# The need for updated traffic noise spectra, used for calculation of sound insulation of windows and facades

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## ABSTRACT

The international standard ISO 717-1 is used for defining single-number quantities for airborne sound insulation in buildings and of building elements. It also takes into consideration spectrum adaption. The $C_{tr}$ spectrum, which represents urban road traffic, originates from the Nordtest Method NT ACOU 061 (1987). This spectrum is the average of measurements done in Denmark and Sweden in the 80s. A closer look at the original reports reveals a difference in the two spectra at low frequencies, and indicates an influence by other low-frequency sources. This, seen together with recent measurements in Italy and Serbia (2013), suggests that the $C_{tr}$ spectrum in ISO 717-1 may be more dominant in the low frequencies than the actual urban road spectrum generated from vehicles today. The development in vehicle technology during the last decades, may also contribute to this. $C_{tr}$ correction is used for calculating indoor noise levels from outside traffic noise and for characterizing the performance of building elements. Examples of calculations with typical constructions are presented using both the $C_{tr}$ spectrum and more recently measured spectra. The consequences of uncertainties in the existing $C_{tr}$ spectrum and of using an updated traffic noise spectrum are discussed.

## 1. INTRODUCTION

The traffic noise spectrum adaptation term $C_{tr}$ was introduced in the 1996 edition of ISO 717-1 [1] and has since been widely used for characterizing the sound insulation of windows and façades against traffic noise. However, the standard has no reference to the origin of the spectrum, and today, twenty years later, very few persons may actually know the reference. Actually, the spectrum is based on measurements that are more than 30 years old, and to some extent not very reliable.

The purpose of this paper is threefold: 1 – to shed some light on the origin of the $C_{tr}$ spectrum, 2 – to demonstrate through a few examples the consequences of using alternative newer traffic noise spectra, and 3 – to argue that the noise source (road traffic in cities) has changed over the years, and that the typical spectrum today is quite different from the $C_{tr}$ spectrum.

## 2. THE ORIGIN OF THE $C_{tr}$ SPECTRUM

The $C_{tr}$ spectrum, which represents urban road traffic spectrum in ISO 717-1 [1], was adopted from the Nordtest Method NT ACOU 061 (1987) [2]. The purpose of that method is to specify traffic noise reduction indices of windows and to give guidelines on how to use these indices. Annex A of the method gives many examples of different traffic noise spectra (road, rail, aircraft), one of which represents the urban road traffic with about 10 % heavy vehicles and a speed of 50 km/h. The origin of this spectrum is the mean value of 18 measurements from Copenhagen and Gothenburg with reference to reports by the Danish Acoustical Institute [3] and the National Swedish Building Research Council [4]. These reports are in Danish and Swedish, respectively.

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The report from Denmark gives a method for calculating the noise inside the closed city courtyards. The measurements were made in Copenhagen in 1984. Six typical building blocks were studied, and in each case simultaneous noise measurements were performed at the front facing a busy street and in the courtyards. The measurements were used for verifying and simplifying the proposed calculation method. Thus, the purpose of these measurements was not to find traffic noise spectra that could be representative for typical urban traffic noise.

The report contains measurement results from eight series on the front façades. The measurement periods varied in duration between 10 and 30 minutes. The traffic speed is reported for only half of the measurements (about 60 km/h). For the remaining measurement situations it is only reported that the traffic had a steady flow. The number of passing vehicles is not reported for all measurement series, but where it is, the percentage of heavy vehicles is reported to be between 5 and 10 %.

Figure 1 shows the results from eight measurement series normalized to 0 dBA. A closer study of the report reveals a number of disturbances from other noise sources during the measurements, such as door slamming, airplane take-off, terminal operations at Kastrup airport, diesel train passing, sweeping, and pigeons. The registered disturbing noise sources are more dominant in the frequency range below 500 Hz and it is reasonable to assume that they have influenced the measurement results. The large variation in the lower frequency range may also be an indication of these disturbances. The curves are more uniform at higher frequencies.

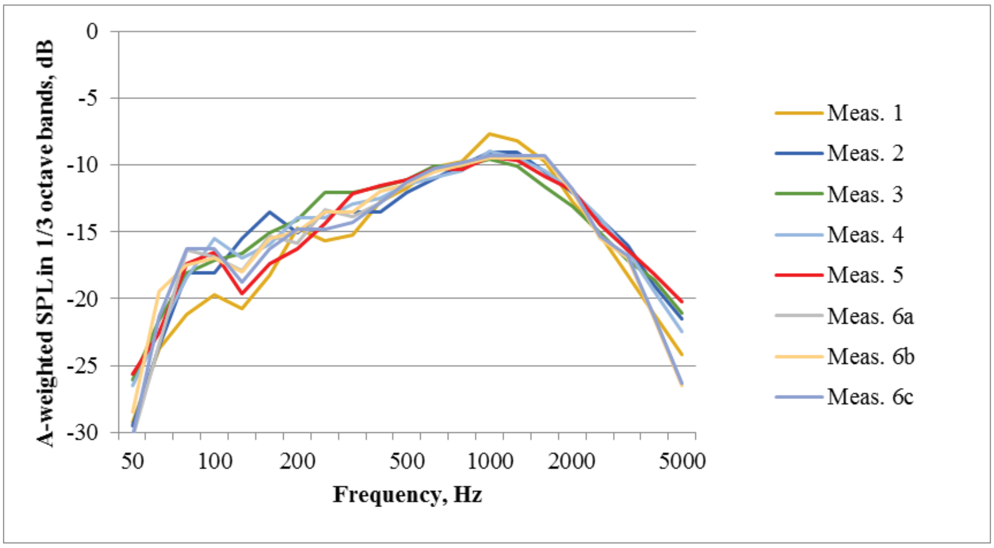


Figure 1: Eight measured normalized spectra of Copenhagen study.

The subject of the report from Sweden is sound classification of windows. The report introduces a “new” noise spectrum for road traffic, which is based on ten measurements at ten different locations in Gothenburg, Sweden during October 1985. The report does not give any further details regarding measurement and traffic conditions. The comparison of the average values of the spectra from the two reports in figure 2 shows that the spectrum from Gothenburg contains much less low frequency energy than what was measured in Copenhagen.

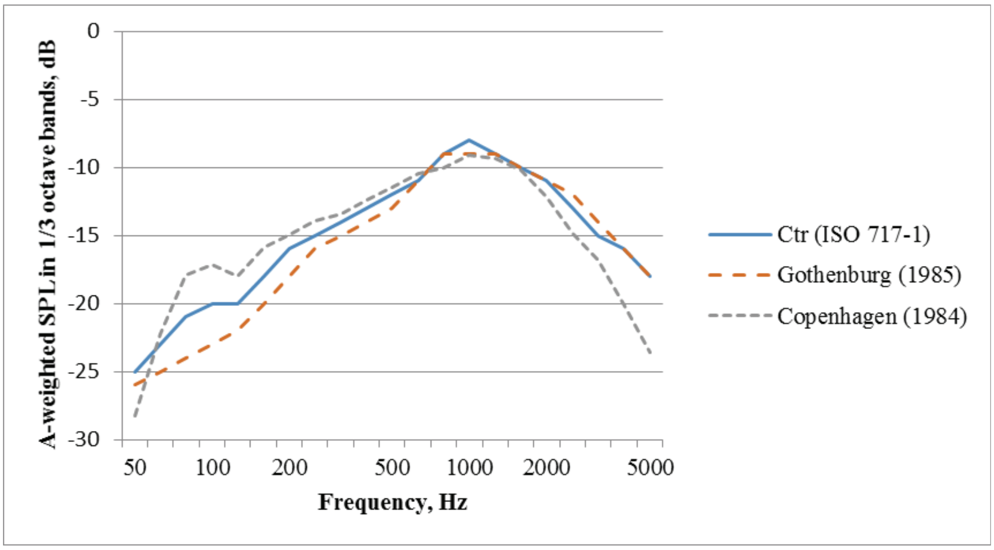


Figure 2: Comparison of Gothenburg and Copenhagen normalized spectra with the $C_{tr}$ spectrum.

## 3. MORE RECENT MEASUREMENTS OF NOISE FROM URBAN TRAFFIC

Two studies from 2013 presented recently measured spectra for urban traffic noise [5, 6]. Both studies concluded that the $C_{tr}$ spectrum includes higher noise level values for frequencies below 500 Hz than the measured spectra in these studies.

Figure 3 summarizes the measurement normalized to 0 dBA.

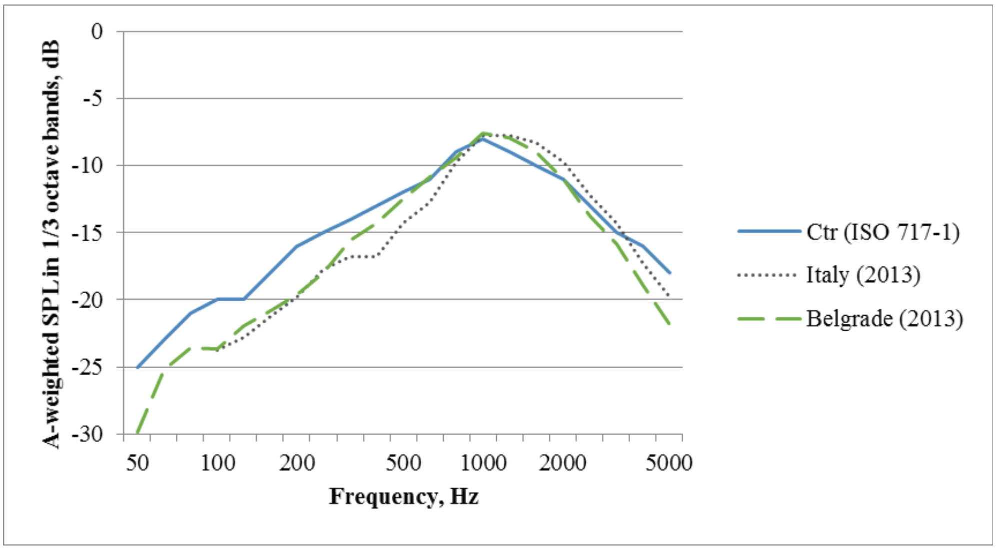


Figure 3: Comparison of recently measured normalized spectra from Italy and Belgrade with $C_{tr}$ spectrum

We are not familiar with details regarding speed limit and the percentage of heavy vehicles in the Belgrade study, but it is reported that the traffic noise was recorded at six locations in the Belgrade urban zone. From the Italian study the speed limit and the number of heavy vehicles is reported only for a selection of measurements, the speed being 50 km/h and the percentage of heavy vehicles between 0 and 3 %.

## 4. CHANGES IN CHARACTERISTICS OF VEHICLES

Since the data used in the $C_{tr}$ spectrum originates from measurements done in the 1980s, it is reasonable to question whether this spectrum is still representative for the noise emitted from cars today. A number of power unit noise reduction measures have been introduced, such as improvement of the exhaust systems, optimization of the engine structures and improvement of the combustion systems. Studies on noise emissions from motor vehicles in road traffic indicate [7] that the sound pressure level for urban traffic (50-60 km/h) has not changed in the period 1987-2001. Figure 4 and 5, with data adapted from a report by Sandberg, 2001 [8], (originally Hoogwerff, 2001 [9]), compare the frequency spectra of vehicle pass-by measurements made in 1974 and 1999. The figures represent the pass by levels of light vehicles at 50 km/h and the heavy trucks at 70 km/h. The report states that the differences in the 125-500 Hz frequency range suggest a decrease of power unit noise for light vehicles. The results for heavy vehicles in figure 5 indicate a similar development. We are at this time not familiar with any more recent studies where this has been a topic of research.

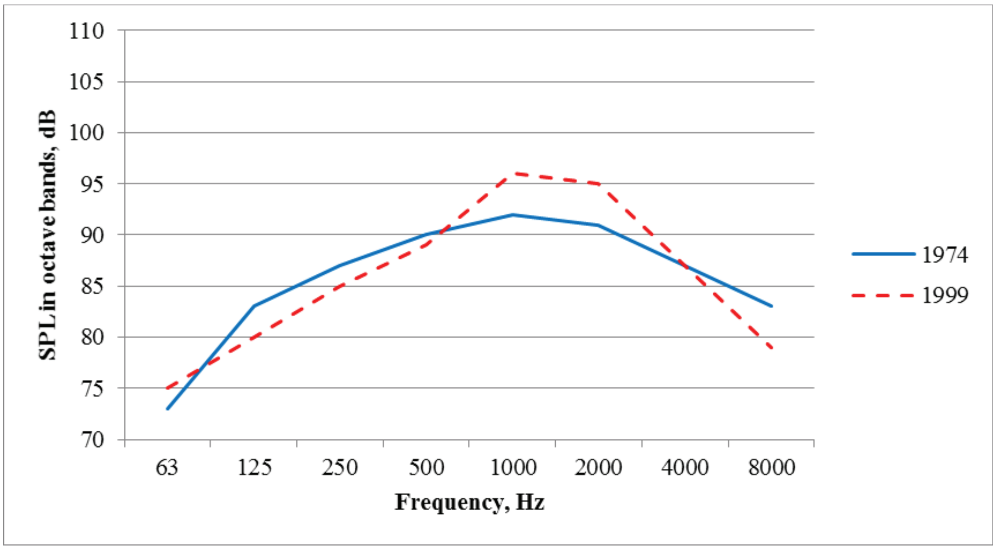


Figure 4: Comparison of frequency spectra of vehicle pass-by measurements for light vehicles at 50 km/h made in 1974 and 1999. Data adapted from Sandberg, 2001 [8].

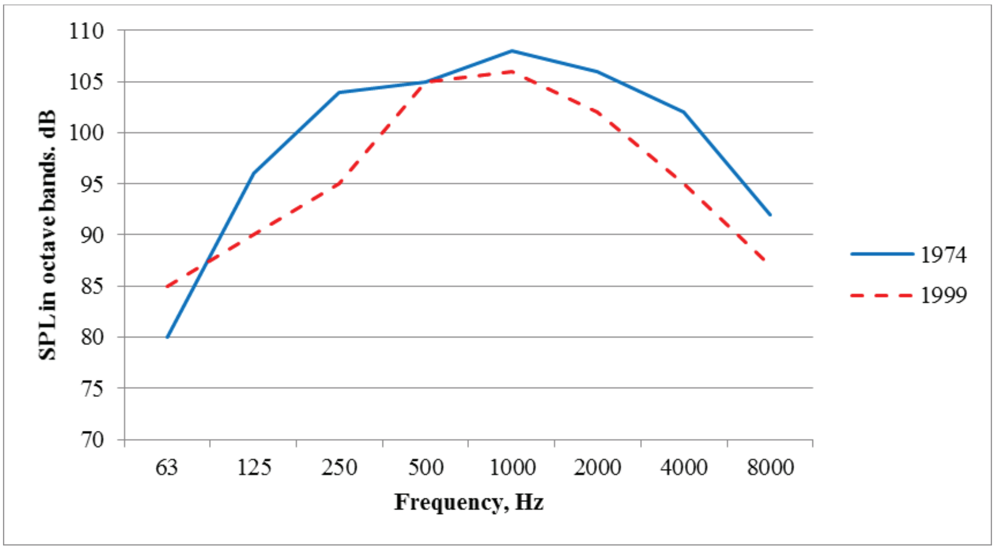


Figure 5: Comparison of frequency spectra of vehicle pass-by measurements for heavy trucks at 70 km/h made in 1974 and 1999. Data adapted from Sandberg, 2001 [8].

## 5. CALCULATIONS

$C_{tr}$ correction is used for calculating indoor noise levels from outside traffic noise and for characterizing the performance of building elements. The influence of using an “incorrect” spectrum for façade calculations can be demonstrated through simplified calculations.

The software we have used for these calculations is Støybygg 3, developed by Sintef IKT in Norway. This software uses the calculation method from Håndbok 47 [10], which is used for indoor noise calculations in Norway. This method calculates the indoor level based on the outdoor levels, the size of the building elements, the sound reduction of the building elements and the spectrum correction according to ISO 717. The method specifies that the $C_{tr}$ spectrum is to be used where traffic speed is 50 km/h.

The calculation method from Håndbok 47, has been modified in the software so that the levels are calculated with sound reduction in 1/3 octave bands as input, instead of using single number $R_w$-values. Also for spectrum correction, the whole spectrum is used as input, instead of single number C-values. This makes it possible to modify the correction spectra.

We have performed the calculations with three different spectra for comparison:

- The $C_{tr}$ spectrum
- The spectrum from Gothenburg (1985)
- The spectrum from Belgrade (2013)

Calculations were done using a room with a volume of 26 $m^3$ and a façade of 8 $m^2$. The wall surface was 6,4 $m^2$ and the window surface 1,6 $m^2$, i.e. 20 % of total façade area. The reverberation time in the room was set to T=0,5 s. The outdoor level was $L_{Aeq}$=55 dB.

We investigated three typical windows with wooden frames and frame built wooden walls with two types of gaps. The sound reduction characteristics of these building elements [11] are shown in figure 6 and 7.


Figure 6: Sound reduction of the three window types used in the calculations.

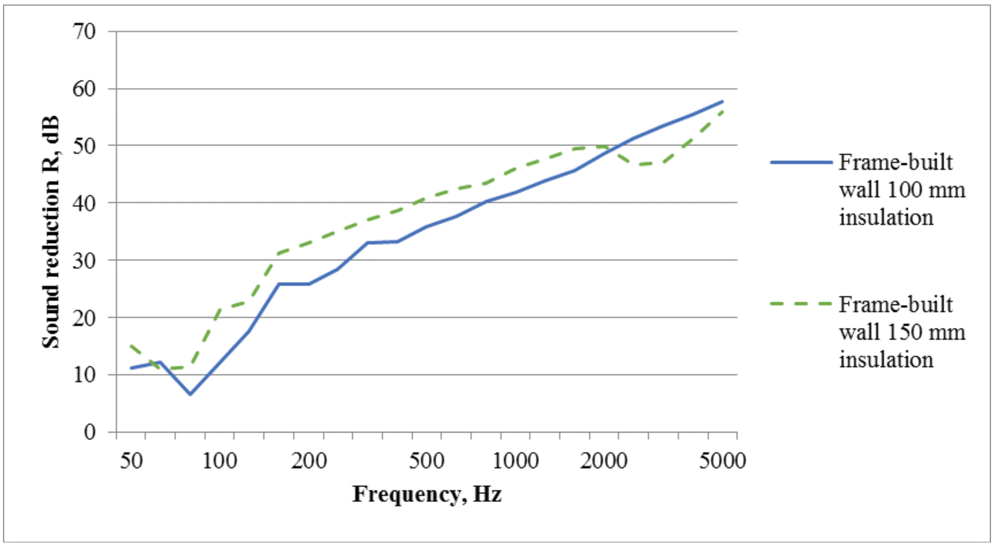


Figure 7: Sound reduction of the two wall types used in the calculations.

Table 1 summarizes the calculation input for four evaluated building element combinations and the calculation results. The "contribution" columns show the contribution to indoor level from each building element, which depends on the type and size of the element. The total level inside the room is the sum of all contributions.

Table 1: Calculation input and results. Calculated with frequency range 100-3150 Hz

| Building element | $R_w$ | $C_{tr\ 100\text{-}3150}$ | Size | Contribution $C_{tr}$ spectrum | Contribution Gothenburg spectrum | Contribution Belgrade spectrum |
|---|---|---|---|---|---|---|
| Frame built wall, 100 mm insulation | 38 | -8 | 6,4 | 26,6 | 24,6 | 24,0 |
| Window 4-15-4 | 32 | -5 | 1,6 | 23,1 | 22,1 | 21,1 |
| **Total level inside the room** | | | | **28,2** | **26,5** | **25,8** |
| | | | | | | |
| Frame built wall, 100 mm insulation | 38 | -8 | 6,4 | 26,6 | 24,6 | 24,0 |
| Window 4-40-4 | 27 | -4 | 1,6 | 27,3 | 26,5 | 26,0 |
| **Total level inside the room** | | | | **30** | **28,6** | **28,1** |
| | | | | | | |
| Frame built wall, 100 mm insulation | 38 | -8 | 6,4 | 26,6 | 24,6 | 24,0 |
| Window 4-10-(4/1/4) | 39 | -5 | 1,6 | 17 | 15,9 | 15,4 |
| **Total level inside the room** | | | | **27** | **25,2** | **24,6** |
| | | | | | | |
| Frame built wall, 150 mm insulation | 44 | -7 | 6,4 | 19,5 | 17,9 | 17,4 |
| Window 4-15-4 | 32 | -5 | 1,6 | 23,1 | 22,1 | 21,1 |
| **Total level inside the room** | | | | **24,6** | **23,5** | **22,6** |

The results indicate that the calculated indoor levels are higher when using the $C_{tr}$ spectrum. The difference in total calculated indoor level may be as high as 1.8 dB, when comparing the $C_{tr}$ spectrum with the spectrum from Gothenburg (1985), and 2.4 dB when comparing with the spectrum from Belgrade (2013). The difference depends on the type of building element in the room.

What is typical for the chosen building elements is that the sound reduction is poor at lower frequencies, due to cavity resonance. Frame-built wooden walls, which are more common in the Nordic countries than elsewhere in Europe, will be particularly affected by changes in the traffic correction spectrum at lower frequencies. However, this will in general affect indoor levels in rooms where the façade has a high proportion of windows.

We have performed the same calculations with an extended frequency range. A comparison between the results with frequency range 100-3150 and 50-3150 indicate a significant difference in level contribution for frame built wooden walls.

The difference in total calculated indoor level in table 2 may be as high as 2.2 dB, when comparing the $C_{tr}$ spectrum with the spectrum from Gothenburg (1985), and 2.5 dB when comparing with the spectrum from Belgrade (2013).

Table 2: Calculation input and results. Calculated with frequency range 50-3150 Hz

| Building element | $R_w$ | $C_{tr\ 50\text{-}5000}$ | Size | Contribution $C_{tr}$ spectrum | Contribution Gothenburg spectrum | Contribution Belgrade spectrum |
|---|---|---|---|---|---|---|
| Frame built wall, 100 mm insulation | 38 | -13 | 6,4 | 31,7 | 29,5 | 29,2 |
| Window 4-15-4 | 32 | -5 | 1,6 | 23,2 | 22,2 | 21,2 |
| **Total level inside the room** | | | | **32,3** | **30,3** | **29,8** |
| | | | | | | |
| Frame built wall, 100 mm insulation | 38 | -13 | 6,4 | 31,7 | 29,5 | 29,2 |
| Window 4-40-4 | 27 | -4 | 1,6 | 27,4 | 26,6 | 26,1 |
| **Total level inside the room** | | | | **33,1** | **31,3** | **30,9** |
| | | | | | | |
| Frame built wall, 100 mm insulation | 38 | -13 | 6,4 | 31,7 | 29,5 | 29,2 |
| Window 4-10-(4/1/4) | 39 | -5 | 1,6 | 17,2 | 16,2 | 15,6 |
| **Total level inside the room** | | | | **31,9** | **29,7** | **29,4** |
| | | | | | | |
| Frame built wall, 150 mm insulation | 44 | -15 | 6,4 | 27,5 | 25,5 | 25,2 |
| Window 4-15-4 | 32 | -5 | 1,6 | 23,2 | 22,2 | 21,2 |
| **Total level inside the room** | | | | **28,9** | **27,2** | **26,6** |

## 6. CONSLUSIONS

The $C_{tr}$ spectrum, which is used for classifying the sound reducing properties of building elements and for calculating indoor levels from traffic noise, is based on uncertain data from two studies. It was never the intention of the study performed in Copenhagen 1984 to use the measurements for defining the reference spectrum of urban traffic. The measurements were used with a view to confirming and simplifying a calculation method for calculating noise levels inside the closed city courtyards. The measured spectra are most likely affected in the lower frequencies by many of the reported disturbances.

The details about measurement conditions for the ten measurements in Gothenburg 1985 are not known, but the differences in lower frequencies when comparing with the Copenhagen 1984 spectrum are clear.

The spectra from recent measurements seem to be more similar to the Gothenburg spectrum, and with even lower levels in the 100-500 Hz frequency range. The lower levels in lower frequencies may, notwithstanding any possible methodical flaws in the Copenhagen study, also be the result of changes in vehicle noise characteristics. The indoor level calculations from this study show that the levels may in reality be up to 2.4 dB lower, using the Belgrade spectrum.

Another possible explanation for the lower low-frequency levels in the Belgrade and Italian studies, may be the proportion of heavy vehicles in the measurement series. The Italian study reported a fairly low proportion, while no data was available for the Belgrade study. The data we have had access to is insufficient to draw any clear conclusions on this point – this will require further analyses and/or measurements.

Over the past years, there has been a lot of discussion whether the frequency range of the ISO 717-1 method should be extended down to 50 Hz. The Cost report [12], which is a summary of a 4-year European collaboration states: *"Down to 50 Hz seems to be reasonable to consider especially to address light weight constructions and noise from heavyweight traffic"*. Our calculations show that it is even more important to collect new data for urban traffic spectrum and revise the ISO-717-1 if these recommendations are to be implemented in the future.

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