regulations and the first standard of its kind we know of in the world. Its basic approach is now found in many different occupational noise measurement standards around the world, including ANSI and ISO.

Z107.58 - Noise Emission Declarations for Machinery, the newest Canadian acoustics standard, helps customers to buy and manufacturers to certify quiet equipment for industry. Health Canada is expected to shortly come out with a technical guideline promoting its voluntary use. In the European Union, the ISO standards which it summarises are law.

CAN3-Z107.4-M86 - Pure Tone Air Conduction Audiometers for Hearing Conservation and for Screening and CAN/CSA-Z107.6-M90 Pure Tone Air Conduction Threshold Audiometry for Hearing Conservation, are not widely used and while they fit within a Hearing Conservation committee, they might be replaced with similar international or US standards.

This combination of standards would cover measuring noise exposure, buying quiet equipment, hearing protection and measurement of hearing loss, basically the activities required for hearing conservation in industry. As such, they would make a sensible package of acoustical standards to be looked after within the auspices of the CSA Strategic Steering Committee for Occupational Health and Safety Standards.

A final standard, Z107.52-M1983 (R1994) Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources would fit within this group, but it is quite out of date and as Z107 could not identify any group willing to take it on, it is unlikely it would be transferred to Z94.2.

There is also an Acoustics chapter within the CSA Office Ergonomics standard, written by a working group from Z107. It is likely this group would now be appointed by Z94.2.

The other Z107 standards consist mostly of standards relating to environmental noise, an area outside the purview of Health and Safety. They include:

- CAN3-Z107.54-M85 (R1993) Procedure for Measurement of Sound and Vibration Due to Blasting Operations. This standard requires revision but is referred to by Ontario noise guidelines. It may be withdrawn.
- CAN/CSA-Z107.9-00: Standard for Certification of Noise Barriers. This standard provides municipalities,

developers, road and highway departments, railways and industry with a standard specification which can be used to define the construction of barriers intended to be durable enough for long term use in Canadian conditions. It has been widely cited in both Canada and the US. Specifically it is quoted verbatim in Ottawa regulations and forms the basis for the US Highway Barrier Design Manual. This standard might be suitable for the CSA Built Environment committee.

- Wind Turbines – A group chaired by Brian Howe assisted the CSA wind turbine committee with the acoustical aspects of their standards, specifically with adopting the ISO measurement procedures in ISO 61400.
- ISO 1996 Description, Measurement and Assessment of Environmental Noise has been endorsed by CSA. This endorsation may now be withdrawn. If it is, it will be recommended within Standard Z107.10, discussed below.

In addition, Z107 has traditionally been a venue for reviewing other Canadian standards activities. As such it has subcommittees providing liaison with Canadian Advisory Committees to related ASTM, ISO and IEC committees specifically in Building Acoustics, Instrumentation, Acoustics and Noise. These advisory committees are run by the Standards Council of Canada and are harmonised with the Z107 committee to which they have reported regularly on progress and upcoming issues. Draft international standards are provided on a private website to which members have access in order to review them and recommend Canada's position. It would be useful if these groups could find a home within Z94.2, but they are somewhat broader in scope than just Health and Safety.

The Canadian Acoustical Association (CAA) has agreed in principle to provide a home for those acoustical standards activities not picked up by CSA and to continue the coordinating role carried out by Z107. CAA was originally founded as the Canadian Committee on Standards until it transferred this role to Z107 and since then the two groups have had close ties, with the Z107 meeting being held each year as part of the CAA Acoustics Week in Canada conference.

One standard which would clearly fall within CAA's scope would be Z107.10, Guide for the Use of Acoustical Standards in Canada. This standard is intended to be a review of Canadian and International acoustical standards judged suitable for use in Canada and includes references on the scope of each standard and notes on their use in a Canadian context. The intent was to make this an online standard, upgraded each year and with references to the standards writing organisations where each standard could be purchased. So far, it has been limited to a static paper or pdf version which is slow to update, especially when CSA has no funds for such work. Given the ease of online publication, this is a natural standard for CAA to take over. It can be updated just as originally planned, and published on the CAA website. Available at little or no cost to acousticians and the general public, both in Canada and around the world, this standard's wider availability would promote the use of acoustical standards and also provide a useful service to CAA members, especially the consulting community.

The CSA is one of only four standards writing organisations accredited by the Standards Council of Canada and as such is entitled to write standards which can become National Standards of Canada. While the CAA can prepare standards useful to its members and others willing to use them, its standards will not become National Standards of Canada. This makes it less likely such standards will be recognised in legislation. However it can continue to coordinate the various groups representing Canada on Canadian, US and International standards committees.

This summary outlines the present situation as of December 3, 2009 following a meeting with CSA. Until CSA decides what they wish to do in terms of expanding Z94.2, which will likely happen before March 2010, there is the possibility of further change. However, within CSA or within CAA the acoustical standards activities and coordination will continue. The next full meeting is expected to be in October during the Victoria conference.

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CANADA WIDE SCIENCE FAIR

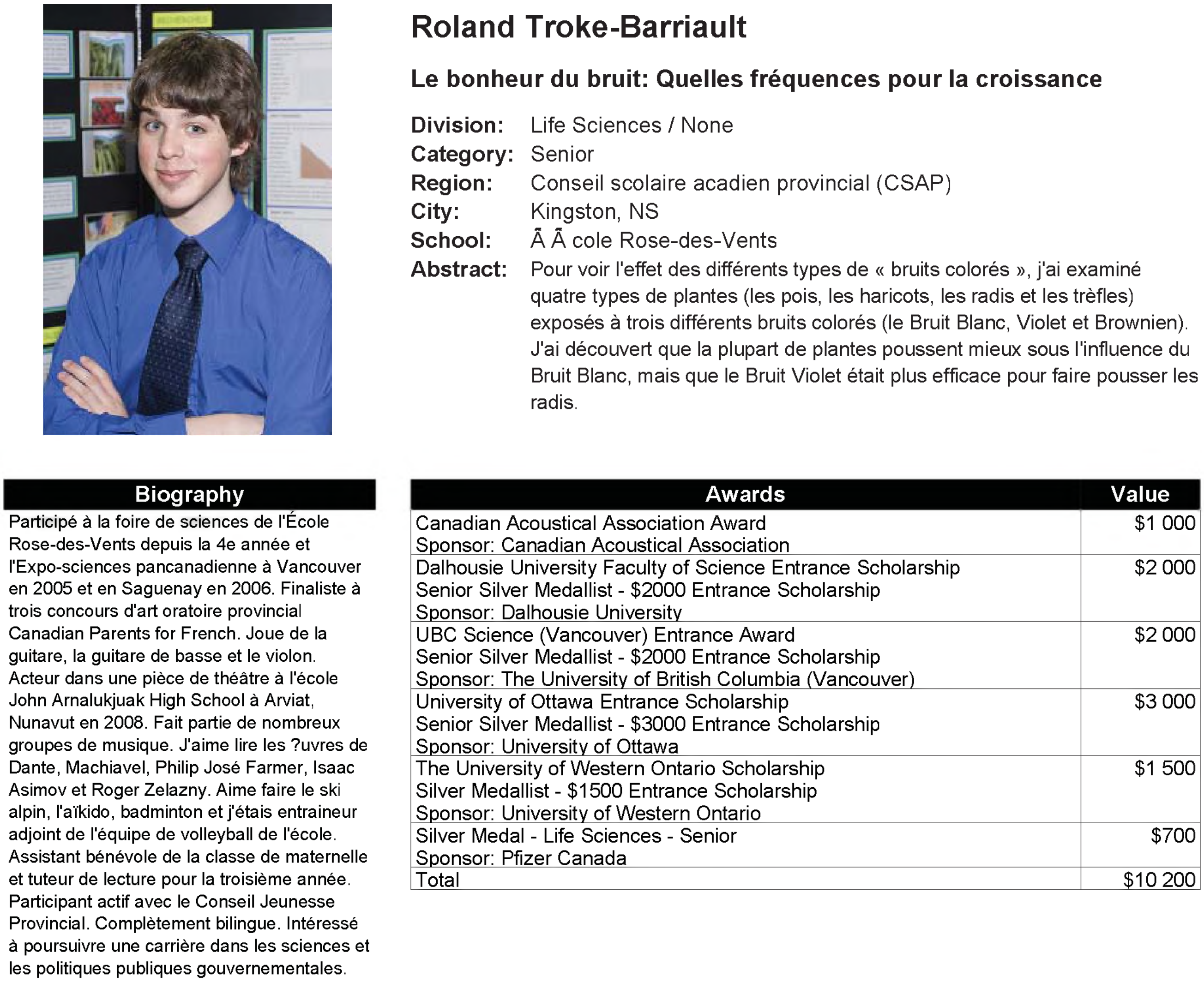
From File Reports

Roland Troke Barriault is the winner of this year's Special Award from the Canadian Acoustics Association for his project on sound and plant growth, called "Happiness of noise: Frequencies for growth".

Roland Troke Barriault is a grade twelve student from Kingston, Nova Scotia. He participated at the Ecole Rose–des-Vents science fairs since 4th grade and participated at the Canada Wide Science Fairs in Vancouver in 2005, Saguenay in 2006, and Winnipeg in 2009. Finalist of three NS Concours d'art Oratoire (Public speaking competitions) organized by the Canadian Parents for French. Actor in the John Arnalukjuak High School Theatrical Group and a finalist in the Skills Canada Competition in Nunavut in 2008. Student Representative on the Comité d'École Consultatif (school advisory committee) and Student Council Treasurer. Active participant with the Conseil Jeunesse Provincial and represented Nova Scotia at the 2007 Parliament Jeunesse. Enjoys the written works of Dante, Machiavelli, Philip Jose Farmer, Isaac Asimov and Roger Zelazny. Plays guitar, bass and violin and active in several musical bands. Participates in downhill skiing, Aikido, badminton and is a former assistant coach for the ERdV junior male volleyball team. Classroom assistant for the ERdV kindergarten and reading tutor for third graders. Received the Queen Elizabeth the II medal and is a Millennium Excellence Laureate. Awarded the UOttawa Dean's Merit and Renewable Admissions Scholarships, Conseil scolaire acadien provincial Bursary for excellence in French, Kingston Lion's Club Bursary and ÉRdV Parents Committee Bursary for community volunteer work and sustained academic achievement. Active in the UOttawa Debating Society. Completely bilingual and interested in pursuing a career in the sciences, as well as in politics..

Roland's full article will appear in French in the June 2010 issue of Canadian Acoustics.

His winning project's abtarct is: To observe the effect of different types of "coloured" noises, I examined four types of plants (peas, beans, radishes and shamrocks) exposed to three varieties of "coloured" noise (white noise, violet noise and Brownian noise). I discovered that most plants grew better when exposed to white noise, but that violet noise was more efficient at stimulating radish growth.



Roland Troke-Barriault

Le bonheur du bruit: Quelles fréquences pour la croissance

Division: Life Sciences / None
Category: Senior
Region: Conseil scolaire acadien provincial (CSAP)
City: Kingston, NS
School: Ã Ã cole Rose-des-Vents
Abstract: Pour voir l'effet des différents types de « bruits colorés », j'ai examiné quatre types de plantes (les pois, les haricots, les radis et les trèfles) exposés à trois différents bruits colorés (le Bruit Blanc, Violet et Brownien). J'ai découvert que la plupart de plantes poussent mieux sous l'influence du Bruit Blanc, mais que le Bruit Violet était plus efficace pour faire pousser les radis.

Biography

Participé à la foire de sciences de l'École Rose-des-Vents depuis la 4e année et l'Expo-sciences pancanadienne à Vancouver en 2005 et en Saguenay en 2006. Finaliste à trois concours d'art oratoire provincial Canadian Parents for French. Joue de la guitare, la guitare de basse et le violon. Acteur dans une pièce de théâtre à l'école John Arnalukjuak High School à Arviat, Nunavut en 2008. Fait partie de nombreux groupes de musique. J'aime lire les ?uvres de Dante, Machiavel, Philip José Farmer, Isaac Asimov et Roger Zelazny. Aime faire le ski alpin, l'aïkido, badminton et j'étais entraineur adjoint de l'équipe de volleyball de l'école. Assistant bénévole de la classe de maternelle et tuteur de lecture pour la troisième année. Participant actif avec le Conseil Jeunesse Provincial. Complètement bilingue. Intéressé à poursuivre une carrière dans les sciences et les politiques publiques gouvernementales.

Awards	Value
Canadian Acoustical Association Award Sponsor: Canadian Acoustical Association	$1 000
Dalhousie University Faculty of Science Entrance Scholarship Senior Silver Medallist - $2000 Entrance Scholarship Sponsor: Dalhousie University	$2 000
UBC Science (Vancouver) Entrance Award Senior Silver Medallist - $2000 Entrance Scholarship Sponsor: The University of British Columbia (Vancouver)	$2 000
University of Ottawa Entrance Scholarship Senior Silver Medallist - $3000 Entrance Scholarship Sponsor: University of Ottawa	$3 000
The University of Western Ontario Scholarship Silver Medallist - $1500 Entrance Scholarship Sponsor: University of Western Ontario	$1 500
Silver Medal - Life Sciences - Senior Sponsor: Pfizer Canada	$700
Total	$10 200

OBITUARY / OBITUAIRE - EDGAR SHAW

SHAW, Edgar Albert George, BSc, PhD, FRSC;
July 10 1921 - October 18 2009.

Beloved husband of the late Millicent (Chandler) Shaw, Edgar Shaw died peacefully in hospital on the evening of October 18th, 2009 with the love of his family by his side. Dr. Shaw was born in Teddington, Middlesex, England. He began his formal education as a scholarship student at Harrow School and finished it by completing a doctorate at Imperial College, London. Edgar's informal learning continued throughout his life. He was deeply interested in a variety of subjects including; mycology, carpentry and the interplay of science and religion. His interest in the visual arts ran from Inuit art to Diane Arbus to Rembrandt. On the musical side, he was a long time supporter of the Ottawa Symphony Orchestra, and the National Arts Centre Orchestra. During World War II, Edgar served with the British Ministry of Aircraft Production. His work on the development of radar in London, Washington DC and New York City, was vital to the war effort. Dr. Shaw had a long and successful career in acoustics during his employment at the National Research Council (NRC) in Ottawa.

Prepared by:

Edgar Shaw's family

Dr. Edgar Shaw was a remarkable scientist, a supportive co-worker, a gentle teacher, and a good friend. He is commonly referred to as a "gentleman" by colleagues from around the world.

Edgar was highly-regarded internationally for his careful and definitive research. In recognition, he was elected Fellow of the Royal Society of Canada in 1975 and received the Rayleigh medal from the Institute of Acoustics (UK) in 1979.

His work was often ahead of his time. For example, his research on the directional listening properties of the ear was always recognized as being of the highest quality but only in recent years has this work been exploited. Now, every product on the market that creates realistic, three-dimensional sound and every paper on the subject of head-related transfer functions can be traced back to Edgar's pioneering studies.

He was an inventor. The probe microphone that he developed to measure sound around the ear was innovative. His approach was subsequently taken up by Brüel and Kjær and their probe microphone is now marketed worldwide.

His research spanned many areas of acoustics. He has studied hearing protectors and earphones, the measurement of hearing (audiometry), the vibrational behaviour of the violin, occupational noise exposure, the effect of noise on birds, noise exposure in the community, and more. A prevailing theme can be recognized: it is his concern for the human condition. Edgar was a humanitarian and he wanted his work to benefit his fellow humans.

Edgar had a long and successful career in acoustics at the National Research Council (NRC). He began in 1951 after emigrating from the United Kingdom. From 1975 to 1986 he was Head of the Acoustics Section in what was then the Division of Physics. Many of us were fortunate to work with Edgar. He collaborated and published with other members of the lab, including George Thiessen, Joe Piercy, Nils Olson, and Mike Stinson. But his influence was felt beyond these formal interactions. He was available to everyone at all times, to provide practical and knowledgeable advice and guidance. After his retirement in 1986, Edgar continued to come in to the lab, as a Researcher Emeritus.

Edgar Shaw gave service to the field of acoustics at the highest level. He served as President of the Acoustical Society of America and as President of the International Commission for Acoustics. The Canadian Acoustical Association established the annual Edgar and Millicent Shaw Postgraduate Prize in Acoustics in his honour.

Most important of all, we will keep a fond memory of Edgar Shaw in our hearts.

Prepared by:

Mike Stinson, National Research Council of Canada, and

Gilles Daigle, National Research Council of Canada

OBITUARY / OBITUAIRE - ELZABIETA SLAWINSKI

Elzbieta Slawinski:
September 14, 1938 - November 9, 2009.

Elzbieta passed away peacefully in Calgary on Monday, November 9, 2009. She is survived by her husband Andrzej, her two sons Michael and Raphael and their spouses Elena and Vera, and family members in Canada and Poland. She was born in Warsaw, Poland, in 1938, and it was there that she completed her university studies, earning a doctorate in Natural Sciences in 1978. In 1982, with her husband and sons, she immigrated to Canada and settled in Calgary. In 2005 she retired from the University of Calgary as a Professor Emeritus of Psychology. She was a dedicated teacher and researcher, and mentored a number of graduate students. Elzbieta was a woman of many interests and talents. She gave shelter to and cared for many abandoned animals; she actively supported the Humane Society and wildlife conservation. An outstanding climber and skier during her youth, she never lost her passion for the outdoors, and indulged it in Europe, North Africa, Oceania, and South and North America.

Prepared by:

Elzbieta's family

ICSV 17

THE 17th INTERNATIONAL CONGRESS ON SOUND & VIBRATION

CAIRO 18 - 22 JULY, 2010

Call for Abstracts

All potential attendees are invited to submit an abstract (300 words maximum) related to the congress topics before the extended abstract deadline of 31 January, 2010. The 27 regular session topics and 35 special structured session topics can be found on the ICSV17 website at www.icsv17.org/index.php/ICSV17/ICSV17 Authors of accepted abstracts will be asked to submit their full papers to the ICSV17 website later.

Invitation:

We are pleased to welcome you to the 17th International Congress on Sound and Vibration (ICSV17) to be held in Cairo, Egypt, from 18 to 22 July 2010. ICSV17 is one of the largest congresses in the world in the fields of acoustics, noise and vibration, and therefore is a major opportunity for you to present your latest results and learn about the most advanced theories, technologies and applications. It is the annual premier world event organized by the International Institute of Acoustics and Vibration (IIAV).

Under the Auspices of:

- International Institute of Acoustic and Vibration (IIAV); The Acoustical Society of Egypt
- Ain Shams University and Nile University

In Cooperation with:

International Union of Theoretical and Applied Mechanics (IUTAM); American Society of Mechanical Engineers International (ASME International); and Institution of Mechanical Engineers (IMechE)

The Soundscape: Our Sonic Environment and the Tuning of the World

By R. Murray Schafer

Destiny Books, 1994. xii + 301 pp. Price: US$16.95

ISBN: 089281455-1

It was with caution that I walked, with the aid of my silent guide, blindfolded around Niagara-On-The-Lake accompanying composer and author Murray Schafer on an acoustic walk organized as part of this year's Acoustics Week In Canada. Along the way, in which I predicted on the basis of my own acoustic input I was on the edge of a great lake (later revealed to be a disused factory), he asked "Which of the sounds you heard was the further away?" Questions such as these reveal a commitment in Murray's work towards Clairaudience (or clean hearing), in which the listener learns to become acutely sensitive to their acoustic environment, with the ultimate aim of improving (rather than simply eradicating) the sonic world through better design.

In the first half of The Soundscape, Murray begins by reviving in us an appreciation of the breadth and depth of acoustic stimulation in nature using evocative historical and literary examples and then slowly reveals how man has influenced the sonic environment, first as a result of rural living and then via industrial and electrical revolutions as a result of urban living. Along the way, important perceptual and affective distinctions are made in the soundscape field, between both signals and keynotes: echoing the common visual distinction between figure and ground, and, between centripetal and centrifugal sounds: the church bell for example cited as both a call for community gathering but also as a repellant for evil and unwanted spirits.

The second half of the book is concerned with sound analysis and design. As a Psychologist interested in multi-modal perception, I benefitted particularly from reminders regarding the physical properties of stimulation that underscore the interaction between sound and the other senses. For example, very low frequency sounds share an integral relationship with tactile reception such that we feel them rather than hear them, something that Murray encapsulates in the phrase "touching at a distance" (p. 11). I was also intrigued in the description of certain communities (such as the Mabaan tribe in the Sudan) who do not express presbycusis, and the idea that towns can resonate certain acoustic frequencies and rhythms thereby continuing to underscore the relationship between sensory environment and individual perceptual systems. Other researchers in other domains will no doubt find other morsels of interest.

Not only is Murray responsible for coining the phrase Soundscape but he also established the World Soundscape Project at Simon Fraser University in the late 1960s (audio examples of which can be found at http://www.sfu.ca/~truax/wsp.html). One issue raised by this community was the lingering concern that sound recording should not only be a way to analyze, understand and predict our acoustic world, but it should also serve a way to preserve it. Murray lists a number of sound events saved from extinction as a result of the Project including "The ringing of old cash registers…Razors being stropped…The quiet explosion of old cameras" (p. 209). In addition to sound preservation, Murray also a secondary aim of the Project with respect to sound classification (Chapter Nine) in which tensions between (psycho)acoustic, semantic and aesthetic levels of analysis are identified.

For a book containing observations on the sonic environment as it was at least 15 years ago (after its initial publication in 1977 copyright on the book was reasserted in 1994), one may be initially skeptical regarding its current utility, yet there is much to recommend here. In fact, it is often this very quality that highlights the pervasive nature of many of the issues raised in the book. For example, on the design of the ubiquitous telephone signal Murray prophesizes: "If we must be distracted ten or twenty times each day, why not by pleasant sounds? Why could not everyone choose his or her own telephone signal? In a day when cassettes and tape loops are cheap to manufacture this is entirely feasible" (p. 242). While it has been sound digitization that has led to this eventuality, the affective outcome of this kind of sonic selection may not have been as positive as initially imagined: as willing selectors of our own ring tones we may question the extent of pleasure derived as a function of repeated exposure, as unwilling listeners of other people's sound we must consider the impact of varied tastes in a shared acoustic environment. Other seemingly dated concerns regarding the use of compression and the rate of vocal delivery on the radio foreshadow current debates regarding the so-called 'loudness war' in which the dynamic range is compromised in the pursuit of increased intensity at the later stages of music production (Metallica's Death Magnetic being a recent example), and also concerns regarding the upper limit of own our speech comprehension in an increasingly frenetic soundfield. His commentary on the use of headphones is ambivalent and remains of contemporary relevance, at once drawing attention to the liberating but isolating experience of localizing sound events within the head "…he (sic) is no longer regarding events on the acoustic horizon…He is the sphere. He is the universe…But only when he releases the experience by pronouncing…or singing…does he take his place again with humanity" (p. 119).

In the absence of attending one of Murray's acoustic walks and the active listening that ensues, The Soundscape will remind the reader of the variety of semantic and affective information that sound can provide, in addition to connecting seemingly disparate acoustic events (I was particularly taken with the analogy between the combustion engine and the fart; p. 84). As Murray states, "all research into sound must conclude with silence" (p. 12), as must all books and, indeed, all book reviews. However, consideration of the soundscape raises a lingering set of issues for the acoustic community; issues that may not be easily addressed by a multi-disciplinary field but would nonetheless benefit from additional reflections against the current auditory environment.

Prepared by Dr. Ben Dyson

Ryerson University, Toronto.

What is new in Acoustics in Canada

Jérémie Voix – voix@caa-aca.ca

Hands off: Cellphone driving ban in effect in Ontario

Ontario joined Newfoundland, Nova Scotia, Prince Edward Island, and Quebec in applying new rules for drivers looking to place calls on the road. Other provinces are expected to join them. Statistics support the need for the ban. A recent study by the U. S. National Traffic Safety Administration found that 80 per cent of accidents were caused by “driver distraction”, which along with cell-phone use includes weather, grooming, advertising, smoking, driver fatigue and just about everything that you can see out the window of a car (e.g. shirtless people). “It is not safe to be texting, e-mailing or dialling a phone when you are driving a vehicle,” Transportation Minister Jim Bradley told the public.

[Source: “R U L8? Keep your hands on the wheel”. Andrew Clark. Published on Monday, Nov. 09, 2009 11:33AM EST http://www.theglobeandmail.com/globe-drive/car-life/road-sage/r-u-l8-keep-your-hands-on-the-wheel/article1356598/ Accessed 20091109]

The link with acoustics? Well, Ontario drivers are still allowed to use “hands-free” devices, though some experts believe these are just as distracting, which is clearly an interesting technical challenge, from an acoustical point of view.

Agenda : conférence internationale sur les zones calmes

La Ville de Paris, en collaboration avec le Centre d'information et de documentation sur le bruit et Bruitparif, organise le 5 février 2010 une journée de réflexion sur les zones calmes. Les débats seront largement alimentés par la présentation de retours d'expérience français (Paris, Lyon, Rennes, Strasbourg) et européens (Florence, Oslo, Bruxelles, Hambourg). Ce rendez-vous sera notamment l’occasion de faire un bilan des retours d'expérience des collectivités françaises et européennes ayant déjà élaboré leur Plan de Prévention du bruit dans l'Environnement.

[Source: http://www.bruit.fr/FR/info/Actualites/de/la/gestion/des/nuisances/sonores/1653/12 Dernière consultation : 20091101]

Is your iPod damaging your hearing?

The European Union announced last September that it is capping the volume of such devices after an EU scientific committee warned that prolonged exposure to loud noise from the music players could cause permanent hearing damage. The new rules will require manufacturers to set the maximum volume of personal music players at a safe default level, defined by the scientific committee as either 80 decibels adjusted for exposure limited to 40 hours a week or 89 decibels adjusted for exposure limited to five hours a week. While it might be flawed, Canadian audiologists and hearing-loss-prevention advocates say Canada could learn a valuable lesson from the EU's pro-active stance on noise levels from personal music players. Canada has no rules to govern the volume of the devices – and that is putting the hearing of countless Canadians in jeopardy, experts say. The problem is that many people listen to them on buses, subways, trains and in other loud environments, where they have to turn them up to drown out the noise.
[Source : “Is your iPod damaging your hearing? - The Globe and Mail.” Accessed 20090930 http://www.theglobeandmail.com/life/health/is-your-ipod-damaging-your-hearing/article1304666/]

Vancouver 2010 Cultural Olympiad adds over 70 new projects to eclectic line-up

The Vancouver 2010 Cultural Olympiad is adding more international flair to its impressive line-up of music, theatre, visual arts, dance, and digital programming in its largest announcement of 2010 projects to date - more than 70, including some creative experience: a cell-phone turns into a musical instrument, enabling the user to create a symphony of sound; a green thumb goes to new levels playing with virtual acoustic plants...

[Source: www.vancouver2010.com/culturalolympiad 20091027]

CAA signs Cooperative agreement with IIAV

The Canadian Acoustical Association signed a collaborative agreement with the International Institute of Acoustics and Vibration (IIAV). The two organisations will cooperate in advertizing each other's congresses on printed material and respective websites and in increasing information exchange on matters of mutual interest in the area of acoustics and vibration. About 40 scientific organizations and societies are cooperating with IIAV. For more information about the Institute and its activities, consult www.iiav.org.

L'ACA signe un accord de coopération avec IIAV

L'Association Canadienne d'Acoustique (ACA) a signé un accord de collaboration avec l'Institut international d'Acoustique et Vibration (IIAV). Les deux organisations vont coopérer en faisant la promotion mutuelle de leur congrès sur le matériel imprimé et leurs sites Web respectifs et vont également accroître l'échange d'informations sur des questions d'intérêt mutuel dans le domaine de l'acoustique et des vibrations. Environ 40 organisations scientifiques et sociétés coopèrent avec l'IIAV. Pour plus d'information sur l'Institut et ses activités, consultez www.iiav.org.

Canadian Acoustical Association
Association Canadienne d'Acoustique

PRIZE ANNOUNCEMENT • ANNONCE DE PRIX

Prize

EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS
ALEXANDER G. BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND HEARING
ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL
FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS
RAYMOND HETU UNDERGRADUATE STUDENT PRIZE IN ACOUSTICS

Prix

PRIX POST-DOCTORAL EDGAR ET MILLICENT SHAW EN ACOUSTIQUE
PRIX ETUDIANT ALEXANDER G. BELL EN COMMUNICATION ORALE ET AUDITION (2E OU 3E CYCLE)
PRIX ETUDIANT ECKEL EN CONTROLE DU BRUIT (2E OU 3E CYCLE)
PRIX ETUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE (2E OU 3E CYCLE)
PRIX ETUDIANT RAYMOND HETU EN ACOUSTIQUE (1ER CYCLE)

Deadline for Applications:
April 30th 2010

Date limite de soumission des demandes:
30 Avril 2010

Consult CAA website for more information
Consultez le site Internet de l'ACA pour de plus amples renseignements
(http://www.caa-aca.ca)

Canadian Acoustical Association

Minutes of the Board of Directors Meeting
13 October 2009
Niagara-on-the-Lake, Ontario

Present: Christian Giguère (chair), David Quirt, Rich Peppin, Stan Dosso, Roberto Racca, Tim Kelsall, Ramani Ramakrishnan, Frank Russo, Jérémie Voix

Regrets: Clair Wakefield, Vijay Parsa, Sean Pecknold, Dalila Giusti

The meeting was called to order at 5:02 p.m. Minutes of previous Board of Directors meeting on 25 April 2009 were approved as published in June 2009 issue of *Canadian Acoustics*. *(Moved by S. Dosso, seconded R. Racca, carried).*

President's Report

Christian Giguère reported that there have been no major problems in the affairs of the Association. There has been progress on two current priorities: to develop promotional materials for our Association and to enhance the website with online database and payment features. The former was discussed under Other Business, the latter as an extension of the Secretary's report.

Secretary's Report

David Quirt reported that routine processes of the Association are proceeding with few problems. With respect to routine CAA communications:

- Annual filing with Corporations Canada was submitted and acknowledged.
- Invoices from I-INCE and ICA were received and our Treasurer handled payment.

Issues of Noise News International were mailed to 36 members who requested this option; they arrived from the publisher in the USA about 3-6 months after the cover date. Cost of mailing was covered by the $10 supplementary fee paid by those requesting NNI. Next year NNI moves to electronic publishing, which should eliminate the cost for this distribution activity.

Secretarial operating costs for the fiscal year ended in August totaled $1175 (~20% below last year), mainly for mailing costs and postal box rentals. Given the expected reduction in mailing costs when NNI distribution is stopped, a budget of $1000 is proposed for next fiscal year.

David reported that paid new memberships and renewals are unchanged from last year (318), but there were fewer non-member registrants for the Vancouver conference than at Montreal, so the nominal total membership has dropped. Last year the total was 407 on 4 October, and this year's paid-up total on that date is 374. Essentially, the Association's core membership is constant.

Mailing List (30 Sept.)	**Canada**	**USA**	**Other**	**Change**
Member	217	17	11	**-12**
Student	54	3	3	**-19**
Sustaining	38	3	1	**– 1**
Subscribers	14	9	4	**– 1**
			Total = 374	**-33**

As usual, this report prompted some discussion of possible changes in membership categories and promoting increased membership; in this context Rich suggested a brainstorming session at a future CAA meeting to identify key issues to promote membership. Rich also noted continued interest in adding new categories such as Fellow and Life Membership. There was support for these ideas, but action on new categories was deferred to the next meeting, after implementation of the new online database system. *(Approval of report moved by S. Dosso, seconded R. Racca, carried)*

Discussion then turned to features and cost of the proposed new online database and payment system. The ad hoc group (Christian, Dave, Dalila, Sean) appointed by the Board has investigated this issue and recommends selection of IRM – a

Canadian firm that handles online systems for many Canadian associations. The capabilities proposed at this stage are online database of members, membership payment, and event registration and payment for our conference. IRM also offers website hosting, but this is not recommended now, due to the considerable cost, and some questions about the match between available features and our needs. One-time setup fees for the proposed features would be $2500 (based on IRM's review of our current database structure), and the annual operating cost is $249 / month, plus transaction fees – a total of about $3500/year. It should be feasible to implement this system for the 2010 membership renewal process. *(Proceeding, as detailed in IRM proposal of 5 Oct., was moved by S. Dosso, seconded F. Russo, carried)*

The Board expressed a special vote of thanks to Dave Quirt for his continuing service as Acting-Secretary.

Treasurer's Report

The Treasurer, Dalila Giusti, submitted a report including a preliminary financial statement for the fiscal year. Most expenses were essentially as budgeted and revenue marginally exceeded income. The backlog of invoicing and payments for advertising in Canadian Acoustics has been eliminated. The 2008 conference (Vancouver) made a profit of $894 in addition to the fees for new members. Interest on the capital fund will exceed costs for student awards.

A change of financial year-end to 30 June has been proposed, to permit completion of the annual audit before the fall meeting. Members were duly notified of the proposed change by published announcements at the 2008 AGM and in the journal. (See AGM minutes.)

The proposed budget for 2009-2010 was also discussed. To offset costs of the proposed implementation of online services, a fee increase at the October AGM was suggested (See AGM minutes.)

The Treasurer's report was accepted. *(Moved F. Russo, seconded R. Peppin, carried)*

Editor's Report`

The Editor, Ramani Ramakrishnan, gave a brief report on issues related to Canadian Acoustics. Highlights included:

- All issues have been published on schedule.
- The implementation of online publication of the journal has not advanced significantly.
- There was brief discussion, commending the revamping of the news section of the journal, with less content on international conferences, but more content on regulations, standards, technical news, and other related societies pertinent to Canadian acousticians.
- In 2010, as usual, the June issue will feature content in French, and there will be a special issue focused on acoustical consulting.

The Board made a unanimous vote of thanks to Ramani for his continuing contributions.

CAA Conferences – Past, Present & Future

2008 (Vancouver): A final report for the conference has been received from Murray Hodgson, with the final $3800 transfer of funds. The Board thanked the organizers for the high quality of the meeting.

2009 (Niagara-on-the Lake): The conference at the Pillar and Post Inn on October 14-16 has 125 papers scheduled (including 48 student papers) and 12 exhibitors. Ramani Ramakrishanan is Chair, Frank Russo is Technical Chair, and Rich Peppin organized the exhibition. Extensive financial contributions to support the meeting include a grant from Ryerson University, sponsors for meeting rooms and coffee breaks, and sponsors for the student presentation awards.

2010 (Victoria): The conference will be on October 13-15 at the Laurel Point Inn, the site of the 1999 conference. Stan Dosso (Chair), Roberto Racca (Technical Chair), and Clair Wakefield are leading the team. A broad program—including several sessions on underwater acoustics— is planned. See the announcements in this and subsequent issues of *Canadian Acoustics* and on the website.

Subsequent meetings: Sites for later meetings were discussed. The preferred option for 2011 is a site in Québec, preferably the city of Québec, and key team members have been recruited.

Awards

Frank Russo presented a report summarizing decisions by the coordinators for all CAA awards. There were applications for all awards, and winners have been selected. Winners were announced on 15 October at the banquet, and in this issue of *Canadian Acoustics.* Increased public relations activity (via local press and university channels) is planned, to highlight the winners.

One change to the awards was proposed. It was agreed that the Directors' Award for best article by a professional in *Canadian Acoustics* should not be restricted to Members; conditions for the corresponding student award are unchanged. *(Moved R. Racca, second S. Dosso, carried)*

CAA Website

There was a brief discussion about the CAA website. Sean Pecknold has assumed the duties of Webmaster, and parts of the site have been restored and updated.

Other Business

There were several items of other business:

- Alberto Behar attended for a short time as a guest to suggest that CAA might wish to certify acousticians (as the Swiss Acoustical Society does). He volunteered to investigate and the board agreed that they would wait to see what he discovered.
- CSA Committee Z107 "Acoustics and Noise Control" is facing elimination, due to funding constraints at CSA. Some key standards such as Z107.56 may be transferred to another committee, but some parts will cease. CSA Z107 has been interlinked with CAA from CAA's beginning as the Canadian Committee on Standards. There was broad agreement that orphan parts of the Z107 activity should be assumed by CAA, but that forming a standards development committee accredited by SCC seems unrealistic. *(Approved in principle that CAA will re-assume those activities of Z107 that can be handled with negligible financial commitment, to coordinate Canadian activities on development and maintenance of standards. Moved T. Kelsall, seconded R. Peppin, carried)*
- Promotional materials were developed for distribution at the Inter-Noise '09 conference in Ottawa, including a new brochure in English and French. In this context our old logo was upgraded to high resolution (courtesy of IN'09) and the Board started a process to update the logo design. There was brief discussion of the 8 preliminary design concepts, and it was agreed to handle the selection and revision process by e-mail before the next meeting.
- Christian reported on his participation in the recent Board meeting of IIAV (International Institute of Acoustics and Vibration). The Board decided to accept the invitation to establish a formal agreement of cooperation with IIAV; there is no financial commitment. *(Moved R. Peppin, second R. Ramakrishnan, carried)*
- Stan led a brief discussion of nominations for the election at the Annual General Meeting (See AGM minutes for details).

Adjournment

Meeting adjourned at 10 p.m. *(Moved R. Ramakrishnan, seconded F. Russo, carried)*

Canadian Acoustical Association

Minutes of Annual General Meeting

Niagara-on-the-Lake, Ontario
15 October 2009

Call to Order

President Christian Giguère called the meeting to order at 6:33 p.m. with 30 members present. (Attendance swelled to 37 during the meeting)

Minutes of the previous Annual General Meeting on 07 October 2008 in Vancouver were approved as printed in the December 2008 issue of Canadian Acoustics. *(Moved by R. Peppin, second T. Kelsall, carried)*

President's Report

Christian Giguère briefly summarized his report to the Board meeting on 13 October. He emphasized that the society has stable membership and is maintaining a balanced budget, and he thanked all those who have made contributions to our activities. The key business of the coming year is shifting our operations to a new web-based system to facilitate routine membership and financial transactions.

Secretary's Report

David Quirt gave an overview of membership and operational activity.

- The total of 318 paid renewals and new memberships is identical to last year, but we had the usual bump due to variation in non-member registrations at the conference - this year a decrease of 33 to 374 total.
- An itemized account of the administrative budget of $1175 (mainly mailing expenses) was presented to the Board of Directors.
- Preliminary steps have been taken towards shifting the membership database and renewal process to an online system, and promoting a shift towards more email and online transactions, to handle routine processes with less volunteer effort.

Treasurer's Report

In the absence of the Treasurer, Dalila Giusti, Christian Giguère presented an overview of her written report to the Board on CAA finances. CAA is in good financial shape, with total assets of $286,655 at fiscal year-end (before audit). Total assets rose marginally, and interest on our capital investments will cover all prize awards.

In 2010, a budget deficit is predicted due to increased website and service costs as we implement online payment. Therefore the Treasurer proposed for 2010: a $5 increase in fees for Students (to $35), a $10 increase for Members and Subscribers (to $80), and $50 increase for Sustaining Subscribers (to $350). *(Acceptance of proposed fee structure moved by Rich Peppin, second Stan Dosso, carried.)*

A change of financial year-end to 30 June is proposed, to enable presentation of an audited report at the AGM. This has been advertised, following our standard procedure for bylaw changes. *(Change of financial year-end to 30 June moved by Rich Peppin, second Stan Dosso, carried.)*

(Acceptance of Treasurer's report moved by R. Ramakrishnan, second Frank Russo, carried.)

Editor's Report

Ramani Ramakrishnan gave the Editor's report. *Canadian Acoustics* production has proceeded smoothly throughout the year. There has been no progress on a proposed collaboration with university publishers to establish online publication of *Canadian Acoustics*.

Award Coordinator's Report

Frank Russo acknowledged the continuing hard work by award coordinators, and reported that this year CAA is awarding all prizes, including the Shaw Postdoctoral Prize. In addition, we have sponsors for the three student paper awards for presentations at the conference. (For names of award recipients, see the separate announcement in this issue.)

One minor change in the prizes has been authorized by the Board: the Directors' Award for best article by a professional in *Canadian Acoustics* will not be restricted to Members; conditions for the corresponding student award are unchanged.

Past and Future Meetings

Reports were presented on the past, present and future annual meetings:

2008 (Vancouver): Murray Hodgson submitted a final report. The conference yielded a small profit, and the final balance of $3800 was transferred to CAA.

2009 (Niagara-on-the-Lake): Conference Chair, Ramani Ramakrishanan, reported the meeting at the Pillar and Post Inn (October 14-16) was proceeding well, with a full schedule of 125 papers and a larger-than expected exhibition.

2010 (Victoria): Stan Dosso announced that the conference will be at Laurel Point Inn, beside the harbour in Victoria, on 13-15 October 2010. The team includes Stan Dosso (Chair), Roberto Racca (Technical Chair), and Clair Wakefield. See the announcements on the website and in *Canadian Acoustics* for details.

Subsequent meetings: Proposed site for the annual conference in 2011 is Québec; this is still tentative, but a team is coming together.

CAA Website

Christian Giguère reported that Sean Pecknold has agreed to serve as Webmaster. Some effort is needed to upgrade parts of the site, but basic updates are being implemented rapidly.

Nominations and Election

CAA corporate bylaws require that we elect the Executive and Directors each year. The Past President, Stan Dosso, presented nominations and managed the election process.

This year, Dave Quirt chose not to seek re-election after 8 years as Executive Secretary, and one Director completed his term on the Board - Vijay Parsa. Stan expressed thanks for the contributions by the outgoing Director and for David's years as Secretary. There was enthusiastic applause.

For the election process, Stan read the name(s) of the nominees, and then asked if there were other nominees from the floor.

- First, he presented names of proposed continuing Directors (Rich Peppin, Roberto Racca, Tim Kelsall, Clair Wakefield, Frank Russo, Sean Pecknold, and Jérémie Voix) and his nomination for a new Director (Hugues Nelisse).
- Then, he presented nominees for executive positions (Christian Giguère for President, Dalila Giusti for Treasurer, Ramani Ramakrishnan for Editor, Brad Gover for Executive Secretary)

In each case, there were no other nominations from the floor, so these nominees were declared elected by acclamation.

Other Business

Tim Kelsall presented a brief report about the expected demise of CSA Committee Z107 "Acoustics and Noise Control" and the Board's decision to assume some discontinued CSA activities under the auspices of CAA.

Adjournment

Adjournment was proposed by Stan Dosso and seconded by Ramani Ramakrishnan. Carried. Meeting adjourned at 7:25 p.m.

Canadian Acoustical Association
Association canadienne d'acoustique

2009 PRIZE WINNERS / RÉCIPIENDAIRES 2009

SHAW POSTDOCTORAL PRIZE IN ACOUSTICS / PRIX POST-DOCTORAL SHAW EN ACOUSTIQUE

Majid Navabi (Concordia University)

"Unsteady flow analysis through the valveless acoustic micropump"

BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND HEARING / PRIX ÉTUDIANT BELL EN COMMUNICATION VERBALE ET AUDITION

Huiwen Goy (University of Toronto)

"Articulatory and acoustic changes accompanying different speaking instructions and listening situations"

FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS / PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

Brendan Rideout (University of Victoria)

"Acoustic localization and tracking of marine mammals"

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL / PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

Behrooz Yousefzadeh (University of British Columbia)

"Beam-Tracing Model for Realistic Prediction of Sound Fields in Rooms"

RAYMOND HÉTU UNDERGRADUATE PRIZE IN ACOUSTICS / PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE

Konstantin Naumenko and Jessica Banh (University of Toronto)

"Establishing normative voice characteristics of younger and older adults"

CANADA-WIDE SCIENCE FAIR AWARD / PRIX EXPO-SCIENCES PANCANADIENNE

Roland Troke-Barriault, École Rose-des-Vents (Kingston, Nova Scotia)
"Le bonheur du bruit: Quelles fréquences pour la croissance"

DIRECTORS' AWARDS / PRIX DES DIRECTEURS

Individual Member / Membre Individuel:

Wladyslaw Cichocki (University of New Brunswick)
"The RACAD speech corpus of New Brunswick Acadian French: Design and applications"

Student Member / Membre Étudiant:
Marc-André Gaudreau, École de technologie supérieure, Université du Québec
"Méthode demesures terrain de l'atténuation F-MIRE de protecteurs auditifs durant un quart de travail"

STUDENT PRESENTATION AWARDS / PRIX POUR COMMUNICATIONS ÉTUDIANTES
NIAGARA-ON-THE-LAKE (ON), OCTOBER 14-16, 2009

Brady Laska (Carleton University)
"Subband Autoregressive Modelling of Speech Signals"

Brendan Rideout (University of Victoria)
"Localization of Marine Mammals in an Uncertain Environment"

Blake Butler (McMaster University)
"Temporal representation of pitch in auditory cortex"

CONGRATULATIONS / FÉLICITATIONS

Local marine bio-acoustic source.
(Photo: Gary Woodburn, Tourism Victoria)

— FIRST ANNOUNCEMENT —

ACOUSTICS WEEK IN CANADA

Victoria BC, 13-15 October 2010

Acoustics Week in Canada 2010, the annual conference of the Canadian Acoustical Association, will be held in Victoria BC from 13 to 15 October 2010. This is the premier Canadian acoustical symposium, and this year's exceptional waterfront setting on Victoria's beautiful Inner Harbour will make it an event you won't want to miss. The conference will include three days of plenary lectures, technical sessions on all areas of acoustics, the CAA Annual General Meeting, an Exhibition of acoustical equipment and services, the Conference Banquet and other social events. In keeping with Victoria's ocean setting and the natural beauty of the region, the conference will feature increased focus in the areas of marine and environmental acoustics.

Venue and Accommodation – The conference will be held at the Laurel Point Inn, www.laurelpoint.com, a landmark Victoria hotel. As the sole occupant of a small peninsula separating Victoria's Inner and Outer Harbours, surrounded by quiet gardens and ponds and bordering the seawall walkway, the Laurel Point Inn represents an exceptional location on Victoria's historic waterfront. The Inn is located a short walk from all city centre attractions including the Parliament Buildings, Royal BC Museum, Government Street pedestrian mall, and Inner Harbour marina and causeway, as well as the Ogden Point breakwater, Fisherman's Wharf, and Beacon Hill Park. The Inn boasts 200 luxurious guest rooms, each with balcony and harbour views. The state-of-the-art conference facilities are clustered around the glass-enclosed Terrace Ballroom where meals and the Exhibition will be held. Participants registering with the hotel before 12 September 2010 will receive the special conference room rate of $109/night (single or double occupancy, including complimentary wireless internet and many other amenities). Staying at this outstanding conference hotel will place you near your colleagues and all conference activities, and will help make the meeting a financial success to the benefit of future CAA activities. Reduced room rates are in effect from 10 to 18 October, so consider extending your visit to Victoria for a short holiday!

Plenary Lectures – Plenary lectures are planned in areas of broad and relevant appeal including Marine Bioacoustics, Environmental Acoustics, and Noise Control.

Inner Harbour and Parliament Buildings at dusk.
(Photo: Tyler Ahlgren, Tourism Victoria)

Ogden Point breakwater—a great place for a stroll.
(Photo: Richard Funnell, Tourism Victoria)

Laurel Point Inn and Terrace Ballroom.

Technical Sessions – Technical sessions will be organized in all major areas of acoustics, including the following topics:

- Architectural and Classroom Acoustics
- Bio-Acoustics and Biomedical Acoustics
- Engineering Acoustics and Noise Control
- Physical Acoustics and Ultrasonics
- Musical Acoustics
- Psycho- and Physio-Acoustics
- Hearing and Speech Sciences
- Underwater Acoustics
- Acoustic Signal Processing

If you would like to propose and/or organize a special session on a specific topic, please contact the Technical Chair as soon as possible.

Exhibition and Sponsorship – The conference will include an Exhibition of acoustical equipment, products and services on Thursday 14 October 2010. If you or your company are interested in participating in the Exhibition or in sponsoring conference social events and/or sessions, which presents excellent promotional opportunities, please contact the Exhibition Coordinator.

Social Events – The conference will begin on Wednesday morning with an opening ceremony and welcome. Thursday evening is the traditional CAA Banquet and Awards Ceremony which will feature outstanding cuisine with a West Coast flair.

Courses/Seminars – If you would like to offer a course/seminar in association with Acoustics Week in Canada, please contact the Conference Chair. Assistance can be provided in accommodating such an event, but it must be financially independent of the conference.

Student Participation – Student participation is strongly encouraged. Travel subsidies and reduced registration fees will be available. A hotel room sharing program will be organized to reduce costs. Student presenters are eligible to win prizes for the best presentations at the conference.

Paper Submission – The abstract deadline is 15 June 2010. Two-page summaries for publication in the proceedings issue of *Canadian Acoustics* are due 2 August 2010. Details will be given on the conference website.

Registration – Details of registration fees and the registration form will be available soon at the conference website. Early registration at a reduced fee is available until 12 September 2010.

Fall colours at Butchart Gardens.
(Photo: Nick Redding, Tourism Victoria)

Local Organizing Committee

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Conference Website: www.caa-aca.ca

Source bio-acoustique locale.
(Photo: Gary Woodburn, Tourism Victoria)

— PRÉMIÈRE ANNONCE —

SEMAINE CANADIENNE D'ACOUSTIQUE

Victoria CB, 13-15 Octobre 2010

La Semaine Canadienne d'Acoustique 2010, la conférence annuelle de l'Association Canadienne d'Acoustique va prendre place à Victoria CB du 13 au 15 Octobre 2010. C'est le premier symposium d'acoustique canadienne, et l'exceptionnel bord de mer donnant sur le magnifique port nautique de Victoria en fera cette année un évènement que vous ne voudrez pas manquer. La conférence inclurera trois jours de conférences plénieres, des séssions techniques dans tous les domaines de l'acoustique, la réunion générale annuelle de l'ACA, une exposition d'équipements et services acoustiques, le banquet de la conférence et d'autres évènements sociaux. Etant donné l'environnement océanique de Victoria et la beautée naturelle de la region, la conférence va se distinguer par un interêt accentué pour les domaines de l`acoustique marine et environnementale.

Centre de conférence et Logement – La conférence va prendre place à l'hôtel Laurel Point Inn, www.laurelpoint.com, un hôtel historique de Victoria. Le Laurel Point Inn est un endroit exceptionnel sur le front de mer de Victoria. Il est l'unique occupant d'une petite péninsule separant le port en deux, entouré de jardins et étangs silencieux, et idéalement situé le long de la promenade de la digue. L'hôtel est à quelques minutes à pied de toutes les attractions du centre-ville, incluant les Bâtiments Parlementaires, le Musée Royal de Colombie-Britanique, le centre commercial de la rue du Gouvernement, la Marina de l'Arrière-port, ainsi que la jetée de Pointe Ogden, le Quai des Pêcheurs, et le Parc de Beacon Hill. L'hôtel offre 200 chambres luxueuses, chacune avec balcon et vue sur le port. Les salles de conférence haut-de-gamme sont regroupées autour de la terrasse vitrée de la salle de ball où les repas et l'évènement vont prendre place. Les participants réservant l'hôtel avant le 12 septembre 2010 recevront un tarif préférentiel de $109/nuit (ocupation simple ou double, incluant la connection internet sans fil et pleins d'autres avantages). Rester à cet hôtel extraordinaire va vous placer prêt de vos collègues et de toutes les activitées de la conference, et va contribuer à faire de cette réunion un succès financier pour le bénéfice des activités futures de l'ACA. Les chambres à prix réduits sont disponibles du 10 au 18 octobre, donc n'hésitez pas à prolonger votre visite à Victoria pour prendre quelques jours de vacances.

Sessions Plénières – Des conférences plénières sont prévues dans des domaines d'intérêt général incluant la bio-acoustique marine, l'acoustique environmentale et le contrôle du bruit.

Arriere-port et Batiments Parlementaires au crepuscule. (Photo: Tyler Ahlgren, Tourism Victoria)

Jetée de Pointe Ogden.—un magnifique endroit pour se promener. (Photo: Richard Funnell, Tourism Victoria)

Hôtel Laurel Point et Terrasse vitrée.

Sessions Techniques – Des séssions techniques seront organisées dans tous les domaines principaux de l'acoustique, incluant les thèmes suivants:

- Acoustique Architecturale et Acoustique des Salles de Classes
- Bio-Acoustique et Acoustique Biomédicale
- Ingénierie Acoustique et Contrôle de Bruit
- Acoustique Physique et Ultrasonore
- Acoustique Musicale
- Psycho- et Physio-Acoustique
- Sciences Auditives et de la Parole
- Acoustique Sous-Marine
- Traitement de Signal Acoustique

Si vous désirez proposer et/ou organiser une séssions spéciale, contactez le Président Technique aussi tôt que possible.

Exposition et Commandite – La conférence incluera une exposition d'équipements, produits et services acoustiques, qui prendra place le jeudi 14 Octobre 2010. Si vous ou votre entreprise êtes interessés à participer à l'exposition ou à commanditer les évènements sociaux de la conférence et/ou les séssions, qui permettront d'excellentes opportunités promotionnelles, contactez le coordinateur de l'exposition.

Activités – La conférence commencera le mercredi matin avec une cérémonie d'ouverture et de bienvenue. Jeudi soir se tiendra le traditionnel banquet de l'ACA et la cérémonie de remise des prix ou vous pourrez déguster l'extraordinaire cuisine façon Cote-Ouest.

Cours/Séminaires – Si vous souhaitez offrir un cours/séminaire en association avec la Semaine Canadienne d'Acoustique, contactez le Président de la Conférence. De l'assistance est disponible pour organiser cet évènement, mais il doit être financièrement indépendant de la conférence.

Participation Etudiante – La participation étudiante est fortement encouragée. Des indèmnitées de voyages et des frais réduits d'inscription seront disponibles. Un programme de partage de chambres d'hôtel sera organisé pour réduire les coûts. Les étudiants donnant une présentation sont élligibles pour gagner des prix pour les meilleures présentations de la conférence.

Soumission d'Article – L'échéance pour la soumission des résumés est le 15 Juin 2010. Les résumés de deux pages pour publication dans le numéro d'actes de conférence de *Acoutique Canadienne* sont dus le 2 août 2010. Les détails seront donnés sur le site internet de la conférence.

Inscription – Les détails sur les frais et formulaires d'inscription seront bientôt disponibles sur le site internet de la conférence. Les pré-inscriptions à prix réduits sont disponibles jusqu'au 12 septembre 2010.

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Site web de la conference: www.caa-aca.ca

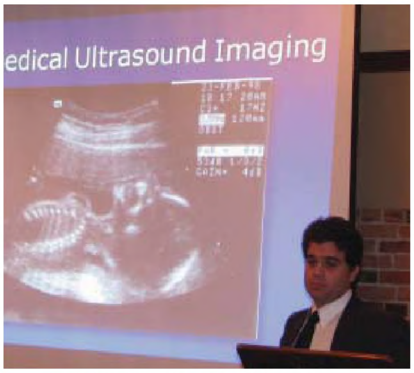
ACOUSTICS WEEK IN CANADA / SEMAINE CANADIENNE D'ACOUSTIQUE
NIAGARAN-ON-THE-LAKE 14-16 OCTOBER/OCTOBRE 2009
---Photo Report / Rapport en photos
by/par Ramani Ramakrishnan

Words of Welcome- Ramani Ramakrishnan and Kendra Schank Smith

Plenary - John Bradley

Plenary - Murray Schafer

Plenary - John Neuhof



Plenary - Michael Kolios

Exhibition -1

Exhibition -2

Exhibition -3

Exhibition -1

Exhibition -2

Exhibition -3

Acoustic Walk with Murray Schafer

Student Prize Winner and
the organizers

Banquet

CAA Award Winners and the CAA Board

EmotiChair

Jazz Group

Jazz Group

The Registration Desk
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Mandy Chan and Megan Muro

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Carmen Branje
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Lisa Chan,
Frank Russo
and
Gabe Nespoli

The Canadian Acoustical Association / l'Association Canadienne d'Acoustique

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The number that follows each entry refers to the areas of interest as coded below.
Le nombre juxtaposé à chaque inscription réfère aux champs d'intérêt tels que condifés ci-dessous

Areas of interest		**Champs d'intérêt**
Architectural Acoustics	1	Acoustique architecturale
Engineering Acoustics / Noise Control	2	Génie acoustique / Contrôle du bruit
Physical Acoustics / Ultrasonics	3	Acoustique physique / Ultrasons
Musical Acoustics / Electro-acoustics	4	Acoustique musicale / Electroacoustique
Psycho- and Physio-acoustics	5	Psycho- et physio-acoustique
Shock and Vibration	6	Chocs et vibrations
Hearing Sciences	7	Audition
Speech Sciences	8	Parole
Underwater Acoustics	9	Acoustique sous-marine
Signal Processing / Numerical Methods	10	Traitement des signaux / Méthodes numériques
Other	11	Autre

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