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Investigation of Correlation between Aircraft Interior Noise Levels and Residential Building Construction Details

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ABSTRACT

Our paper investigates the correlation between aircraft interior noise levels and various residential building construction features. Variables considered include age, size, number of stories, construction type (cape, ranch, etc.), housing type (single-family or multi-family), exterior façade material, and window glazing characteristics. The results of this analysis are then considered in the context of current guidance provided in Appendix R of the Federal Aviation Administration (FAA) Order 5100.38D Airport Improvement Program handbook, which specifics a procedure to determine the eligibility of residences for airport sound insulation programs based on interior noise levels for categories of homes. The assumed intent of this process is to minimize the need to determine aircraft interior noise levels through measurements of building noise level reduction within 100% of homes, but rather test 10% to 30% of the units within each group to determine interior noise levels by category. Ultimately, we were unable to identify any specific building construction details which might result in truly effective categorizations of residences for the purpose of determining sound insulation program eligibility.

1 INTRODUCTION

Airport sound insulation programs implemented in accordance with the Federal Aviation Administration (FAA) Order 5100.38D Airport Improvement Program (AIP) Handbook[1] require acoustical testing to determine program eligibility of residential structures based on aircraft interior noise levels. The FAA eligibility requirements are: (1) structures must be located within the FAA-approved Day-Night Average Sound Level (DNL) 65 dB noise contour and (2) the average interior DNL for the entire structure must be 45 dB or greater.

In order to evaluate the average interior DNL noise level for a residential building against the 45 dB criteria for the purpose of determining sound insulation program eligibility, sponsors must first establish the outdoor-to-indoor noise level reduction (NLR) of all habitable rooms within the structure via acoustical testing and then subtract each measured room NLR from the aircraft exterior noise level value associated with the land parcel of interest to compute the aircraft interior DNL noise level for each tested room. An average interior DNL value is then calculated for the entire residence from the interior noise levels that were determined for each habitable room in the home.

In addition, FAA Order 5100.38D specifies that only 10% to 30% of potentially eligible residences may be acoustically tested. Therefore, in order to determine program eligibility for 100% of homes, all residential units are required to be categorized using various building construction details such as: type of housing (single-family or multi-family), construction type, number of floors, size, and age. The results for the sample of residences tested in each category are then used to determine representative interior noise levels and identify program eligibility for all other homes located within the DNL 65 dB contour. Airport Cooperative Research Program (ACRP) Report 89 Guidelines for Airport Sound Insulation Programs[2] includes additional discussion and consideration of the FAA-required categorization of homes and outlines some areas where additional clarification could be helpful in successfully implementing the process.

In this context, HMMH investigated the correlation between residential pre-construction interior DNL noise levels and various building construction features in order to identify the specific construction details that are likely to result in the most effective categorizations of residences. Variables considered include those listed above as well as exterior façade material and window glazing configuration and thickness. Our selection criteria were that the resulting categorizations should be somewhat mutually exclusive, at least one category should fall almost entirely above or below the 45 dB eligibility threshold, and a direct correlation with average interior DNL noise levels should be observed across the various individual categories.

The FAA Policy, Engineering, Analysis and Research Support (PEARS) Study of Noise Level Reduction Variation[3] also previously evaluated the variability in acoustical testing results among various residential construction exterior façade materials and window configurations. Since only a small number of homes were included in this analysis, the results are limited and not conclusive. Overall, a small offset was observed between homes with wood versus vinyl exterior façade materials and also between residences with both single-glazed windows and additional storm windows and homes with double-glazed insulated windows only and no storms.

2 DATA ANALYSIS

In order to investigate the correlation between residential pre-construction interior DNL levels and various building construction features, we utilized acoustical testing data from a single multi-phase sound insulation program. This provided us with a consistent data set containing acoustical measurement data for 84 single-family homes and 189 multi-family units, as well as corresponding building construction details obtained from the local town assessor's database and/or collected during the acoustical testing conducted at each residence.

Next we compiled overall interior DNL noise level results for each of the various categorizations associated with each particular building construction feature under consideration. This included the maximum, minimum, and average interior DNL noise level for each individual category. The resulting ranges of aircraft interior DNL were then plotted side-by-side for each type of building construction detail and a linear trend line was computed for each data set in order to identify if any correlation was observable between interior DNL noise levels and the relative categorizations. Where possible, supplemental scatter plots were also produced for those building construction features that could easily be associated with a numeric scale, such as total square footage, year constructed, and window glazing thickness. The distribution of interior DNL noise levels was also evaluated for the categorization by residential housing type.

Categorization methods investigated for both single- and multi-family residences include type of housing, construction type, and exterior façade material. Additional categorizations evaluated only for single-family homes include number of stories, total square footage, year and decade constructed, and window glazing configuration and thickness. These categories were very uniform within each of the multi-family buildings tested and are therefore not assessed herein.

3 RESULTS

Figure 1 provides the computed ranges of aircraft interior DNL by residential housing type. While there is some variation in the minimum DNL values, both the maximum and average interior DNL are very comparable among the two categories and within less than 0.5 dB. Therefore a direct correlation between interior DNL noise level and housing type was not observed. Figure 2 shows the distribution of interior DNL values for single-family homes and multi-family units, which clearly indicates that the difference in minimum values is associated with a small number of homes and demonstrates that the overall trend is generally very consistent between the two housing type categories.

Figure 3 provides the calculated ranges of interior DNL by residential construction type. While there is some observed variation in both the maximum and minimum DNL values, the average interior DNL are again very similar among the various categories and within 1 dB. Thus a direct correlation between interior DNL level and construction type was not established.

Figure 4 details the computed ranges of aircraft interior DNL by number of stories for single-family homes. Note that the 1.5-story designation applies to homes with a partial second floor, such as cape style constructions. Again there is a small degree of observed variation in both maximum and minimum DNL values; however the average interior DNL are overall very comparable and within less than 1 dB. Consequently a robust correlation between interior DNL noise level and number of stories was not identified for single-family residences.

Figures 5 and 6 provide calculated ranges as well as individual interior DNL values for single-family homes by total square footage. The average interior DNL values are as before very similar and within less than 0.5 dB. Hence a direct correlation between interior DNL noise level and total single-family home square footage was not found, as evidenced by the computed correlation coefficient and R^2 values for the scatter plot linear fit.

Figures 7 and 8 show calculated ranges and individual interior DNL values for single-family homes by decade and year constructed, respectively. The average interior DNLs are within 1 dB for most categories and within less than 2 dB in total. Overall, a direct correlation between interior DNL noise level and single-family year/decade constructed was not observed, as indicated by the correlation coefficient and R^2 values for the scatter plot linear fit.

Figures 9 and 10 both provide computed ranges of aircraft interior DNL values by residential exterior façade material. Figure 9 indicates that when all available data is included in the analysis, there is an identifiable correlation between interior DNL noise level and exterior facade material. This is largely a result of the inclusion of light-weight mansard and solid concrete wall constructions in the analysis, which have a 3 dB relative offset in average interior DNL values. However as shown in Figure 10, when these more unique wall types are omitted from the calculations and only typical residential façade materials are included, then the average interior DNL values are within 0.5 dB and a distinct correlation is no longer observed.

Figures 11 and 12 detail calculated ranges as well as individual interior DNL values for single-family homes by window glazing configuration and total window glazing thickness, respectively. These figures indicate that there is an identifiable correlation between interior DNL noise level and both window configuration and total glazing thickness, with a 1.5 to 2 dB relative offset in average interior DNL values observed for homes with double-glazed insulated prime windows and no additional storm windows and those residences with double- or single-glazed prime windows that do also have additional storm windows. Figure 13 demonstrates that when façade material and window configuration information are combined, the resulting correlation with interior DNL noise levels is not significantly improved, though a slight difference is noticeable between vinyl and wood constructions for homes with storm windows.

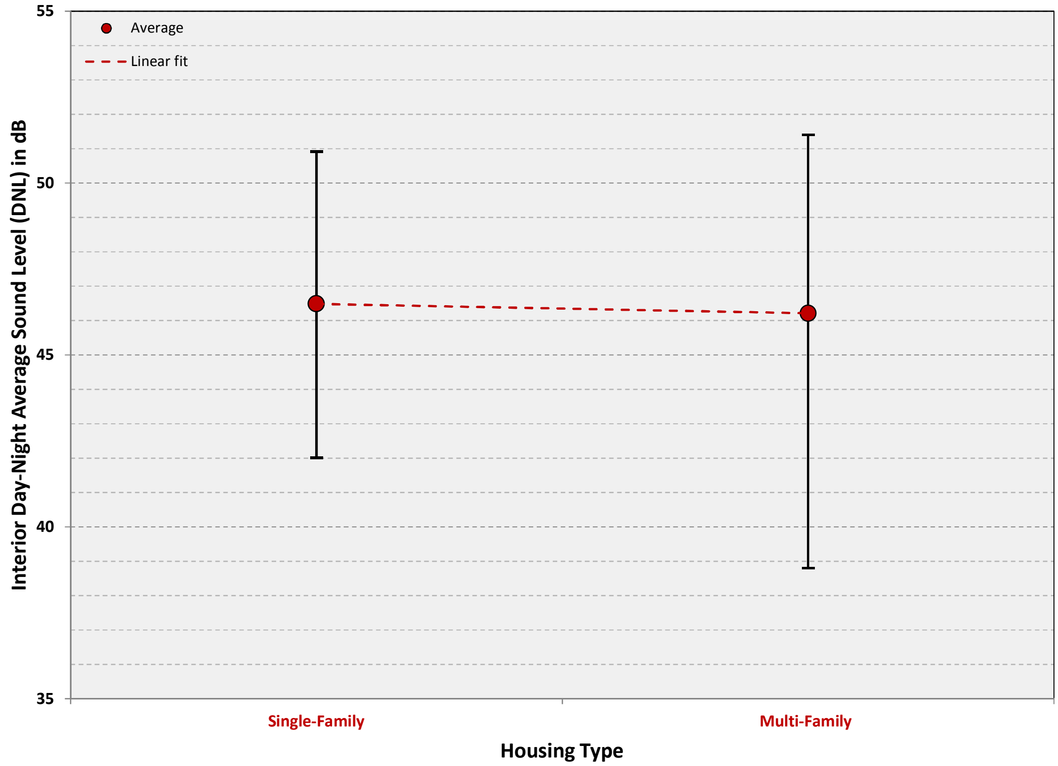

Figure 1: *Range of Aircraft Interior DNL by Residential Housing Type*

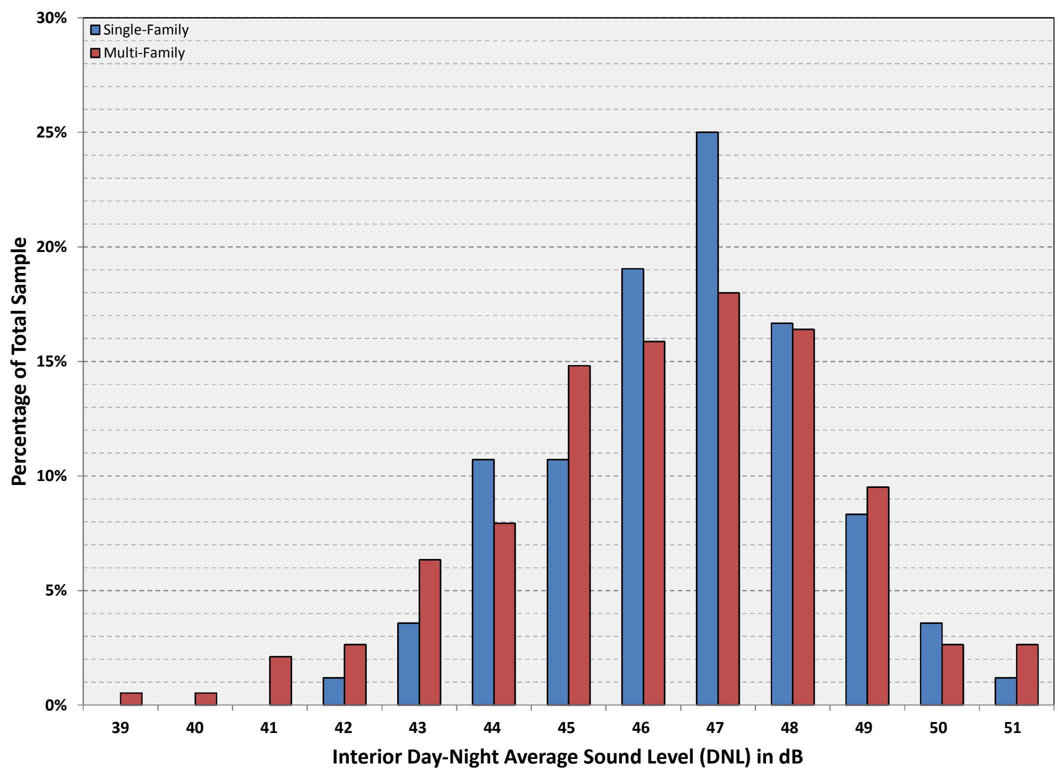

Figure 2: *Distribution of Aircraft Interior DNL by Residential Housing Type*

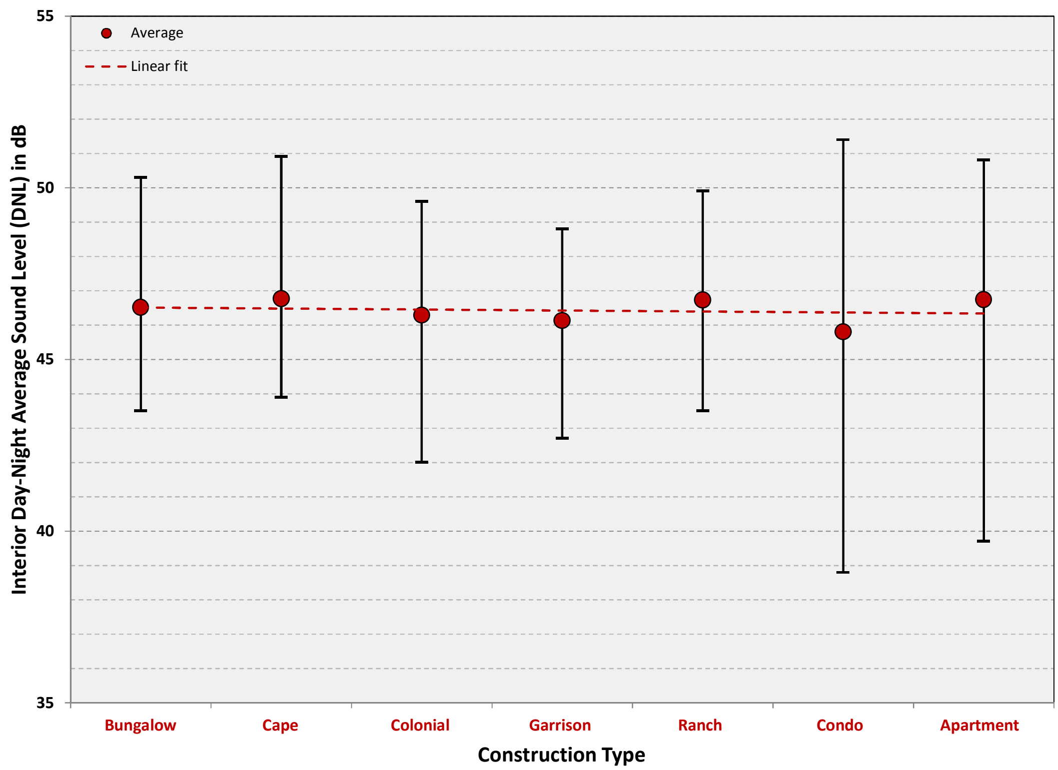

Figure 3: *Range of Aircraft Interior DNL by Residential Construction Type*

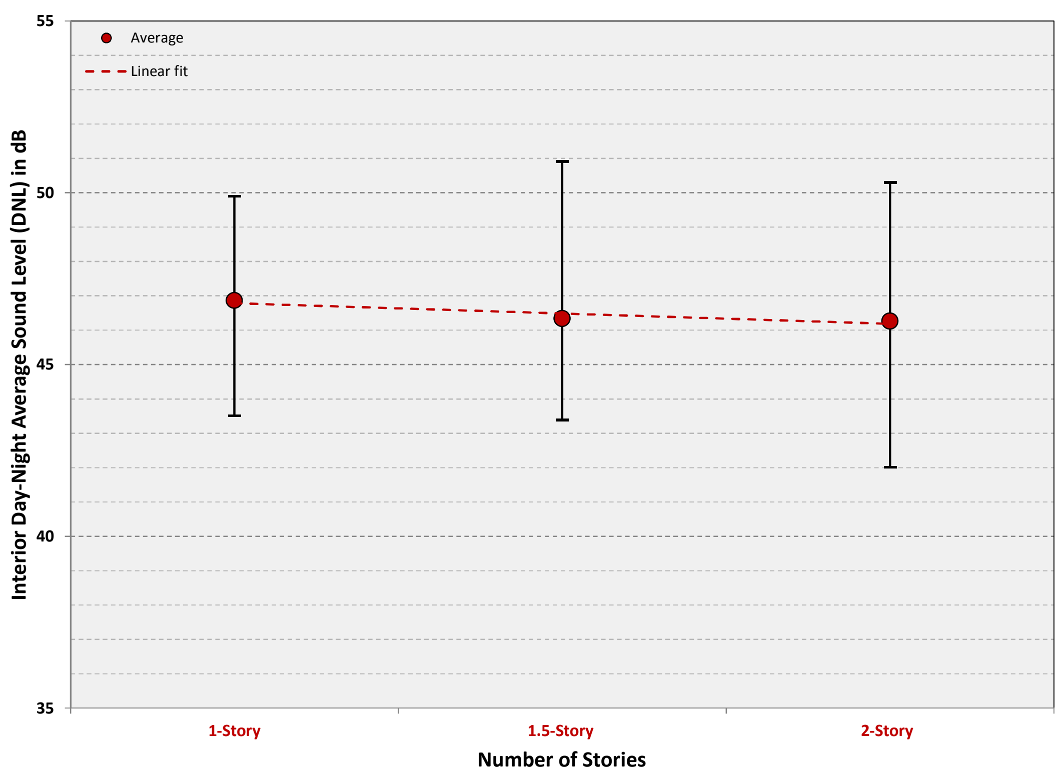

Figure 4: *Range of Aircraft Interior DNL by Single-Family Residence Number of Stories*

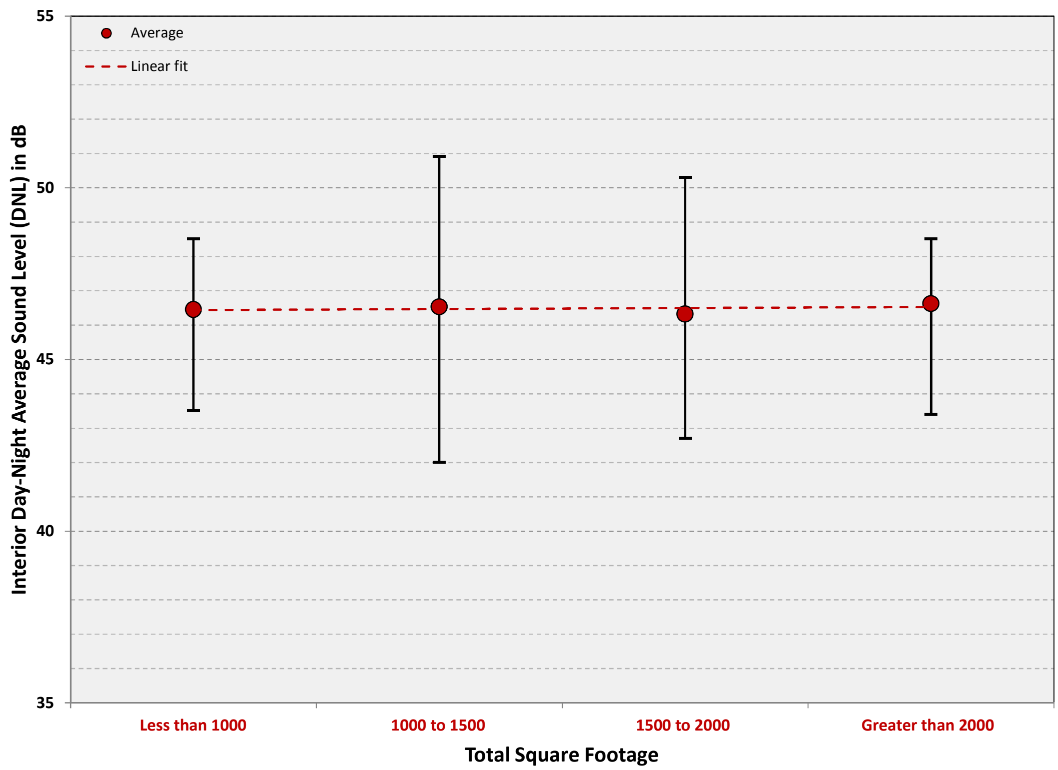

Figure 5: *Range of Aircraft Interior DNL by Single-Family Residence Total Square Footage (1.00 ft^2=0.09 m^2 and 1.00 m^2=10.76 ft^2)*

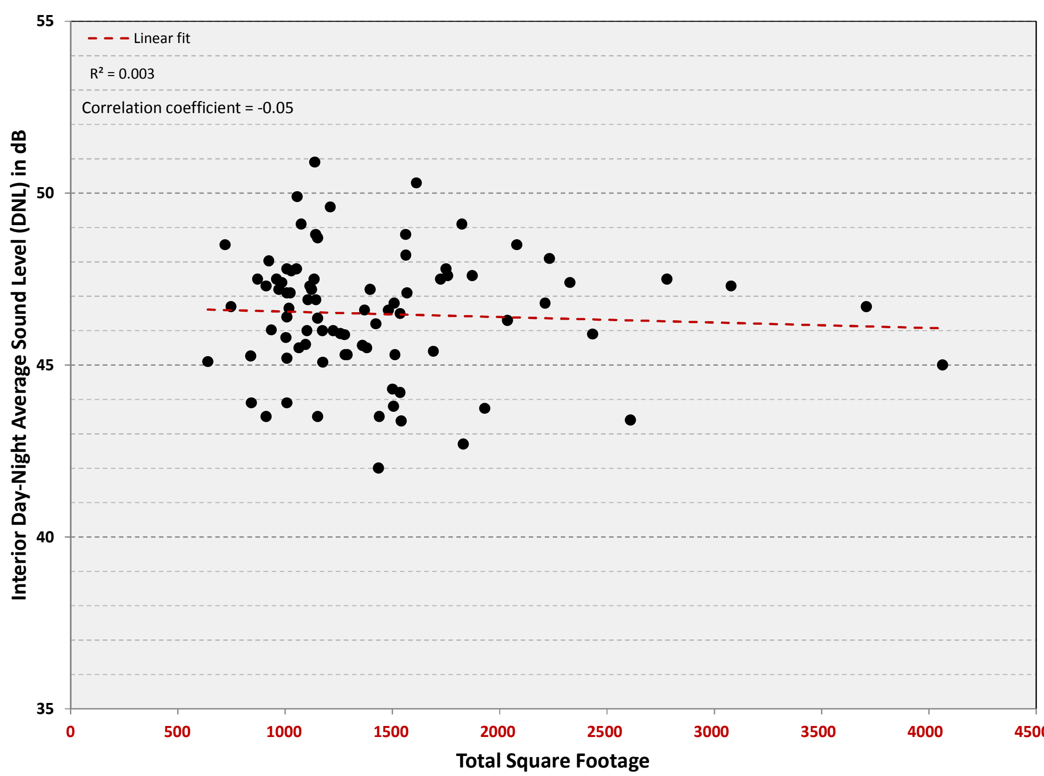

Figure 6: *Aircraft Interior DNL vs Single-Family Residence Total Square Footage (1.00 ft^2=0.09 m^2 and 1.00 m^2=10.76 ft^2)*

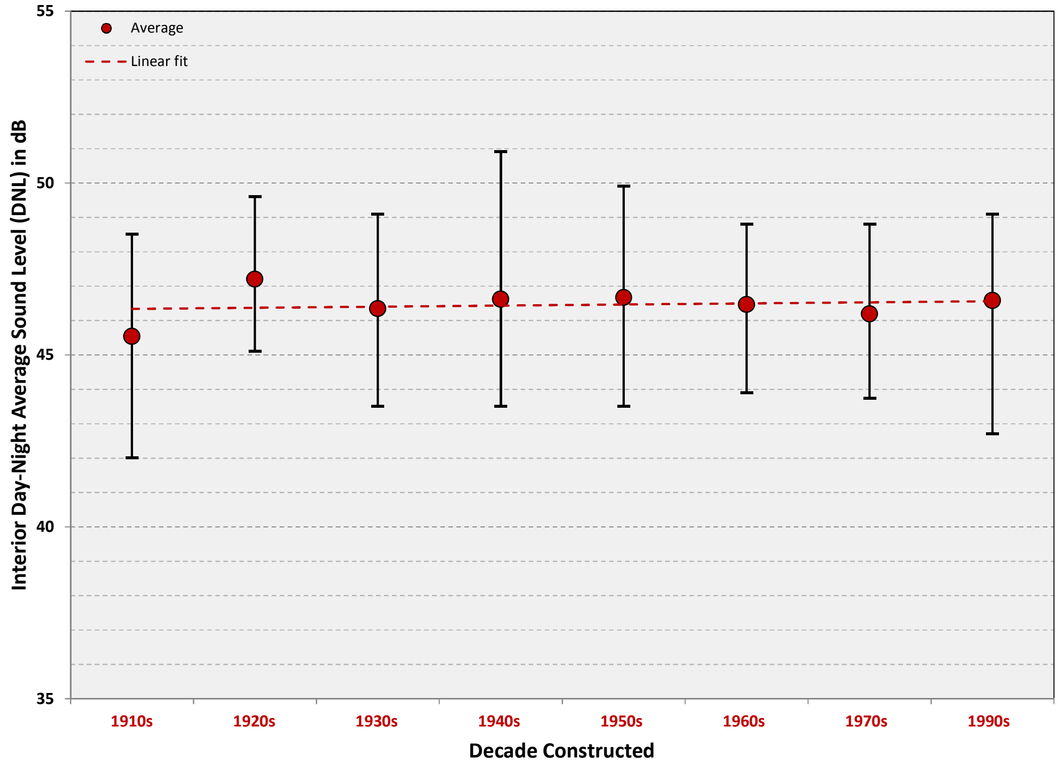

Figure 7: *Range of Aircraft Interior DNL by Single-Family Residence Decade Constructed*

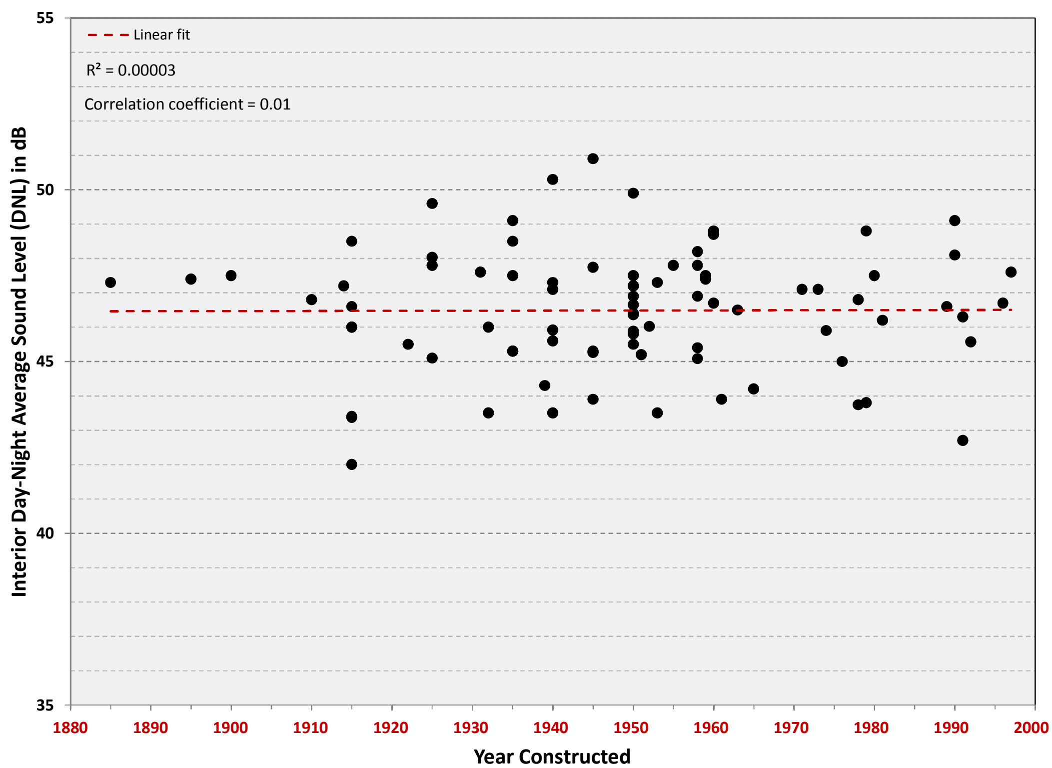

Figure 8: *Aircraft Interior DNL vs Single-Family Residence Year Constructed*

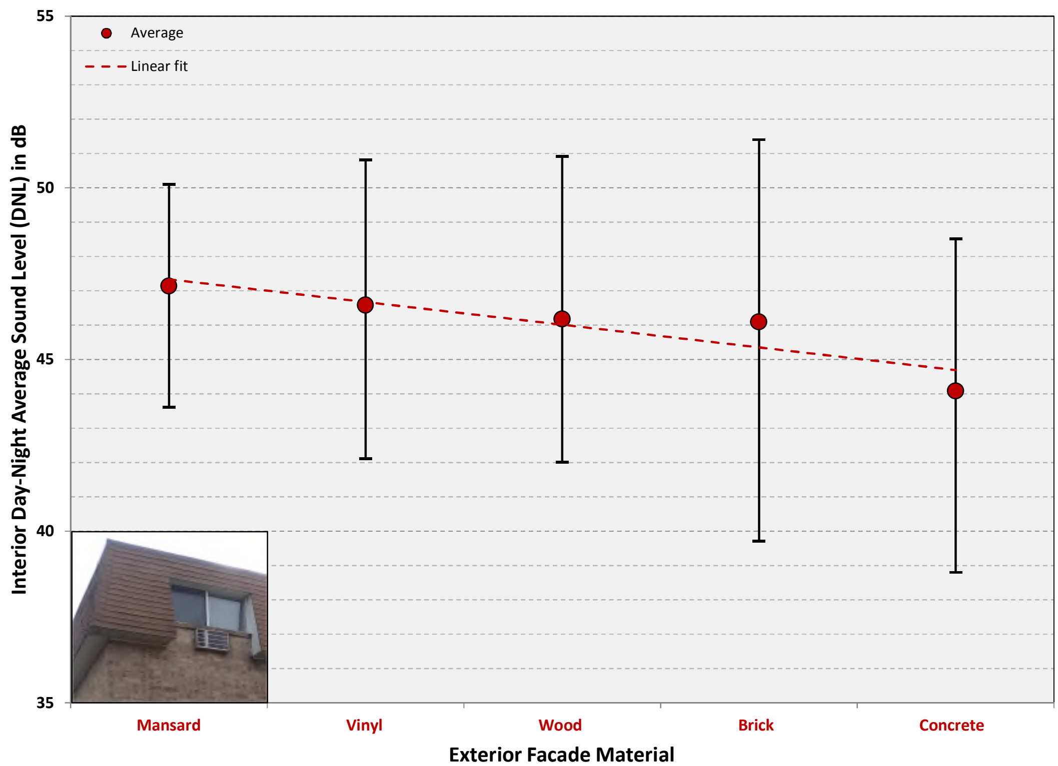

Figure 9: *Range of Aircraft Interior DNL by Residential Exterior Facade Material*

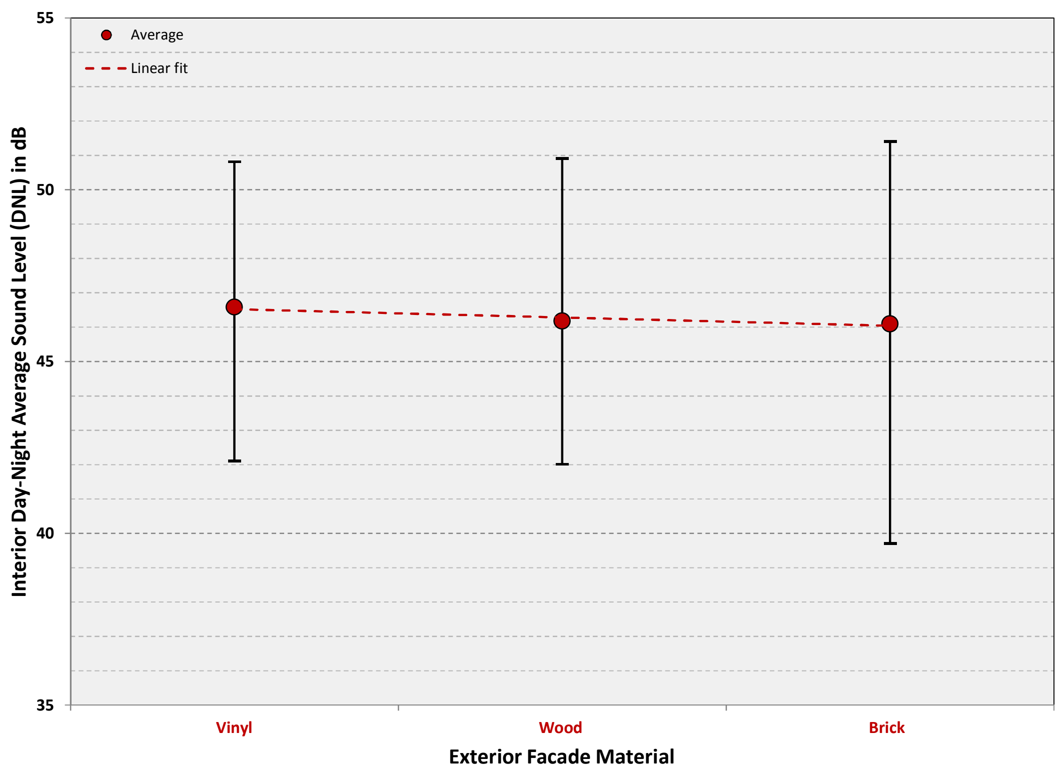

Figure 10: *Range of Aircraft Interior DNL by Most Typical Residential Facade Materials*

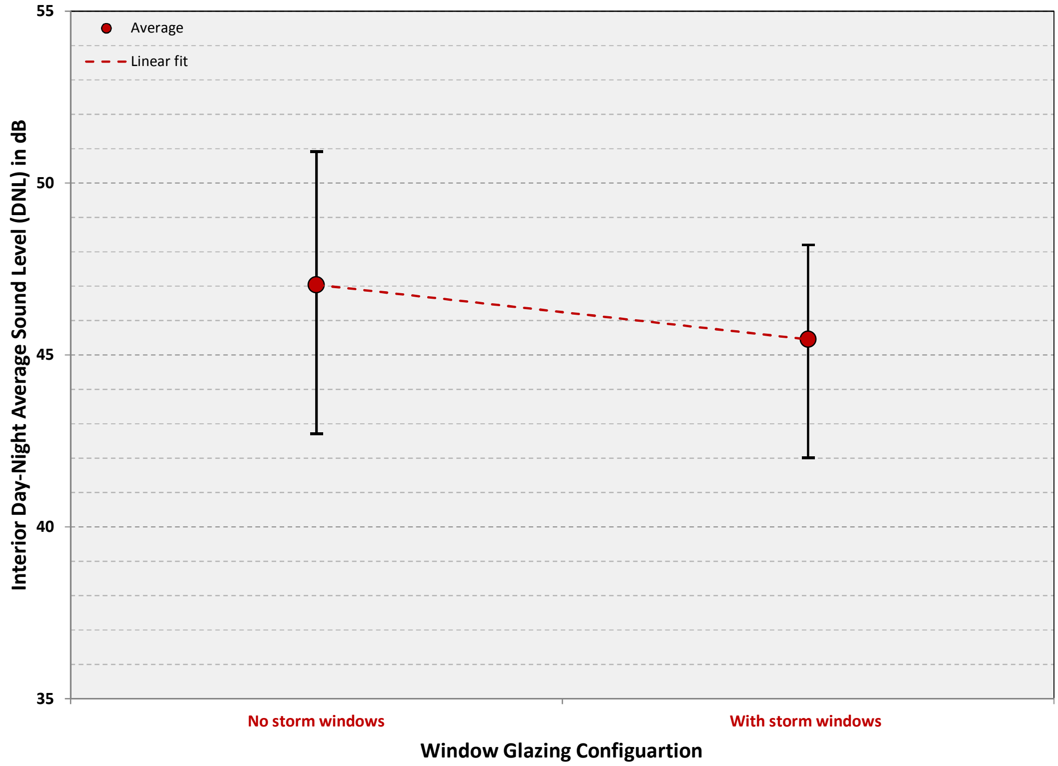

Figure 11: *Range of Aircraft Interior DNL by Single-Family Residence Window Configuration*

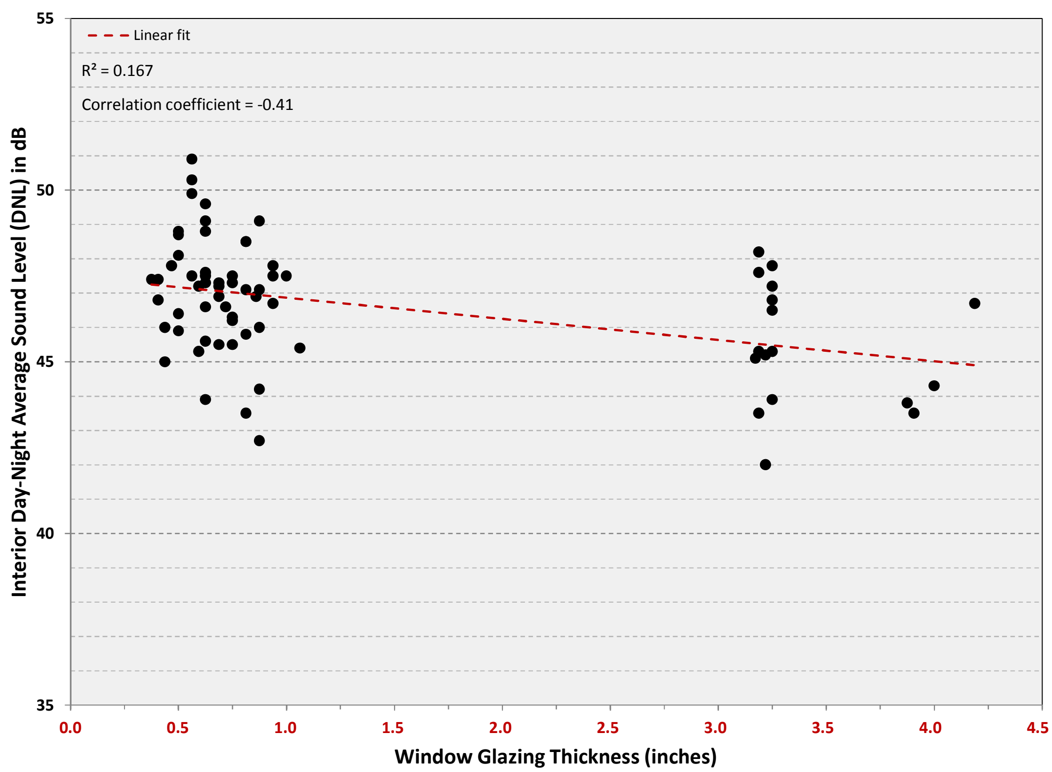

Figure 12: *Aircraft Interior DNL vs Single-Family Residence Window Glazing Thickness (1.00 in = 2.54 cm and 1.00 cm = 0.39 in)*

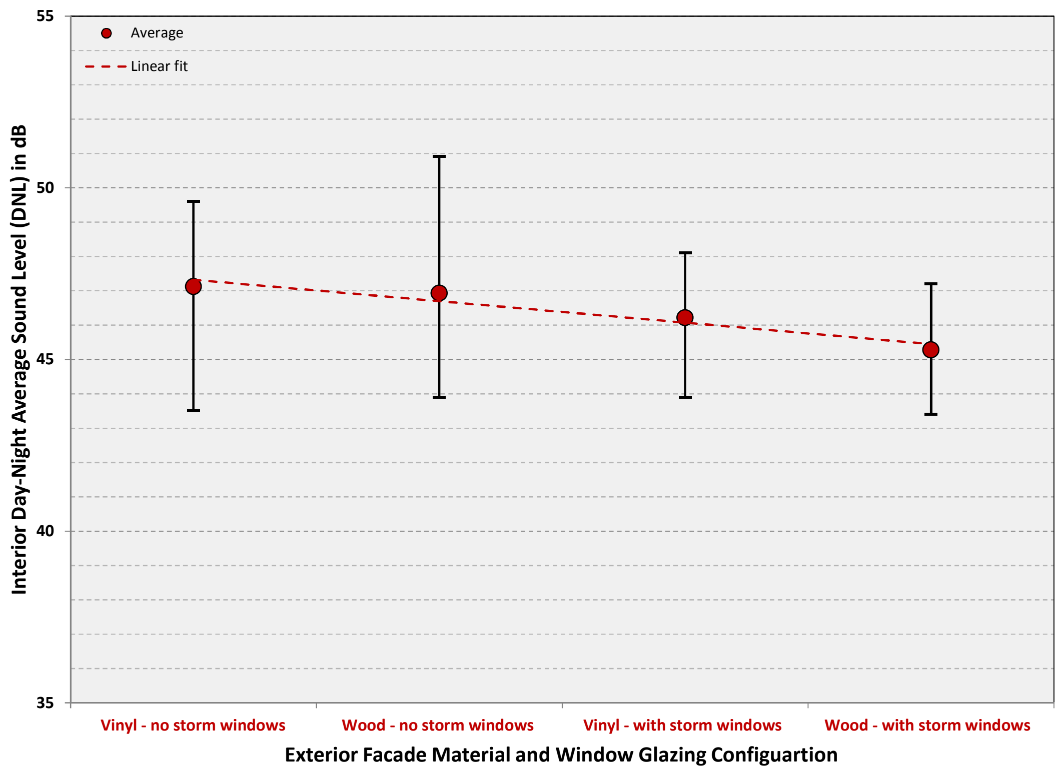

Figure 13: *Range of Aircraft Interior DNL by Single-Family Residence Facade Material and Window Configuration*

4 CONCLUSIONS

Correlations between residential pre-construction interior DNL noise levels and various building construction features were investigated in order to identify the specific construction details that are likely to result in the most effective categorizations of residences for purposes of determining sound insulation program eligibility per the requirements outlined in FAA Order 5100.38D.

We found that the only variables observed to produce an identifiable correlation with average interior DNL noise levels between relative categorizations of residential structures were window glazing configuration/thickness and in some instances possibly also the exterior façade material. However, neither of these categorization methods were able to meet our remaining selection criteria, which are that the resulting categories should be somewhat mutually exclusive and at least one should fall almost entirely above or below the 45 dB eligibility threshold.

Instead we found that even the best possible categorization approaches resulted in ranges of aircraft interior DNL noise levels that directly overlap and all of which span the 45 dB criteria, likely due to unaccounted for factors such as window condition and leakage as well as other sound paths through exterior doors and exhaust vents. Ultimately, we were unable to identify any building construction details which might result in truly effective categorizations of residences.

5 REFERENCES

1. *Airport Improvement Program Handbook,* FAA Order 5100.38D (United States Department of Transportation, Federal Aviation Administration, Washington D.C., 2014).
2. *Guidelines for Airport Sound Insulation Programs,* Airport Cooperative Research Program (ACRP) Report 89 (Transportation Research Board of the National Academies, Washington D.C., 2013).
3. *Study of Noise Level Reduction (NLR) Variation,* FAA Policy, Engineering, Analysis and Research Support (PEARS) Contract No. DTFAWA-11-D-00019, (Landrum & Brown, Boston, 2013).