Determination of the Number of Measurements Required for 95% Confidence in an Upper Quartile Value of Hand-Arm Vibration Measurement Using the Monte-Carlo Method

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Objective

To determine:

• The number of measured hand-arm vibration data sets that will provide
  an estimate of the upper quartile value that is within 10% of the true value with 95% confidence

Part of wider project on how to demonstrate vibration emission of low-vibration machines
Method

- Use the HSE Hand-Arm Vibration Database
  - Assess how data sets could be modelled using random number data sets

- Use the Monte Carlo method
  - Generate large numbers of simulated HAV data sets with:
    - Known target upper-quartile value and variability
    - Varying numbers of sample in data set
  - Assess the computed 75th percentile values and
  - Determine how many samples are required to get within 10% of the target value.
HAV data sets
HSE Hand-Arm Vibration Database

- Database interrogated in April 2020
- Machines for which:
  - more than 20 measurements on the same machine
- 135 machines
- Measurements are:
  - all real work activities
  - not multiple repeats of the same activity
HSE Hand-Arm Vibration Database

- Percentile statistics of the vibration total values were calculated for each of the 135 machines:
  - numbers in the data sets ranged from 21 to 216
  - median number of samples: 30
  - median 75th percentile: 11.24 m/s²

- IQR/Q75 ("variability")
  - measure of variability, independent of actual vibration values
  - median IQR/Q75: 0.31 (Range from 0.10 to 0.63)
Example data sets from HSE data base (sets with 30 samples)
Simulation of HAV data sets
Simulation of HAV data sets

Uniform random number generator:

• Target 75th percentile (Q75): 10 m/s²
  • Median database Q75 value: 11.24 m/s²
• IQR/Q75 (“variability”): 0.1 to 0.6
  • Median database IQR/Q75 value: 0.31
Uniform distribution – 10,000 samples
Uniform distributions - 30 samples
Comparison with real data sets

<table>
<thead>
<tr>
<th>Simulated data</th>
<th>Real data</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Graph 1" /></td>
<td><img src="image2.png" alt="Graph 2" /></td>
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<td><img src="image3.png" alt="Graph 3" /></td>
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<td><img src="image7.png" alt="Graph 7" /></td>
<td><img src="image8.png" alt="Graph 8" /></td>
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**Simulated data**
- Number of samples: 30
- 75th percentile: 10.0
- Interquartile range: 3.0
- Frequency distribution

**Real data**
- Number of samples: 30
- 75th percentile: 20.4
- Interquartile range: 4.2
- Frequency distribution

**Simulated data**
- Number of samples: 30
- 75th percentile: 14.1
- Interquartile range: 3.5
- Frequency distribution

**Real data**
- Number of samples: 30
- 75th percentile: 23.5
- Interquartile range: 4.4
- Frequency distribution

**Simulated data**
- Number of samples: 30
- 75th percentile: 10.0
- Interquartile range: 2.8
- Frequency distribution

**Real data**
- Number of samples: 30
- 75th percentile: 9.3
- Interquartile range: 2.9
- Frequency distribution

**Simulated data**
- Number of samples: 30
- 75th percentile: 10.0
- Interquartile range: 2.0
- Frequency distribution

**Real data**
- Number of samples: 30
- 75th percentile: 7.1
- Interquartile range: 1.5
- Frequency distribution
Conclusion 1

The distributions from real data and simulated data are comparable, so:

- Multiple measurements of HAV on power tools may be simulated by: uniform random distributions
Monte Carlo Simulation
Monte Carlo simulation

Generate data sets:

- Target 75\textsuperscript{th} percentile value of 10 m/s\textsuperscript{2}
- Sample numbers: 5 to 50 (step 1)
- IRQ/Q75: 0.1, 0.2, 0.3, 0.4, 0.6
- Generate versions of each data set 1000 times

For each set, compute:

- Q75 value
- Error from target 75\textsuperscript{th} percentile
- Distribution of errors within the 1000 repeats
Distributions of 75th percentile errors
Distributions for different IQR/Q75 values
Conclusions
Conclusion 2 & 3

For an estimates with 95% confidence:

- For data with the median variability (IQR/Q75 = 0.3), **35 measurements** are required for an upper quartile value within **10%** of the true value.

- For data sets with greater variability (IQR/Q75 = 0.4 and 0.6), between **20 and 30 measurements** are required for an upper quartile value within **20%** of the true value.
Conclusion 4

For practical measurements:

- Between 20 and 30 measurements is likely to achieve a reliable estimate of the true upper quartile value of real-use hand-arm vibration magnitude.
The End

Thank You