

Analysis of the database and proposals for vehicle categories and scenario 1 limit values

Extract from draft final report

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24.01.2011

Data collection and Analysis

- In parallel with authorities' collection of monitoring data, manufacturers provided the consultants with appropriate type approval testing data to prepare an equivalent database for ACEA. Data from 1186 vehicles was collected.
- 126 datasets had to be disregarded (20 duplicates and 106 vehicles with measurement conditions outside the tolerances or other inconsistencies).
- The remaining 1060 datasets were used for the analysis. Table 1 gives an overview of the vehicle categories.
- Some vehicles were certified in different categories (e.g. M1/N1 or N1/N2 or N2/N3). Whenever the methods between the categories differed, more than one sheet for the method B results was issued and the vehicles were assigned to the different categories accordingly.

Data collection and Analysis

- The first step after transfer into the Access database was to check for plausibility and consistency. An unexpectedly high amount of the data had to be corrected due to obvious mistakes. The further analysis was performed using the corrected data.
- The analyses were performed separately for the vehicle categories as defined in UN-ECE's Consolidated Resolution on the Construction of Vehicles (R.E.3).
- The proposals of equivalent limit values are based on cumulative frequency distributions and averages of the method B results (Lurban). The limit value proposal was chosen from the 90% to 95% range of the frequency distributions.
- The differences in average values were used to validate/justify differences in the proposed limits between subcategories.

Number of vehicles in the ACEA database

Category	Subcategory		number of vehicles in database	
			On Road	Off Road
M1	M1-1	pmr <125 kW/t	463	49
	M1-2	125 kW/t < pmr <= 150 kW/t	31	1
	M1-3	pmr > 150 kW/t	40	1
N1/M2-A	N1/M2-A1	GVM <= 2500 kg	49	1
	N1/M2-A2	GVM > 2500 kg	52	14
N2/M2-B	N2/M2-B1	rated speed > 3000 min ⁻¹	30	7
	N2/M2-B2	rated speed <= 3000 min ⁻¹	32	8
N3	N3-1	2 axles, Pn <= 180 kW	11	
	N3-2	2 axles, 180 kW < Pn <= 250 kW	51	14
	N3-3	2 axles, Pn > 250 kW	66	34
	N3-4	> 2 axles	23	25
M3	M3-1	Pn < 180 kW	13	3
	M3-2	180 kW < Pn <= 250 kW	23	
	M3-3	Pn > 250 kW	19	
		Sum	903	157
		Total	1060	

Tyres used for method B for N2 and N3 vehicles

Category	traction tyres	normal tyres
N2	23	31
N2or	13	1
N3	123	36
N3or	62	13
	221	81
	73.2%	26.8%

Table 1b

Comparison of Circa website and ACEA database

vehicle cat	Circa 16.08.2010	ACEA database	
M1	625	585	-40
M3	56	58	2
N1/M2-a	43	116	73
N2/M2-b	35	77	42
N3	121	224	103
	880	1060	

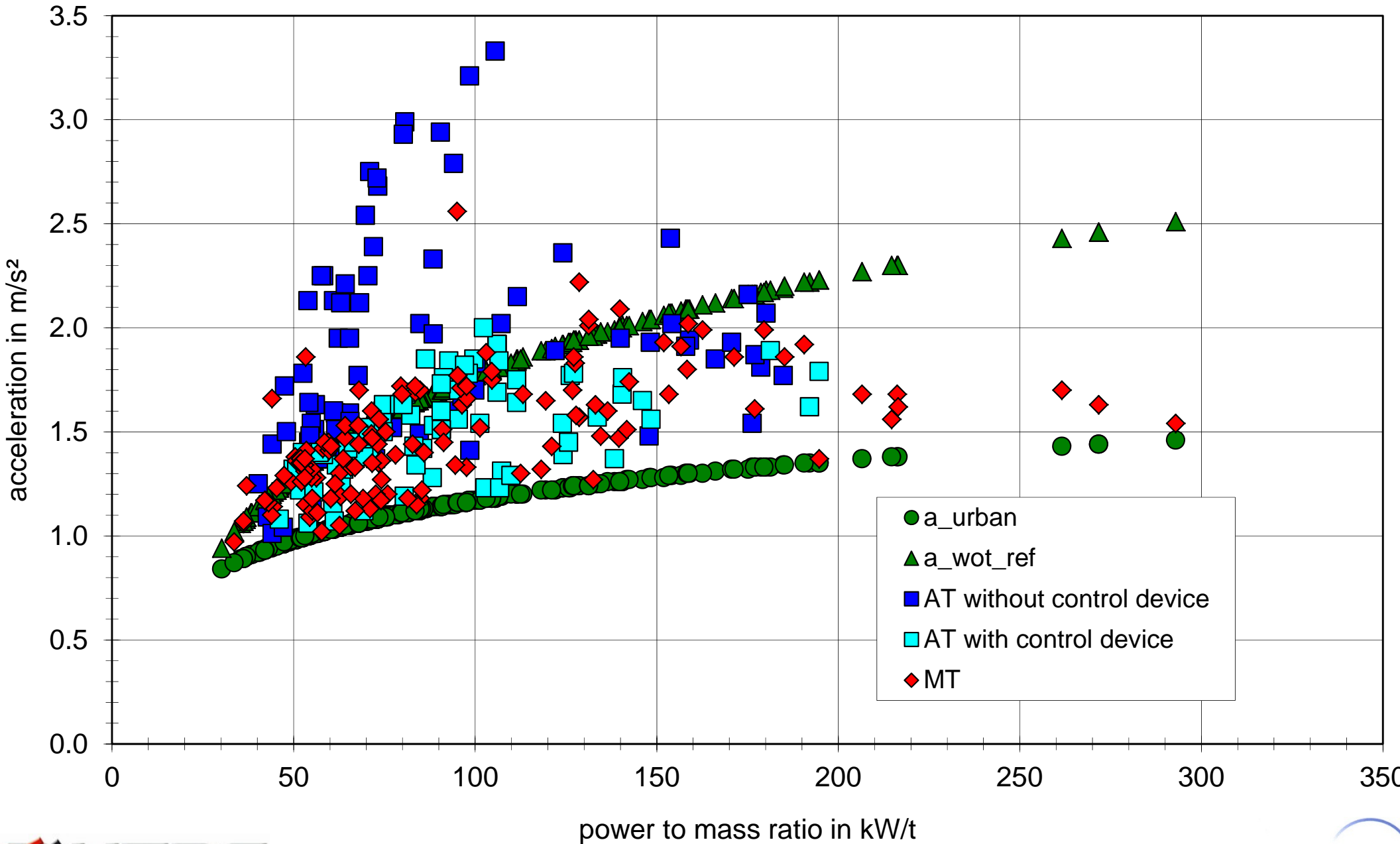
M1 vehicles

- **During the development phase of method B, it was already agreed that the existing vehicle subcategories with different noise limits and further allowances for off road vehicles and direct injection Diesel engines should be reviewed and amended.**
- **With respect to the extra 1 dB for vehicles with direct injection Diesel engines: neither the method B nor method A results show a significant difference between Petrol and Diesel engines. That means this extra 1 dB should be skipped.**
- **With respect to the two manual transmission subgroups tested in 2nd and 3rd gear and in 3rd gear only: the difference in gear use and 1 extra dB for the limit value is based on the concept that high-powered cars with a low market share could get more allowance than normal cars, because they do not contribute to the overall noise exposure.**

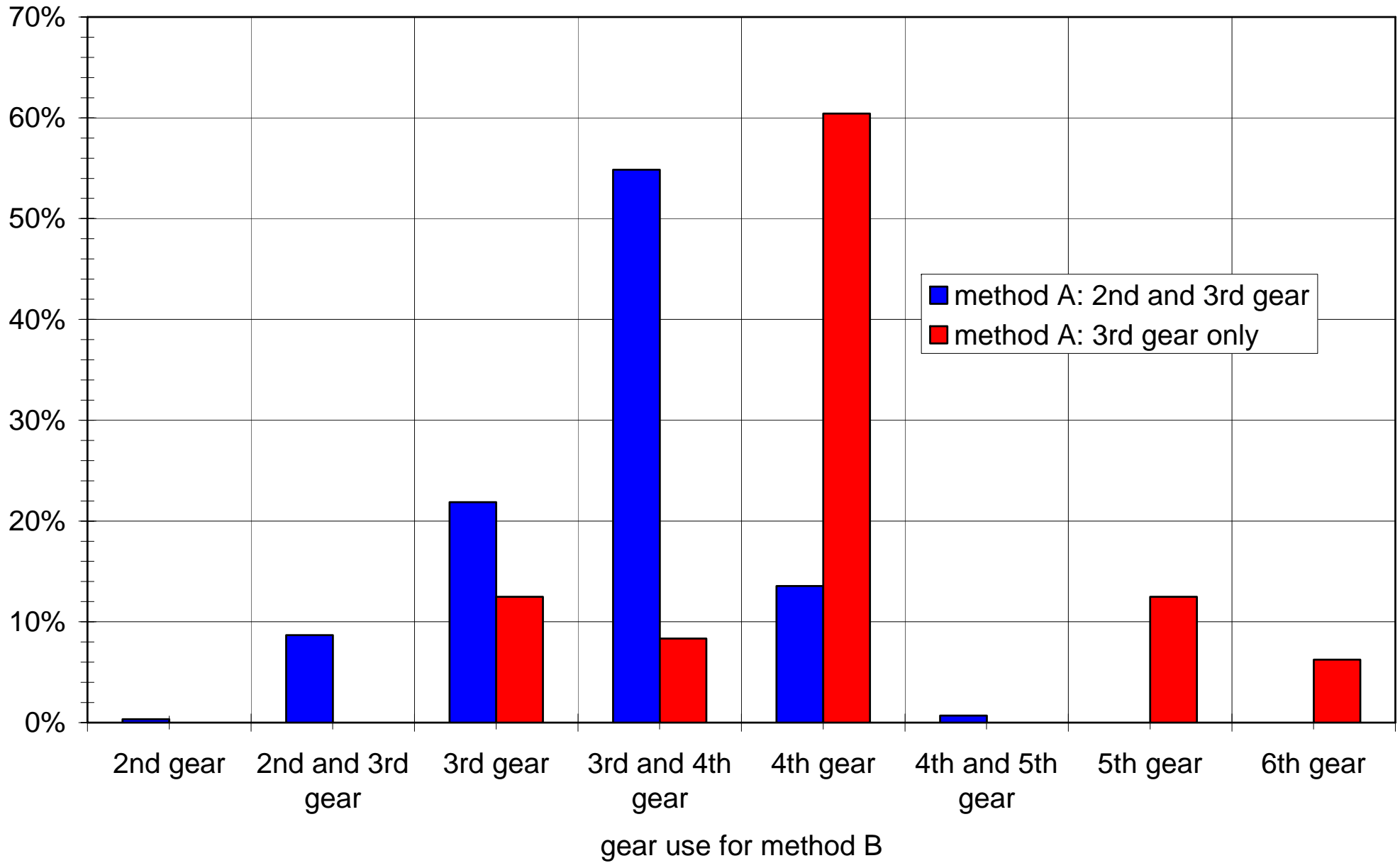
M1 vehicles

- But since the rated power values of the vehicles have increased significantly over the last decades, a low market share is no longer ensured for vehicles having rated power values above 140 kW and rated power to maximum mass ratios of more than 75 kW/t.
- Since method B already requires the rated power to kerb mass + 75 kg power to mass ratio (pmr) for the determination of the measurement conditions and the calculation of the final result, this parameter should be used for amendments.
- The following figures show the acceleration values and gear use for method B.

M1 vehicles, accelerations for method B



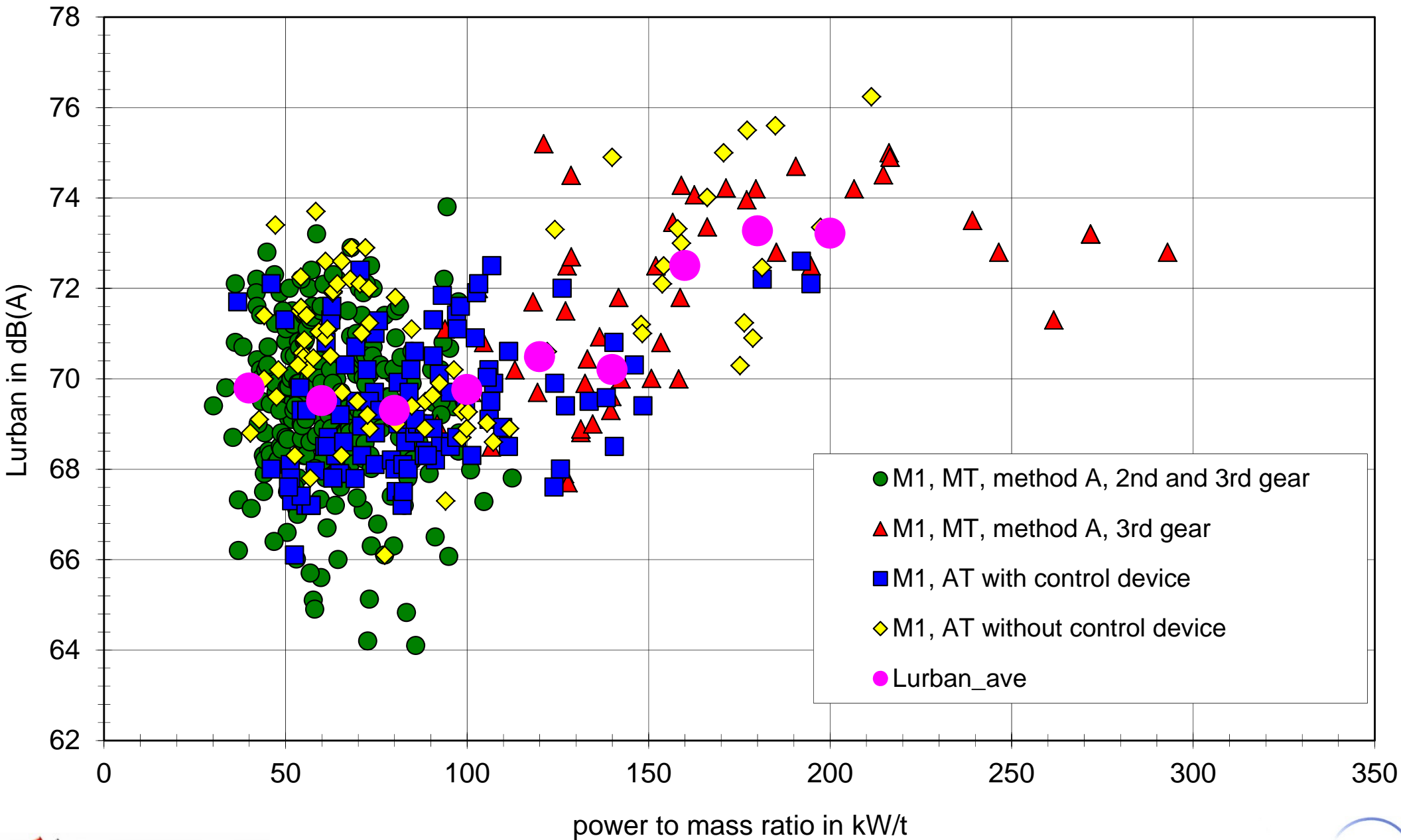
M1 vehicles, gear use, method B



M1 vehicles

- In figure 1 vehicles with automatic transmissions are separated into the subgroups “with and without control devices” to achieve the test requirements, because the calculation equations for a_wot test are different.
- The most frequently used gear ratios for method B are 3. and 4. gear for vehicles which are tested in 2. and 3. gear for method A and 4. gear only for vehicles which are tested in 3. gear only for method A.
- Figure 3 shows the method B results (Lurban) versus power to mass ratio.
- Two different power to mass ratio ranges can clearly be seen: below 100 kW/t and above 150 kW/t with a transition range in between.

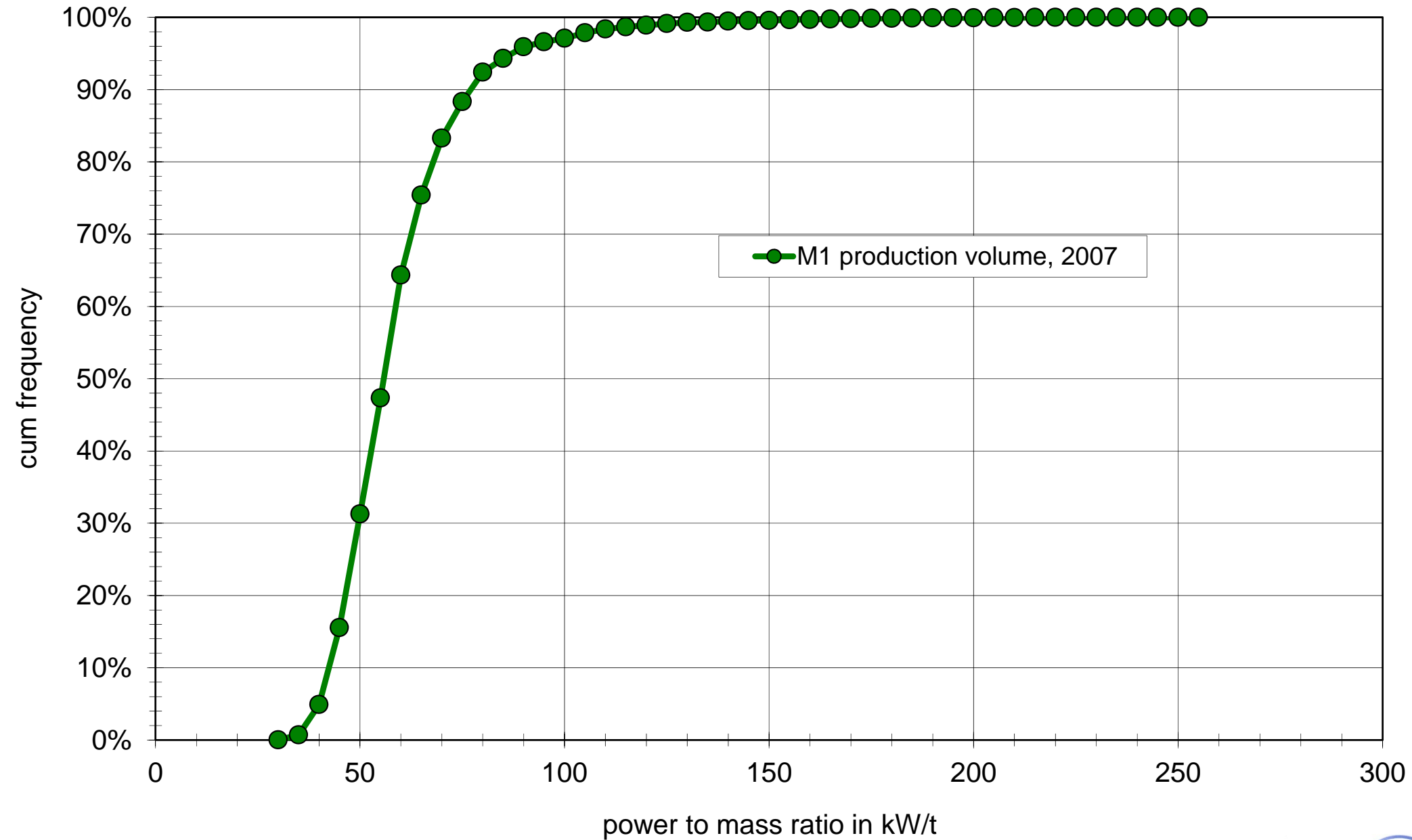
Lurban vs power to mass ratio, M1 subgroups



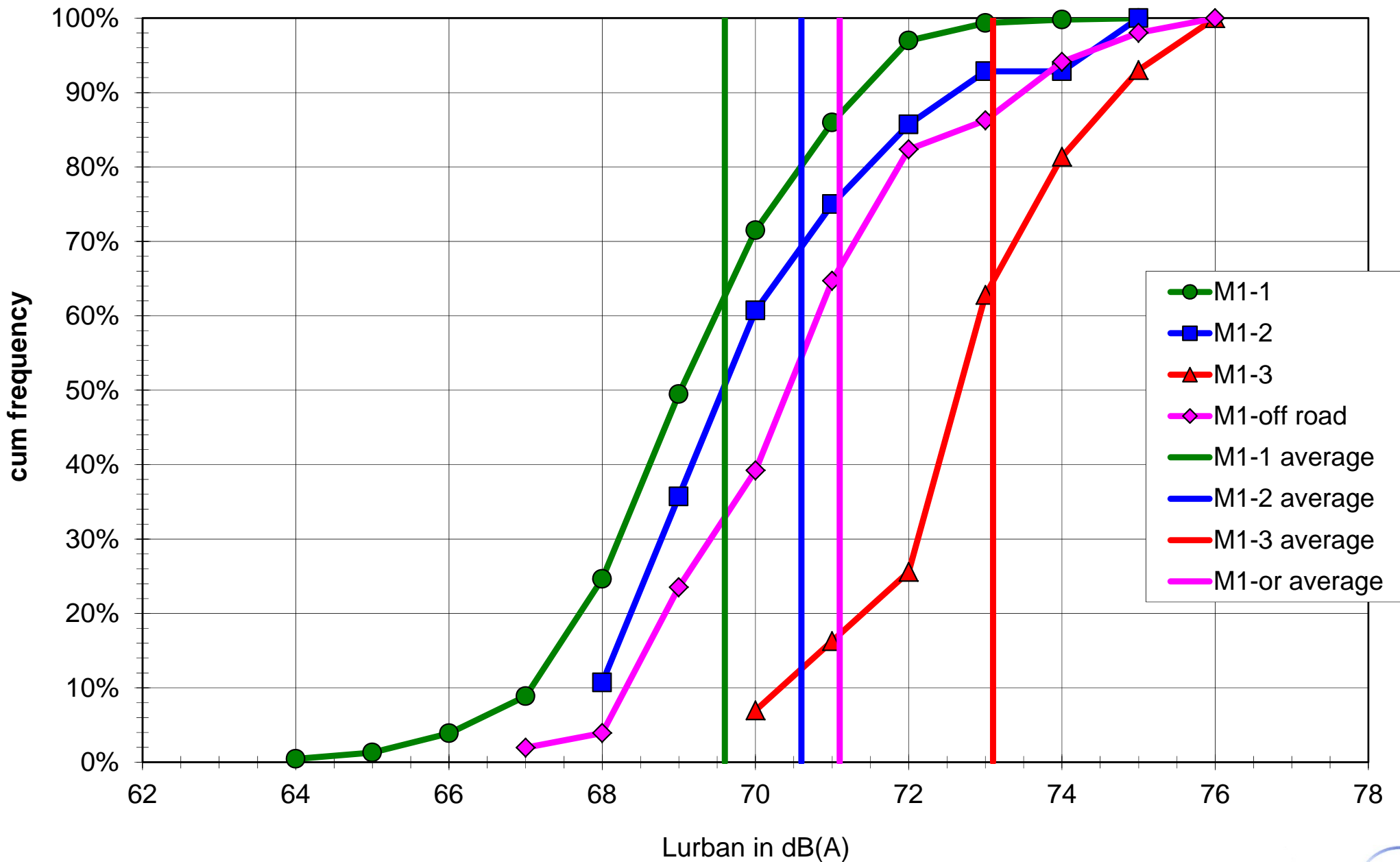
M1 vehicles

- Looking at the sales statistics from 2007 (figure 4) a shift of the upper borderline of the low pmr range from 100 kW/t to 125 kW/t would ensure that less than 1% of the vehicles would be considered high-powered vehicles and subject to extra tolerances.
- This leads to the following proposal for amended subcategories:
 - M1-1, pmr \leq 125 kW/t,
 - M1-2, 125 kW/t $<$ pmr \leq 150 kW/t,
 - M1-3, pmr $>$ 150 kW/t
- The cumulative frequency distributions of Lurban are shown in figure 5, those of the method A results in figure 6, separated for these subcategories.
- Both figures support the proposed subcategorization.

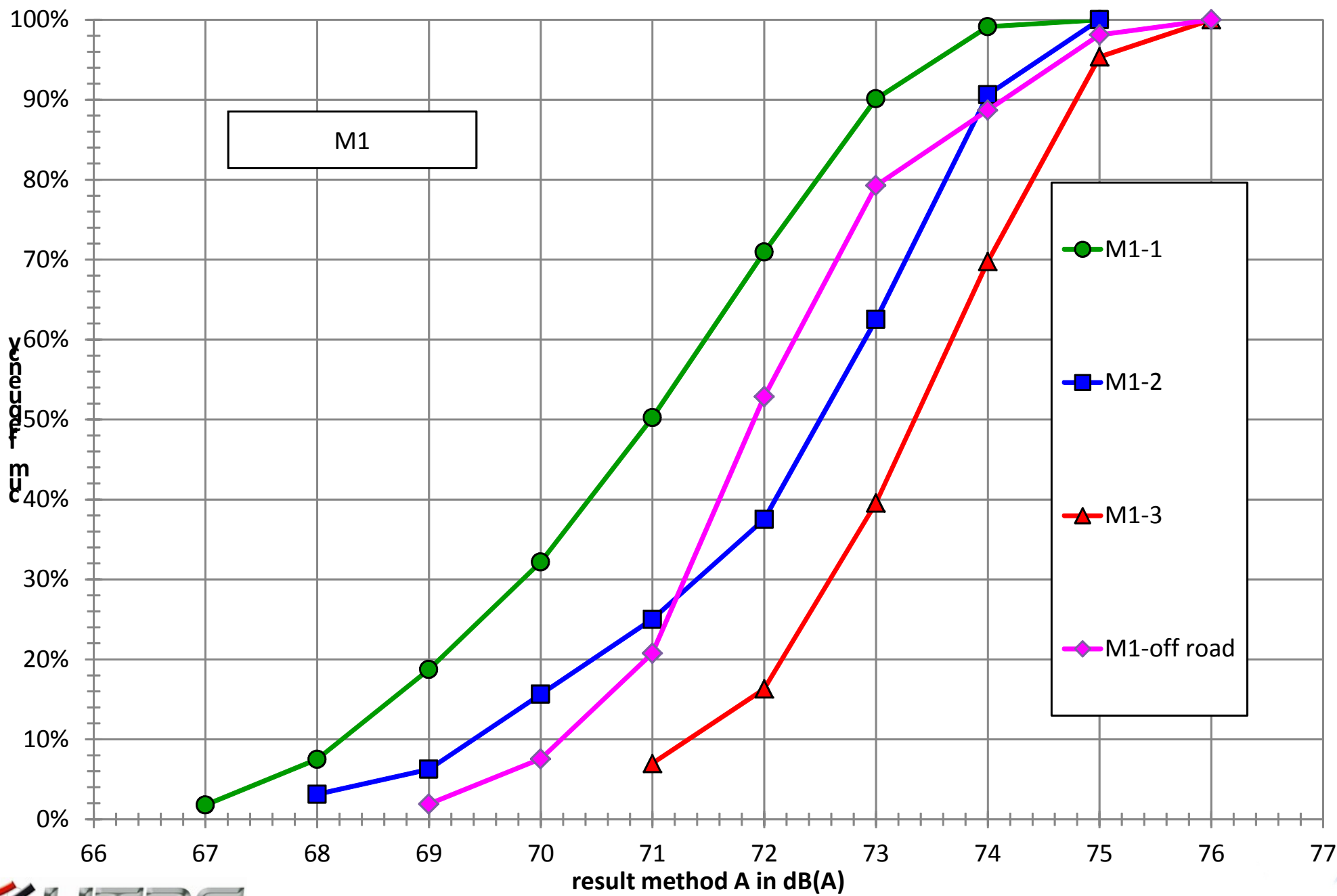
M1 production volume in 2007



M1, Lurban frequency distributions



M1, Lurban frequency distributions



M1, proposal for subcategories and limits

- The M1 database contains 51 off road vehicles, 49 of them with pmr values up to 125 kW/t.
- The cumulative frequency distributions of Lurban and method A results are already shown in figures 5 and 6.
- The method B results are a bit higher than the results for M1-2 on road vehicles.
- This leads to the following proposal for M1 vehicle classes and limit values:
 - M1-1, on road, pmr \leq 125 kW/t 72 dB,
 - M1-2, on road, 125 kW/t $<$ pmr \leq 150 kW/t 73 dB,
 - M1-3, on and off road, pmr $>$ 150 kW/t 75 dB,
 - M1-off road 74 dB.

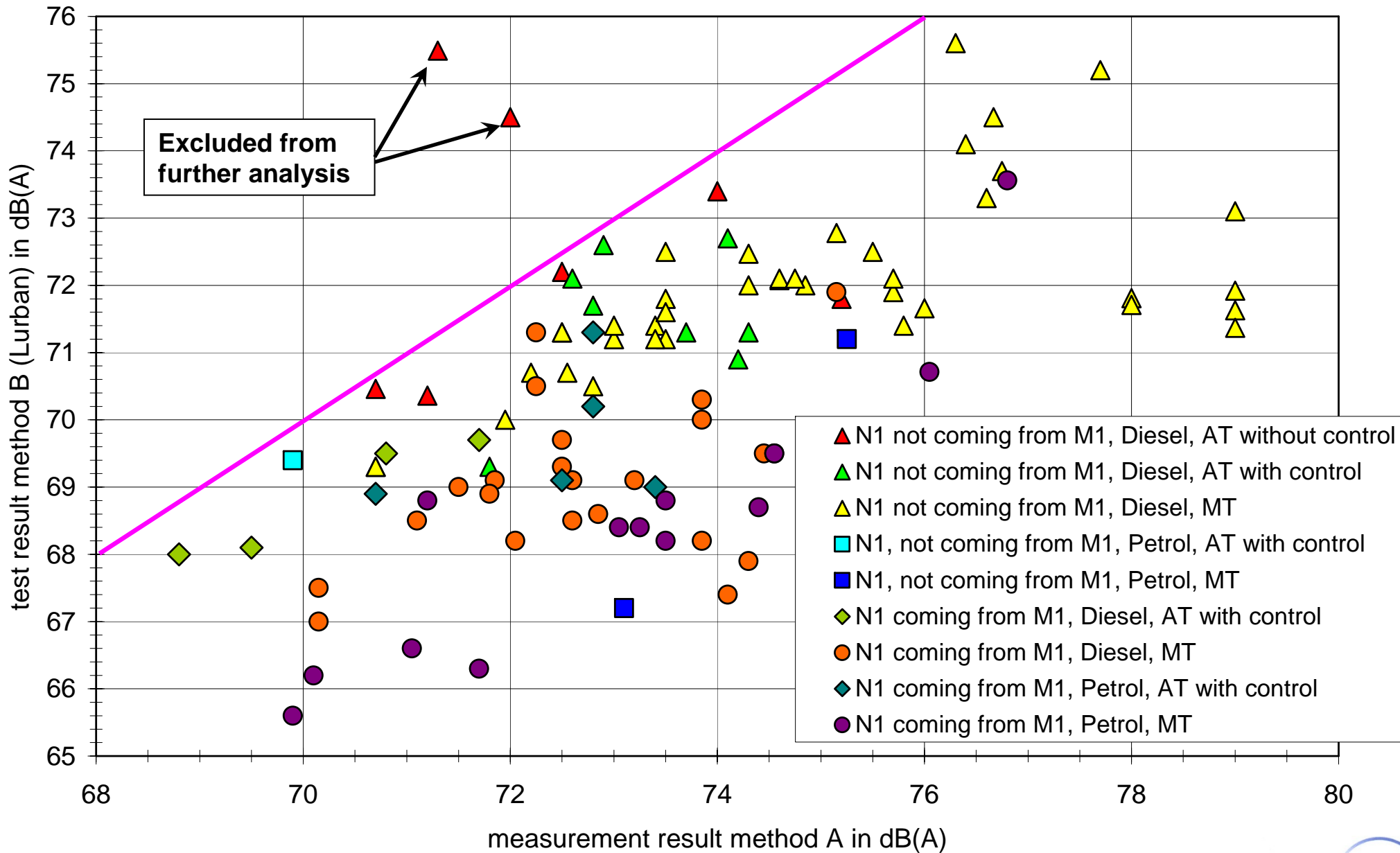
M1, proposal for subcategories and limits

- **In order to avoid that sport utility vehicles and so called “crossover” vehicles can be classified as off road vehicles, the following requirements shall be applied for M1-off road vehicles:**
 - **off road as defined in the UN-ECE consolidated resolution R.E.3 and in addition**
 - **a wading depth exceeding 500 mm,**
 - **a hill climbing ability exceeding 35°.**

N1 and M2-A vehicles

- **N1 vehicles are used for the carriage of goods and M2-A vehicles are used for the carriage of passengers having more than 9 seats, both with GVM up to 3500 kg.**
- **The current method differentiates two subcategories, one with GVM up to 2000 kg and one with GVM above 2000 kg. The limit values are 76 and 77 dB(A) respectively with an additional 1 dB(A) for direct injection Diesel engines.**
- **The N1/M2-a sample contained M1 derivatives (N1 coming from M1 or M1 certified as N1) and “real” N1 vehicles, not coming from M1 vehicles.**
- **Two vehicles with automatic transmission without control devices to reach the required test conditions for method B were excluded from the analysis because their method B results were much higher than the method A results (figure 7).**

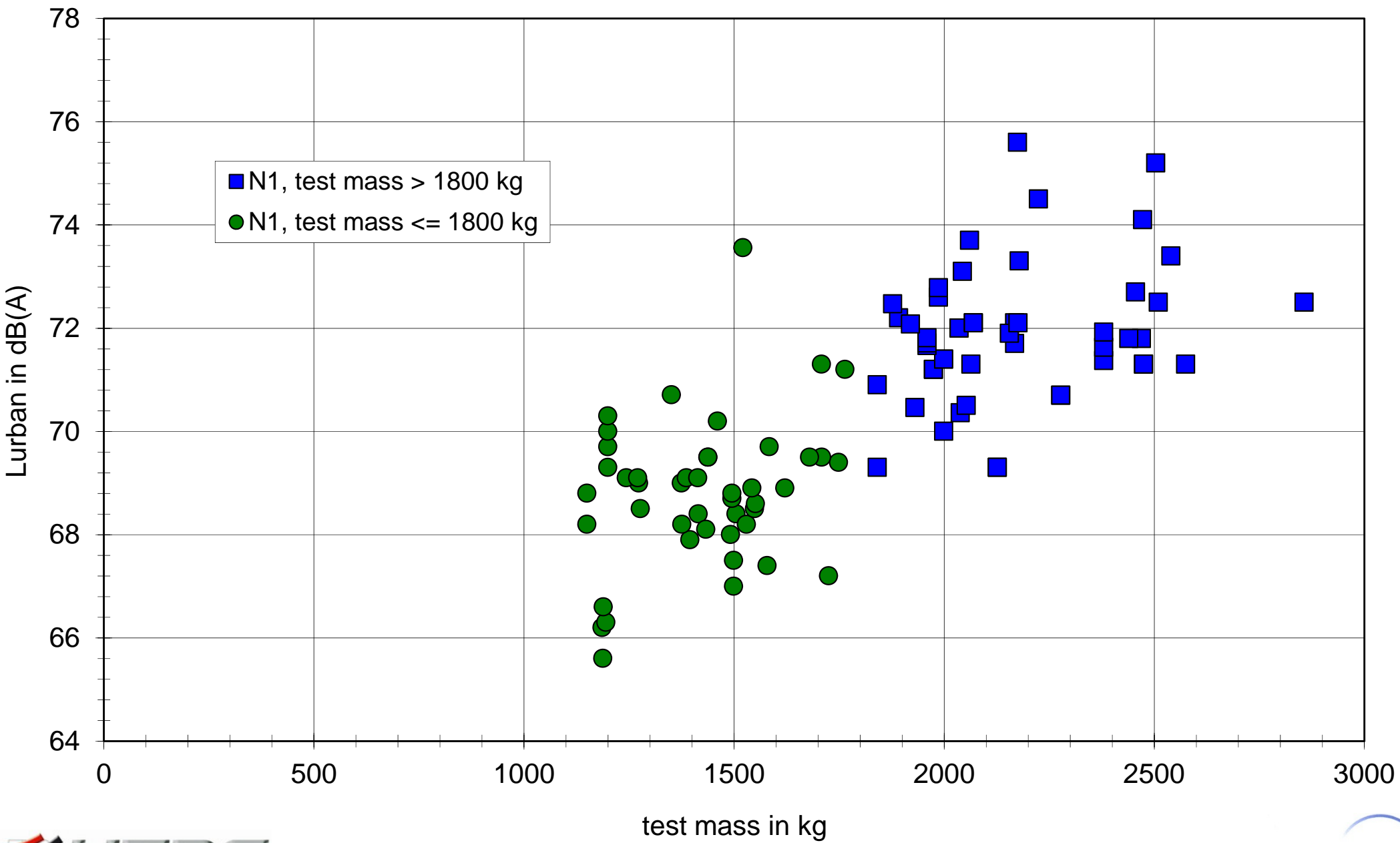
N1/M2-A, Lurban vs Lold



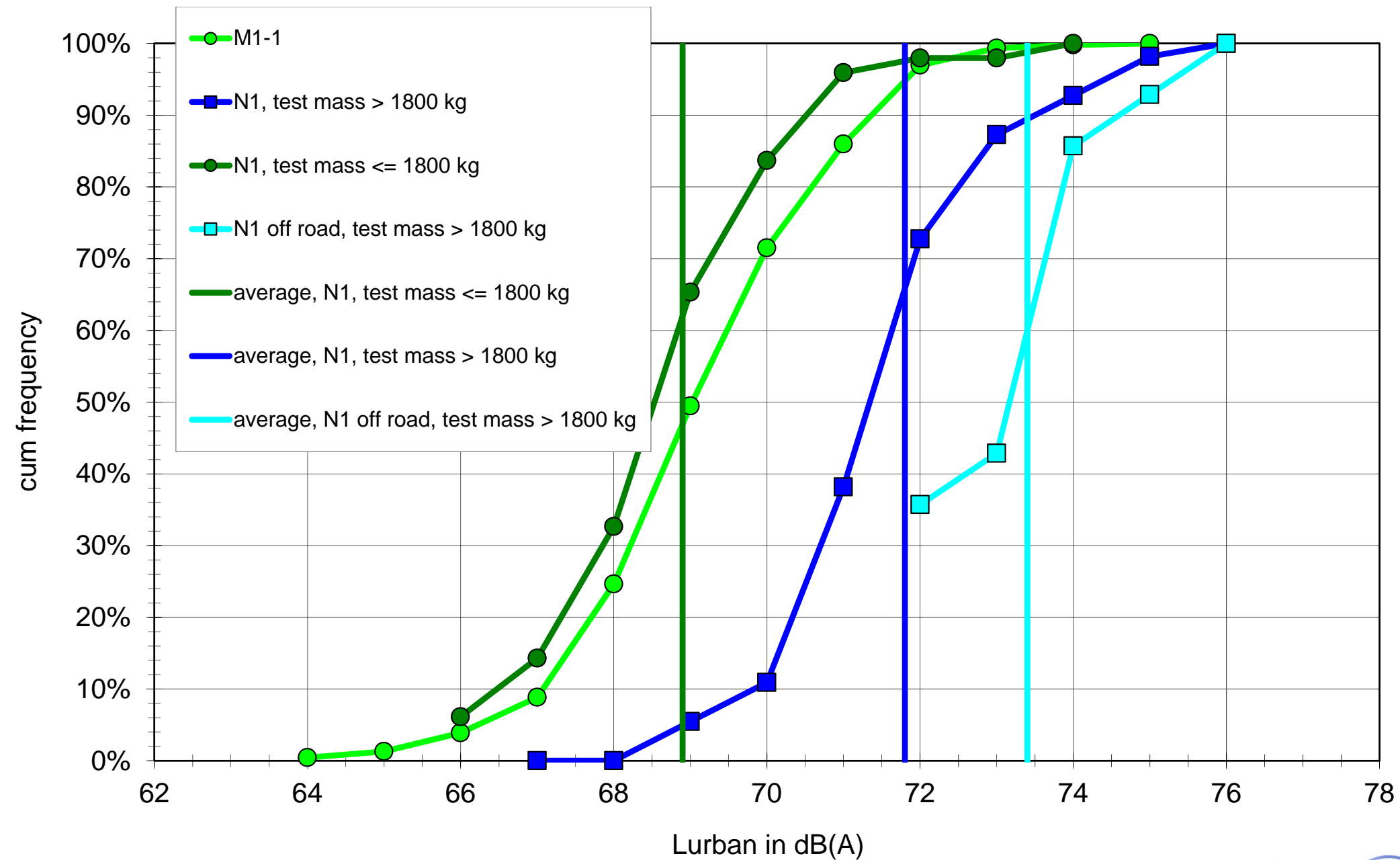
N1 and M2-A vehicles

- The analysis showed significant differences in Lurban between both subcategories. The test mass is a good discriminator between the two subcategories with 1800 kg as borderline (figure 8).
- The cumulative frequency distributions of Lurban are shown in figure 9, those of the method A results in figure 10, separated for the 2 test mass classes.
- The 2 test mass categories are clearly separated in both figures. Figure 10 shows, that vehicles with test mass ≤ 1800 kg fulfill the M1 limit values for the today's method.
- The frequency distributions for the 14 off road vehicles with test mass > 1800 kg are also shown in these figures.
- Both figures support the chosen subcategorization and 1 extra dB for off road vehicles.

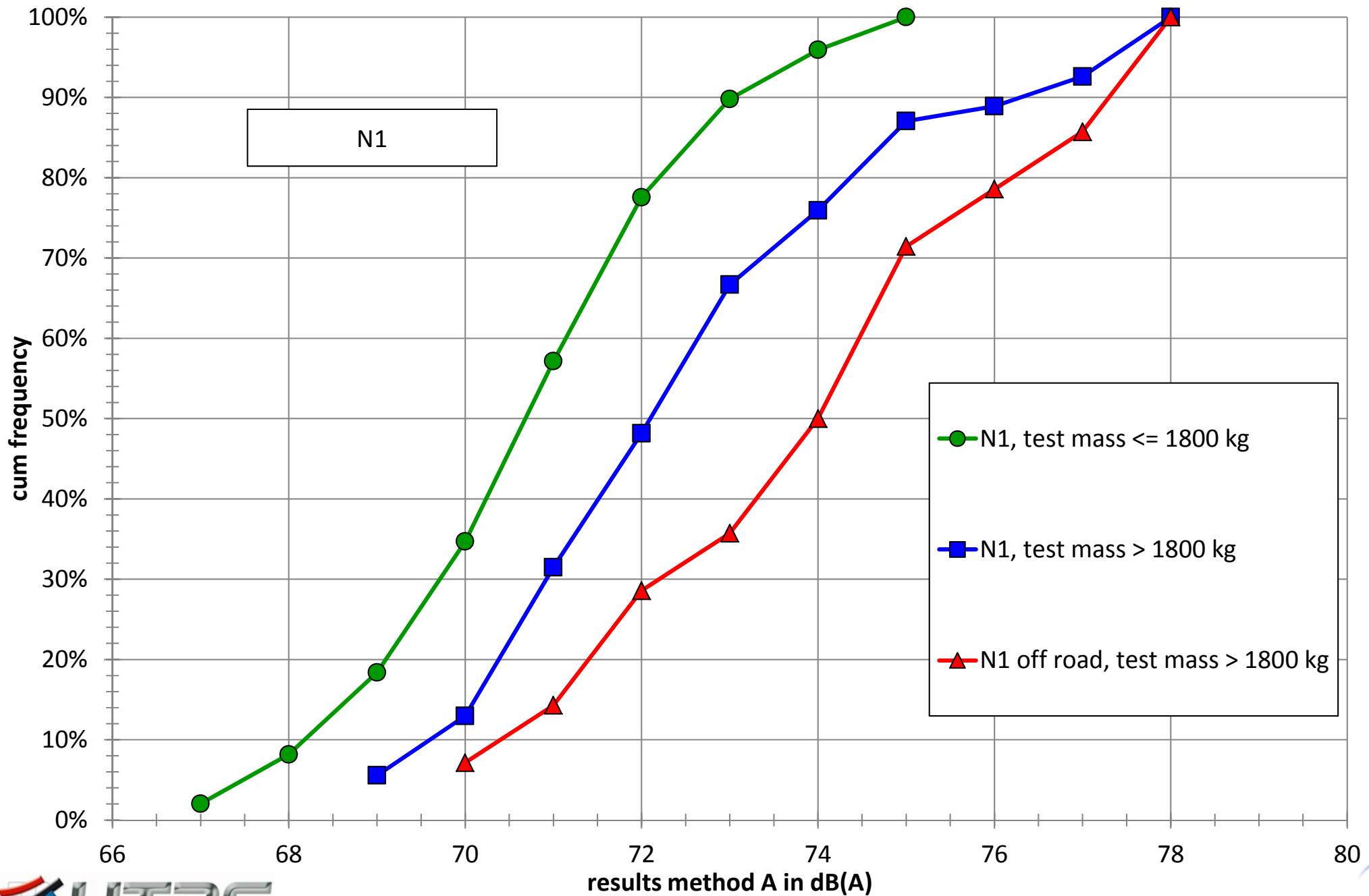
N1/M2-A, Lurban vs test mass



N1/M2-A, Lurban frequency distributions



N1/M2-A, method A results frequency distributions



N1 and M2-A vehicles

- The vehicle manufacturers prefer gross vehicle mass (GVM) as separation parameter but with a borderline of 2500 kg instead of 2000 kg for the existing method, in order to take into account the trends in technical design within the last two decades.
- At the first glance a GVM borderline of 2500 kg seems to be in good accordance with the test mass borderline of 1800 kg, but this needs to be further verified, because GVM was not delivered in the data collection sheets.
- The results lead to the following proposal for subcategories and equivalent limit values:
 - N1/M2-A1, GVM \leq 2500 kg: 72 dB(A),
 - N1/M2-A2, GVM $>$ 2500 kg: 74 dB(A)Plus 1 dB(A) for off road vehicles for both subcategories.

N2 and M2-B vehicles

- N2 vehicles are used for the carriage of goods with $3500 \text{ kg} < \text{GVW} \leq 12000 \text{ kg}$. M2-B vehicles are used for the carriage of passengers having more than 9 seats with $3500 \text{ kg} < \text{GVW} \leq 5000 \text{ kg}$.
- The current method pools these vehicles with N3 and M3 vehicles and applies different limit values based on rated power (less than 75 kW, 75 kW up to less than 150 kW and 150 kW or higher).
- This system needs to be amended anyway because N2 and N3 vehicles have different test conditions in method B. In addition, the rated power borderlines are no longer state-of-the-art due to the trend for higher rated power values.
- There are only 2 N2/M2-B vehicles with rated power below 75 kW in the database, both coming from N1.

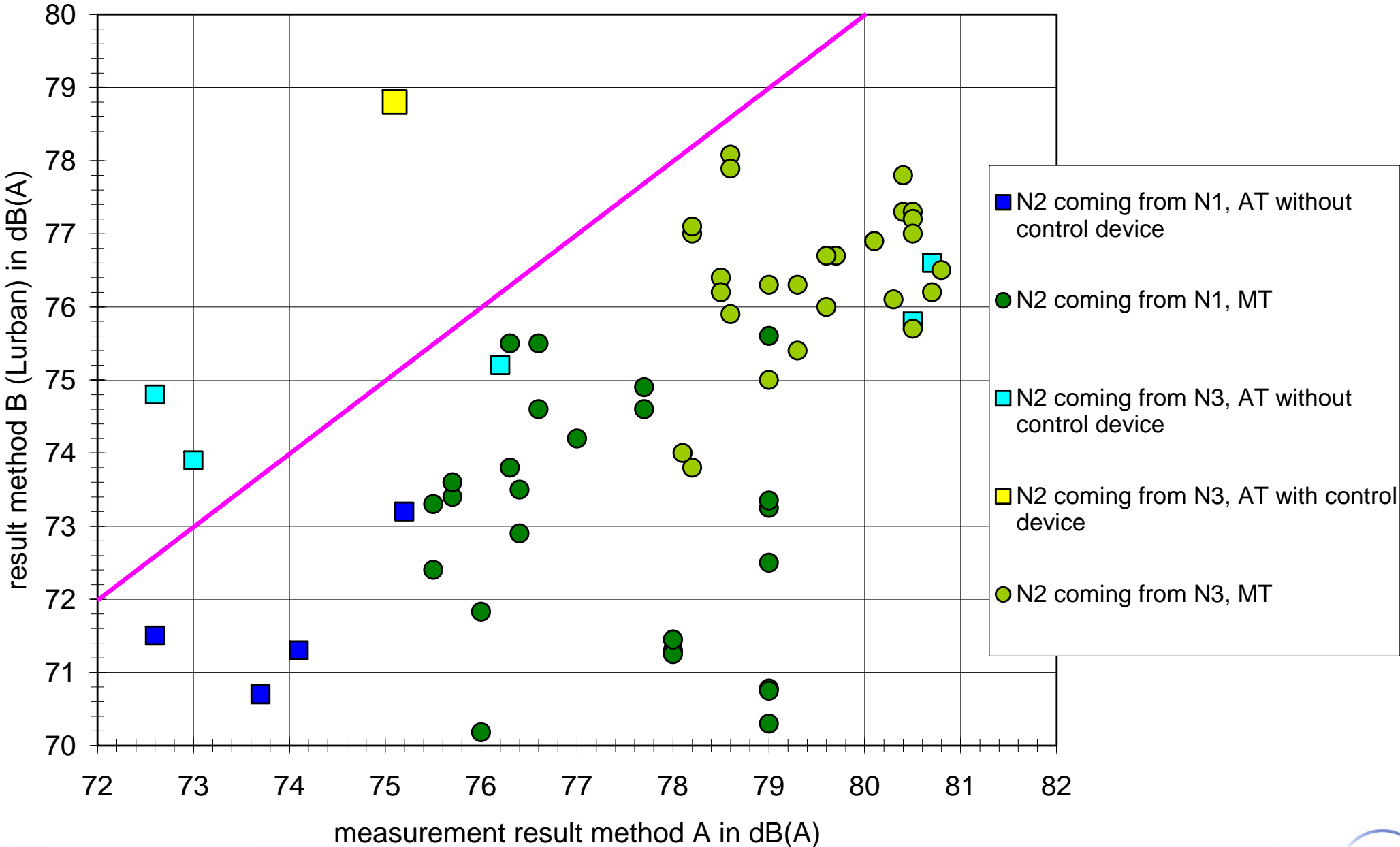
N2 and M2-B vehicles

- In method A the tests are designed in that way that rated speed s is reached within the test track for vehicles with manual transmissions.
- Method B requires full load acceleration tests with the following side conditions: when the reference point passes line BB' (the end of the test track), the engine speed $n_{BB'}$ shall be between 70 % and 74 % of speed s , at which the engine develops its rated maximum power, and the vehicle speed shall be $35 \text{ km/h} \pm 5 \text{ km/h}$.
- Some vehicles in the database have engine speeds $n_{BB'}$ outside the above mentioned tolerance band. Most of them exceed the upper limit. In four extreme cases even rated speed was exceeded.

N2 and M2-B vehicles

- In order to avoid that these vehicles determine the limit proposal, all vehicles outside the engine speed tolerance band were excluded from the further analysis.
- The database contains 62 N2/M2-B vehicles with valid results.
- Figure 11 shows a comparison of the results for methods A and B. The cases where Lurban is higher than the method A result are related to a transgression of the engine speed tolerance band for n_{BB} '.

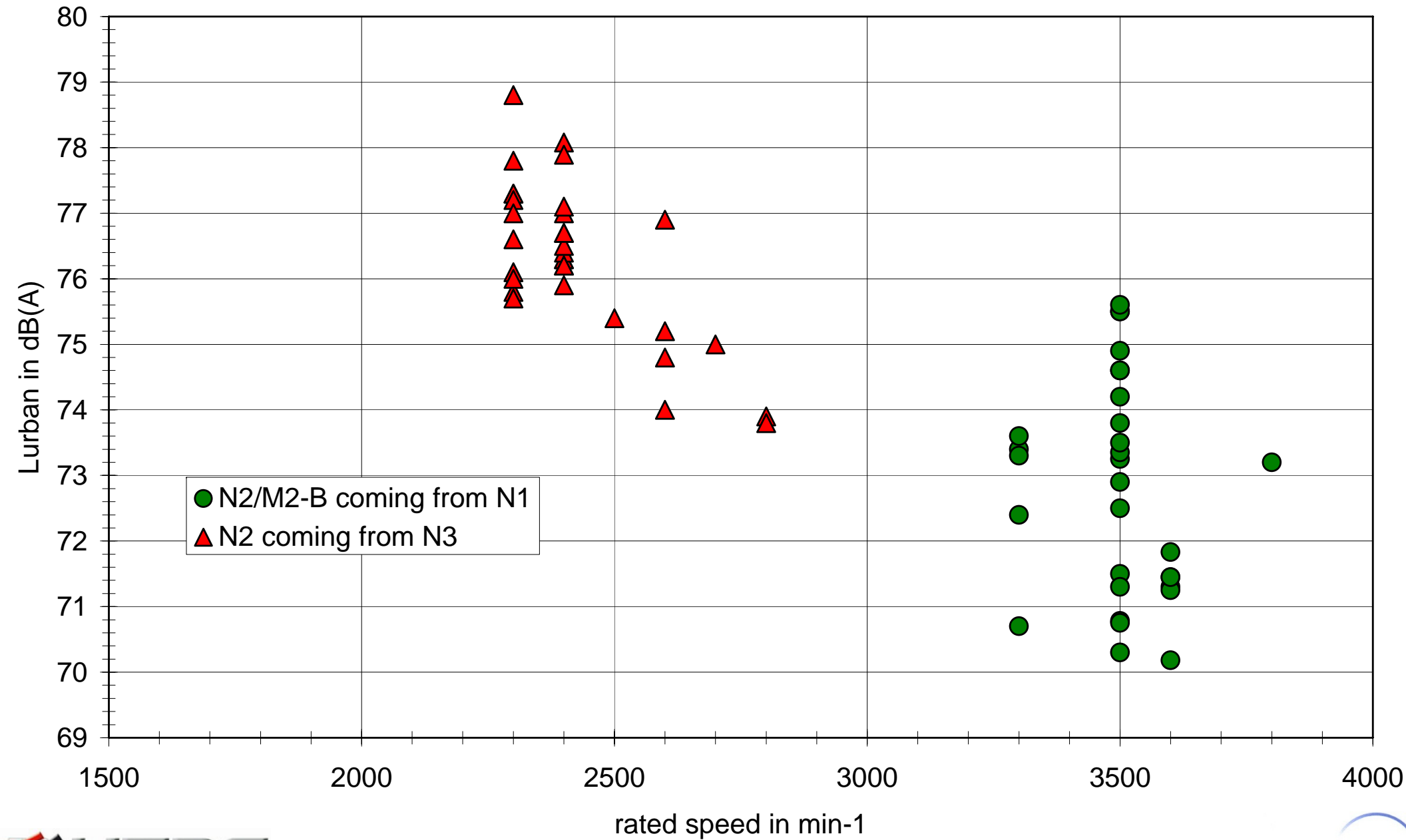
N2/M2-b, Lurban vs Lold



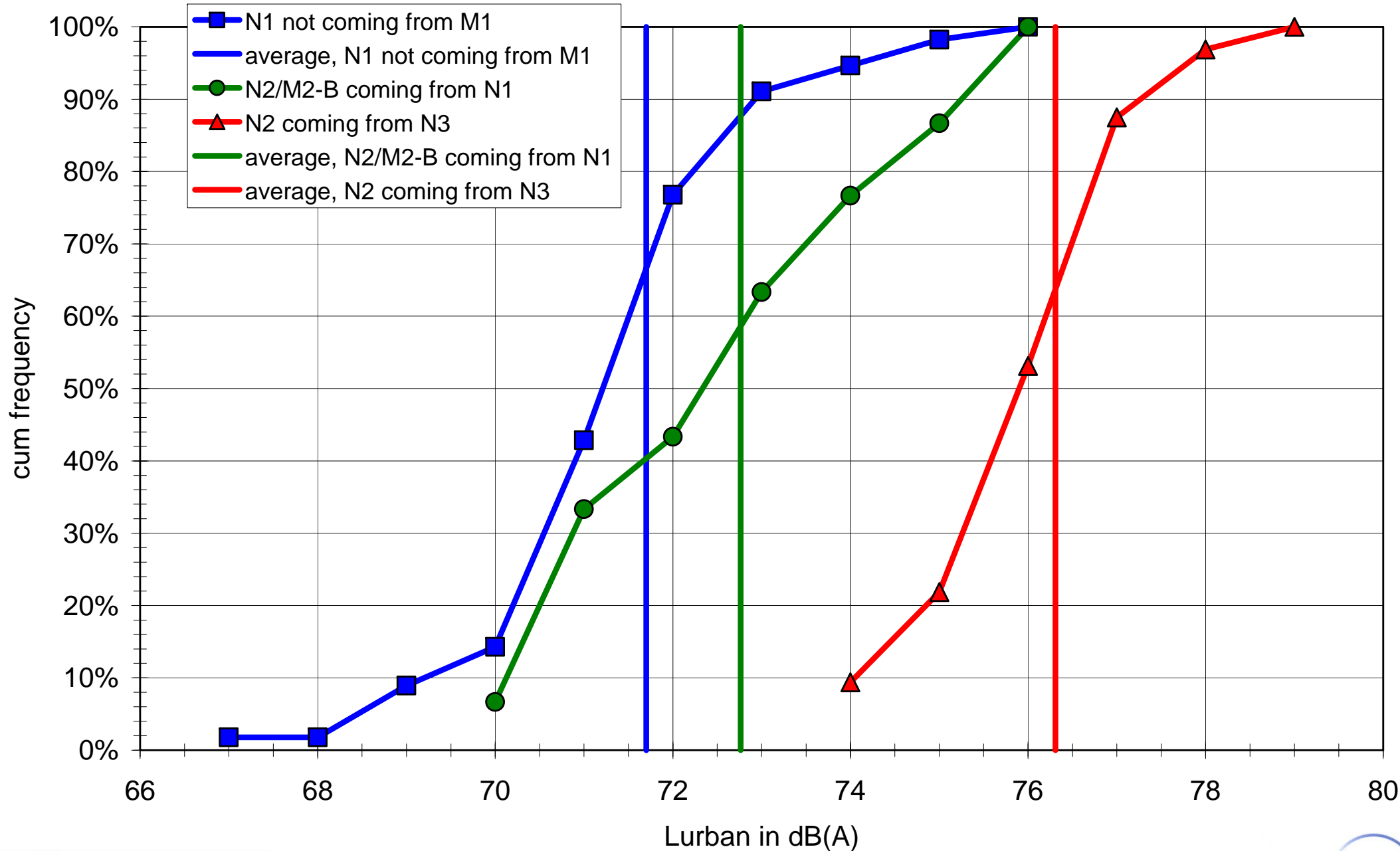
N2 and M2-B vehicles

- All 11 M2-B vehicles are modified versions of N1 or M2-A vehicles. This is obvious because the GVM limitation of 5000 kg is close to the M2-A limitation of 3500 kg.
- Another 19 N2 vehicles are also N1 derivatives.
- The remaining 32 N2 vehicles could be considered as N3 derivatives.
- The assessment parameter is the rated speed of the engine. The N1 derivatives have passenger car based engines with rated speed values above 3000 min⁻¹. The N3 derivatives have truck engines with rated speed values below 3000 min⁻¹.
- Figure 12 shows the Lurban values versus rated engine speed.
- Figure 13 and 14 show the distributions for Lurban and method A results. For Lurban the differences in the averages are even higher than the differences in the 95% percentiles.

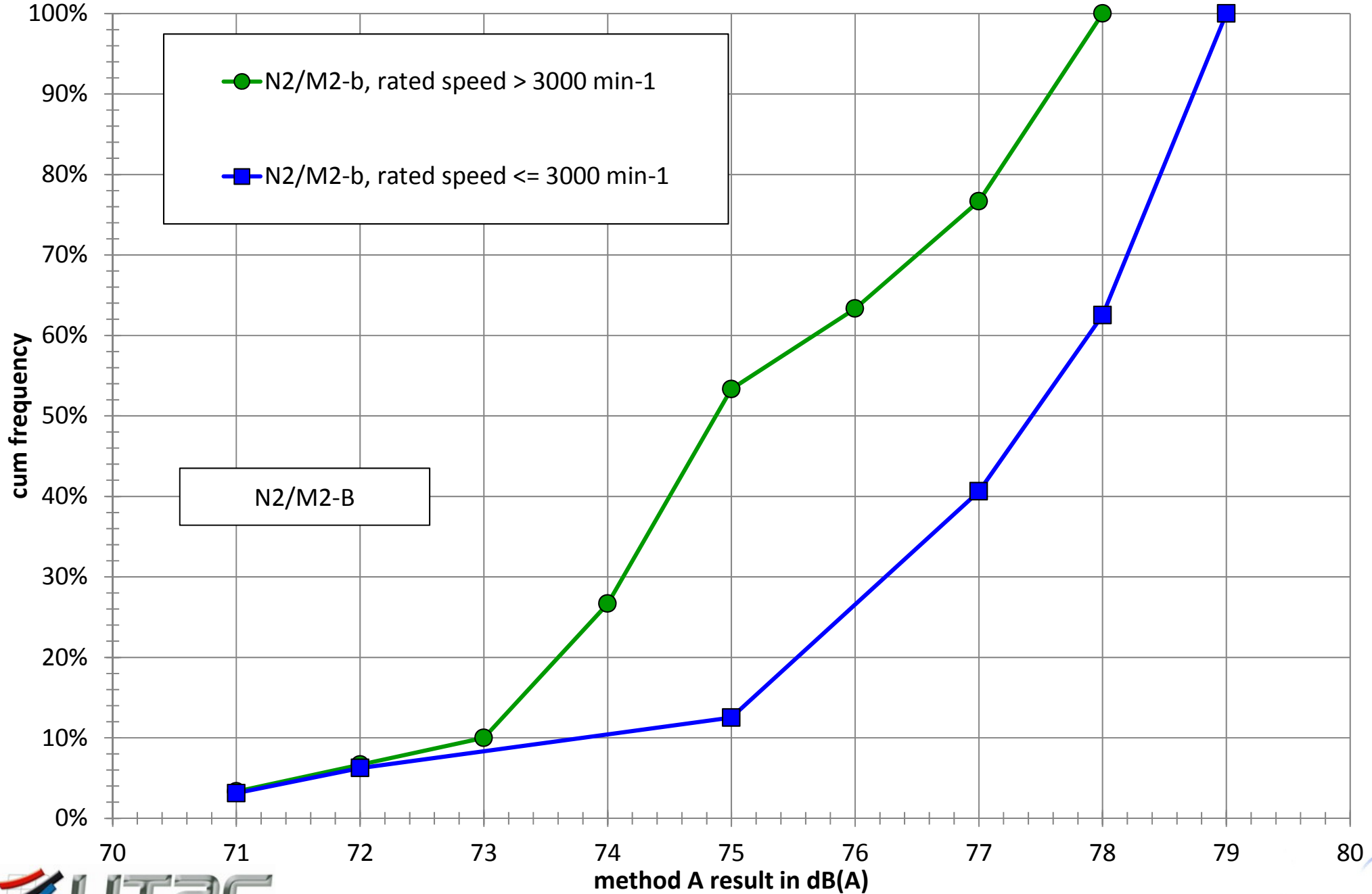
N2/M2-b, Lurban vs rated speed



N2/M2-b, Lurban frequency distributions



N2/M2-b, Lurban frequency distributions



N2/M2-b vehicles

- The database contains the following off road N2/M2-B vehicles:
 - 7 with rated speeds $> 3000 \text{ min}^{-1}$ and HS1
 - 8 with rated speeds $\leq 3000 \text{ min}^{-1}$.
- The average differences compared to the corresponding on road vehicles are 2 dB and 0.5 dB.
- The results lead to the following proposal for subclasses and equivalent limit values:
 - N2/M2-B1, rated speed $> 3000 \text{ min}^{-1}$: 76 dB(A),
 - N2/M2-B2, rated speed $\leq 3000 \text{ min}^{-1}$: 78 dB(A)
- Plus 1 dB(A) for off road vehicles.

Slide 33

HS1

could also be 75 dB
Heinz Steven; 24.01.2011

N3 vehicles

- **N3 vehicles are used for the carriage of goods having a GVM > 12000 kg. The current method differentiates three limit value classes based on rated power (less than 75 kW, 75 kW up to less than 150 kW and 150 kW or higher). The method requires full load acceleration measurements in consecutive gears until the engine speed at BB' (end of the test track) no longer reaches rated speed.**
- **The starting gear and the engine speed at AA' (beginning of the test track) are different for vehicles with rated power up to 225 kW and above.**
- **Method B requires full load acceleration tests with the following side conditions: When the reference point passes line BB', the engine speed $n_{BB'}$ shall be between 85 % and 89 % of speed s , at which the engine develops its rated maximum power, and the vehicle speed shall be 35 km/h \pm 5 km/h.**

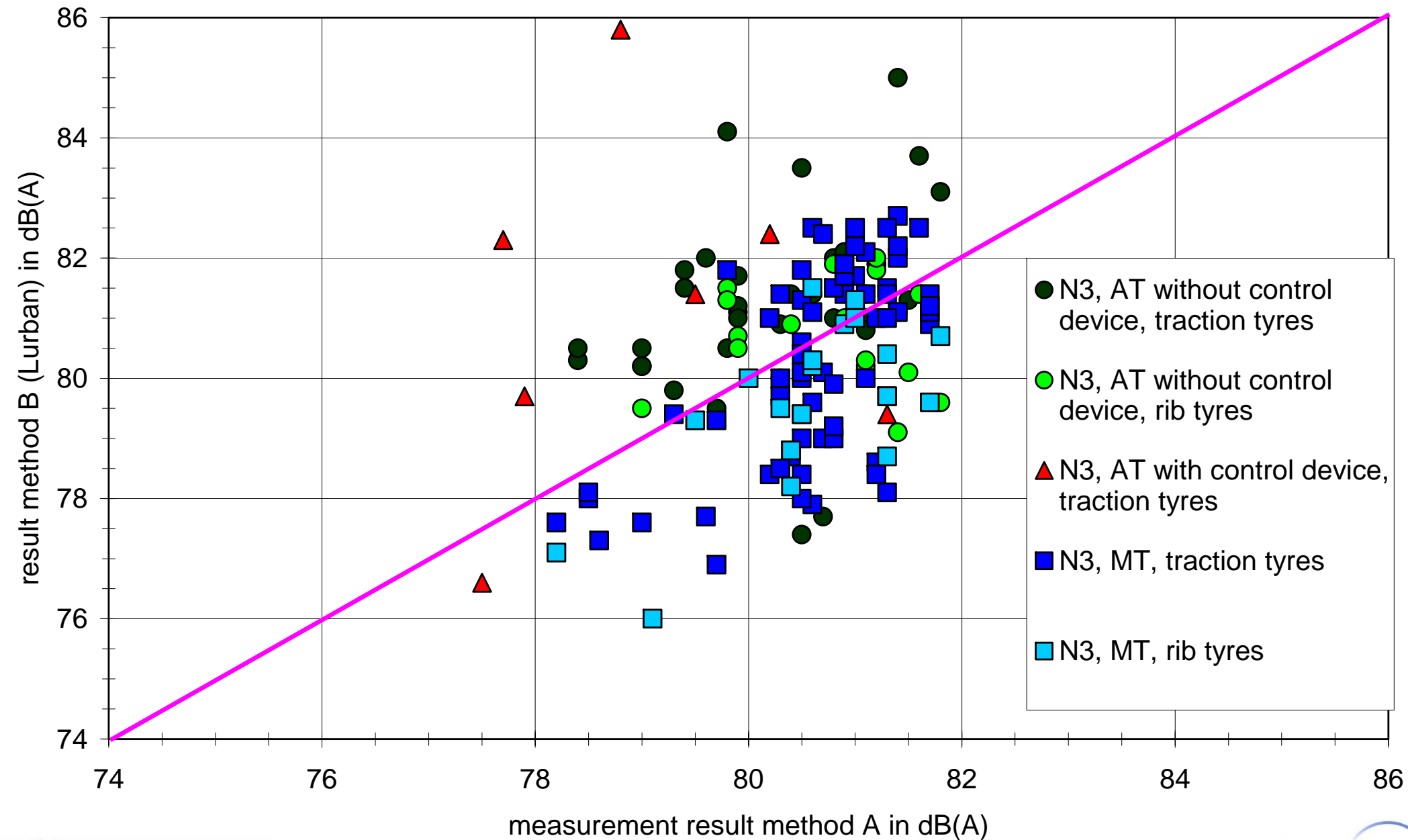
N3 vehicles

- Another difference to method A is the tyre definition. In method A, steer axle rib tyres can be used and the tread depth could be minimum. In method B, tyres representative for the axle must be used and the tread depth must be between maximum and 80%.
- Consequently 77% of the N3 vehicles were equipped with traction tyres on the drive axle(s).
- Some vehicles in the database have engine speeds n_{BB} outside the above mentioned tolerance band. In order to avoid that these vehicles determine the limit proposal, all vehicles outside the engine speed tolerance band were excluded from the further analysis.
- The monitoring database contains 152 N3 vehicles with valid results and with rated power values between 132 kW and 537 kW.

N3 vehicles

- Only 4 vehicles have rated power values below 150 kW and 36 vehicles have rated power values between 150 and 225 kW. This means that 73% of the sample has rated power values above 225 kW.
- Figure 15 shows the comparison between Lurban and method A results.
- A significant part of the method B results is higher than the corresponding method A results.
- For manual transmission vehicles, the method B result can be up to 2 dB(A) higher than the method A result, for automatic transmission vehicles the difference can be up to 7 dB.

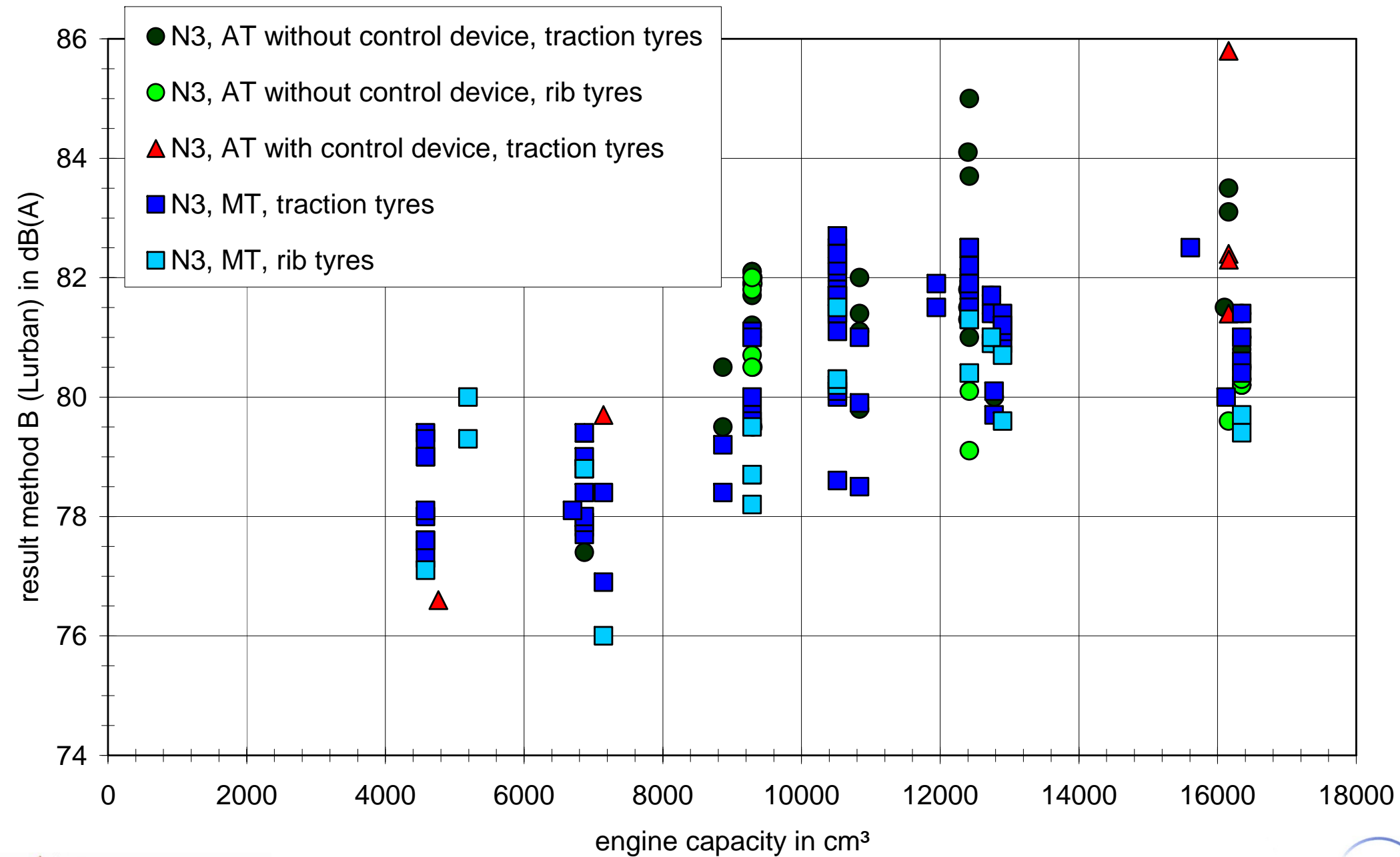
N3, Lurban vs Lold



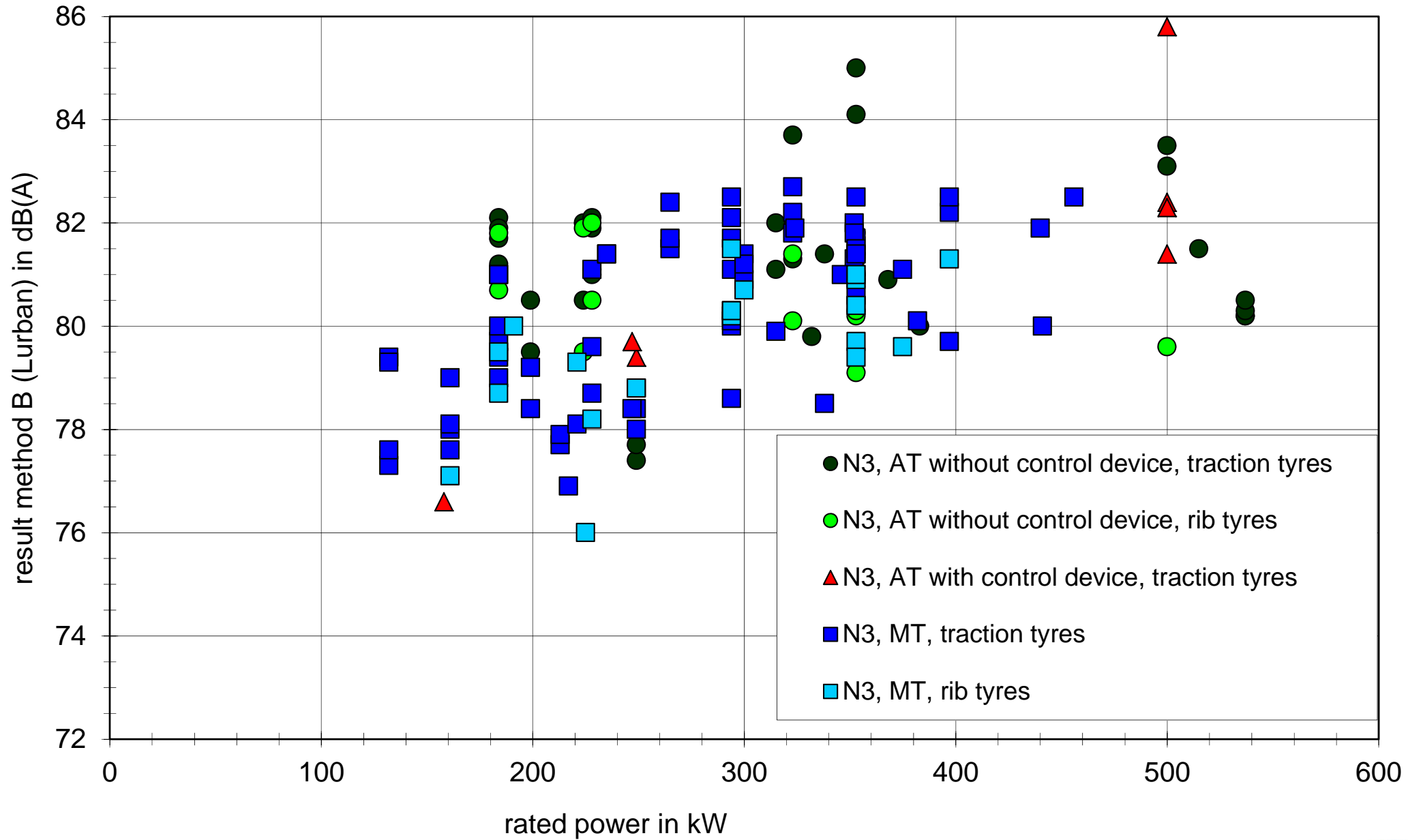
N3 vehicles

- On average the Lurban values increase with engine capacity (figure 16) and rated power (figure 17), but the correlation is rather poor.
- Vehicles with manual transmissions can be subdivided into three rated power ranges with respect to Lurban (figure 18). The borderlines are at 180 kW and at 250 kW.
- The subgroup with automatic transmission is less homogeneous and tends to higher Lurban values than the subgroup with manual transmission (figure 19).
- For vehicles with automatic transmissions, an additional influence of the number of axles is significant. This is not the case for vehicles with manual transmission, but the vehicle sample with manual transmission and more than 2 axles is much smaller than the corresponding sample with automatic transmission (6 versus 22 vehicles).

N3, Lurban vs engine capacity



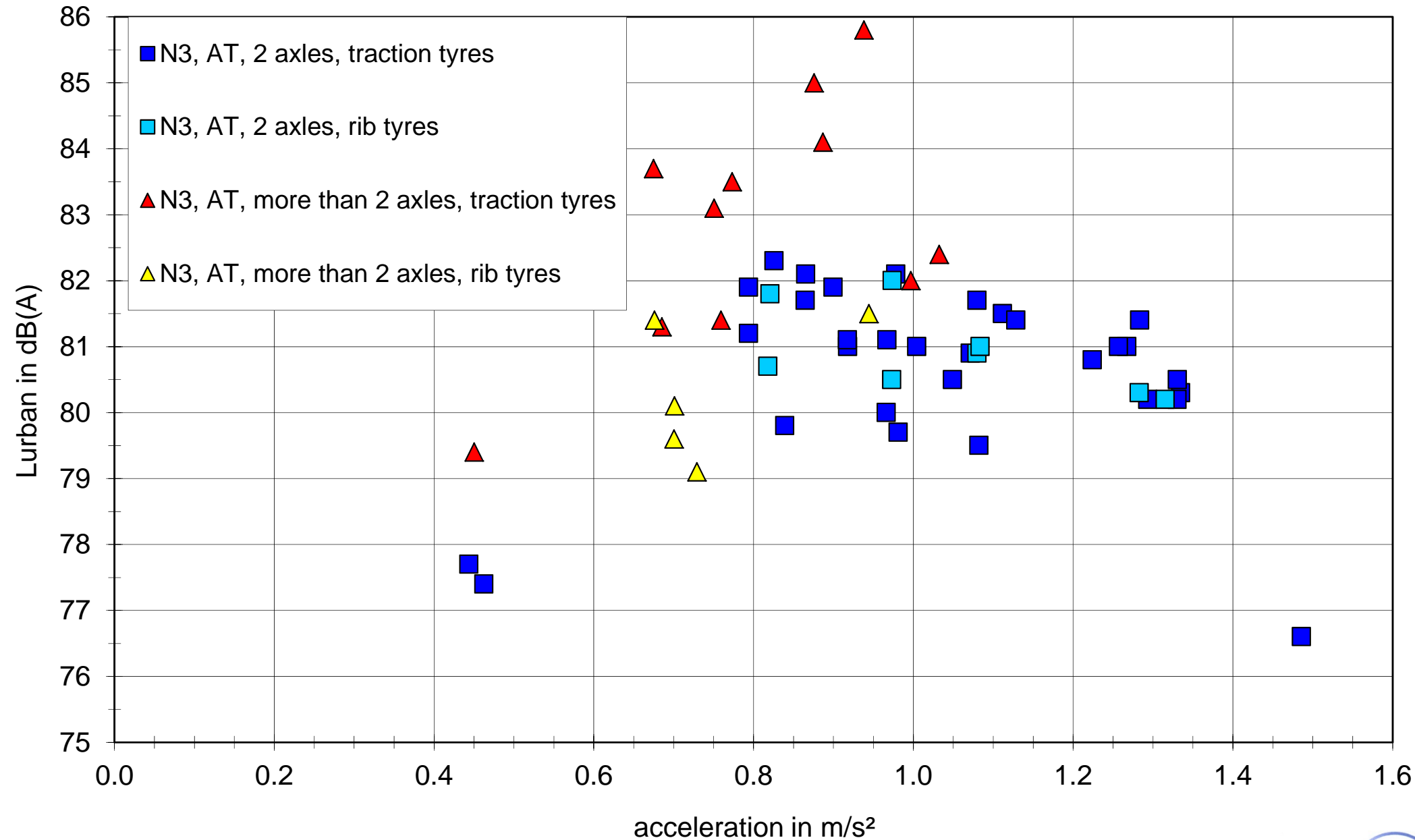
N3, Lurban vs rated power



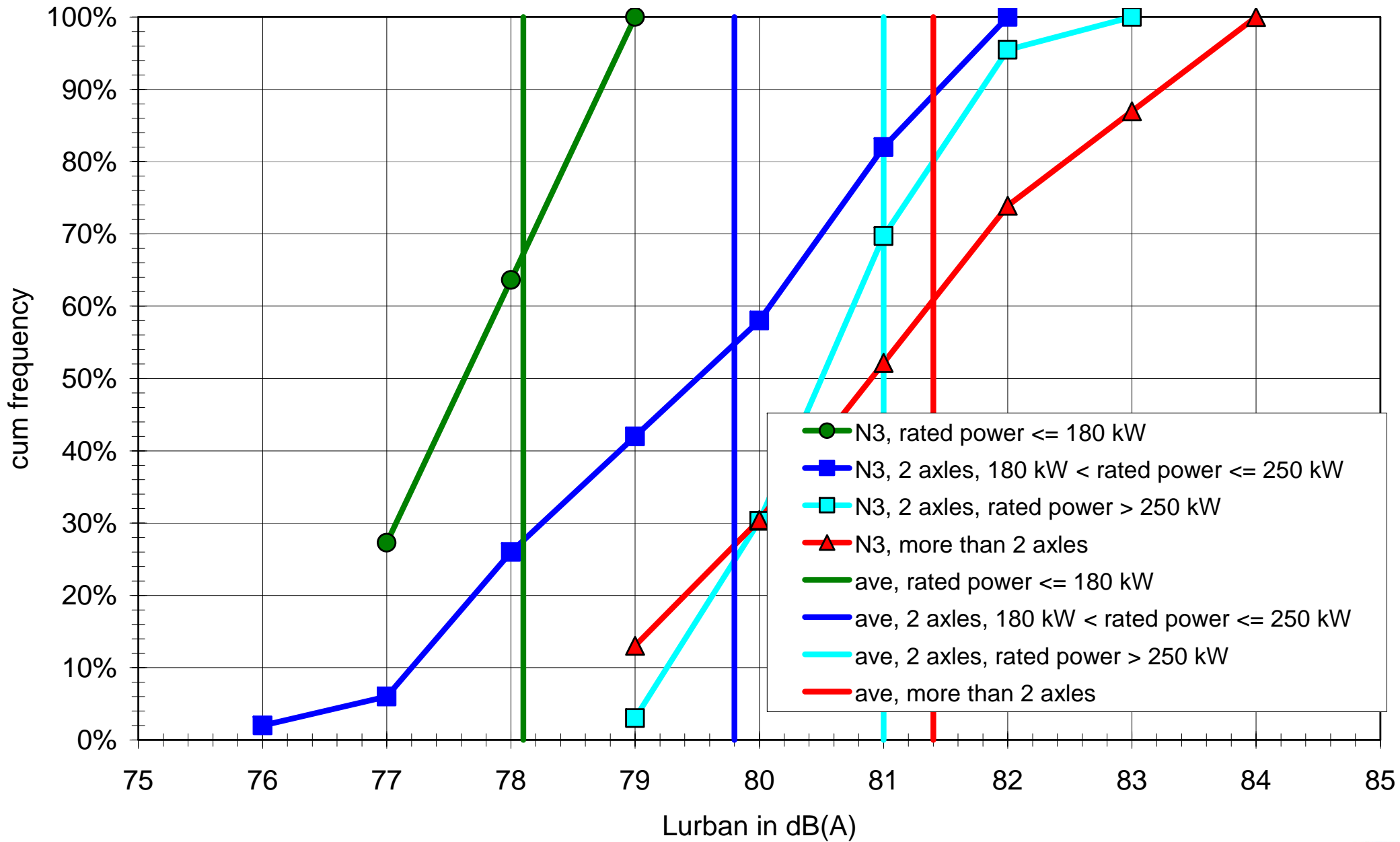
N3 vehicles

- The extreme high Lurban values for vehicles with automatic transmission and 3 axles need further investigation as they cannot be explained by acceleration effects (figure 20).
- The differences between the transmission types are higher than those between the drive axle tyre types.
- The differences between traction tyres and rib tyres are on average 1 dB.
- Figure 21 shows the frequency distributions of the different power subcategories for 2 axle vehicles and the vehicles with more than 2 axles independent from the transmission type.
- The differences are obvious. Vehicles with 2 axles above and below 250 kW rated power have small differences for the 95% percentiles but the averages differ by more than 1 dB(A).
- The method A results do not show such influence of the number of axles (figure 22).

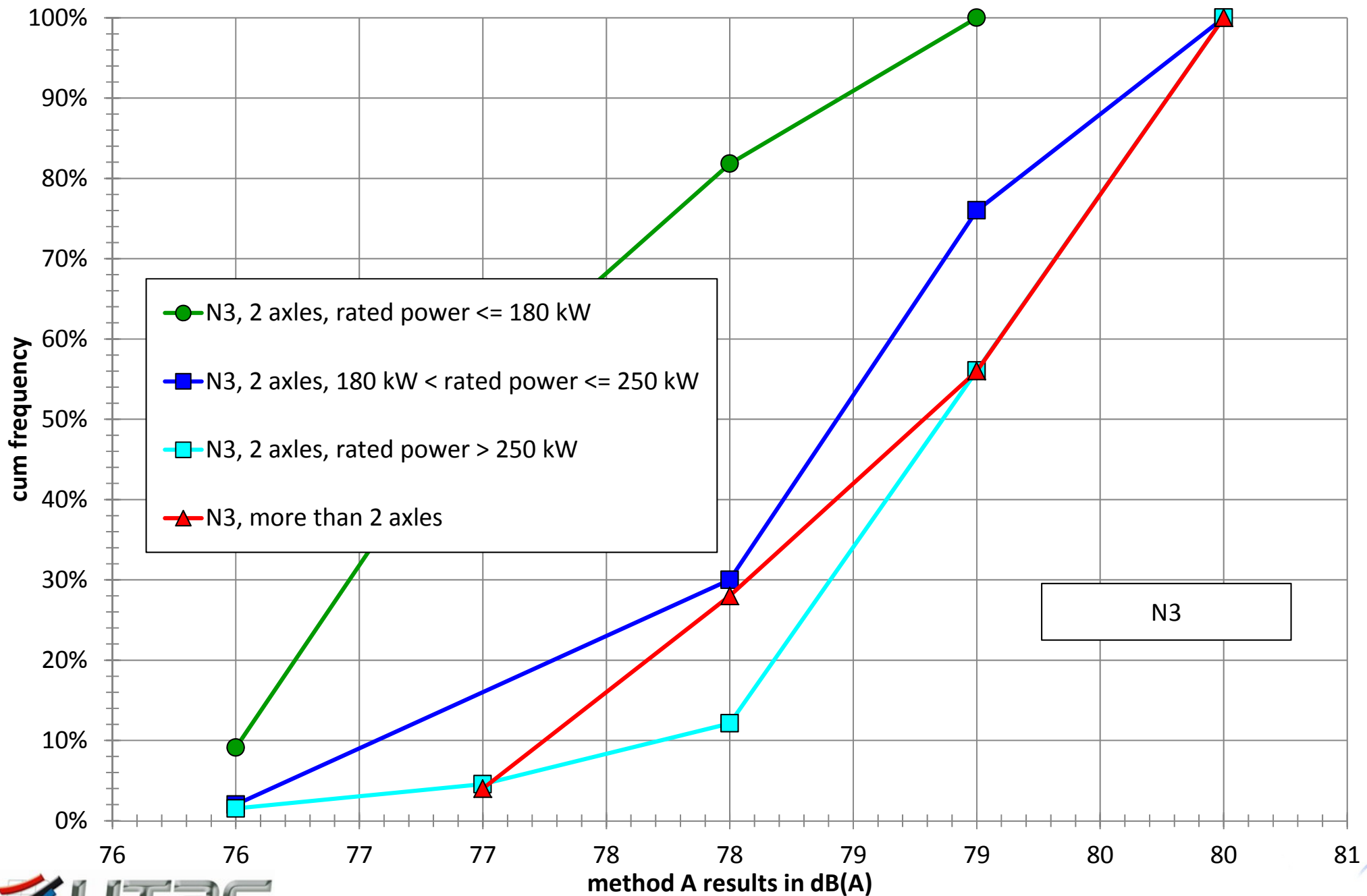
N3 automatic transmission, Lurban vs acceleration



N3, Lurban frequency distributions



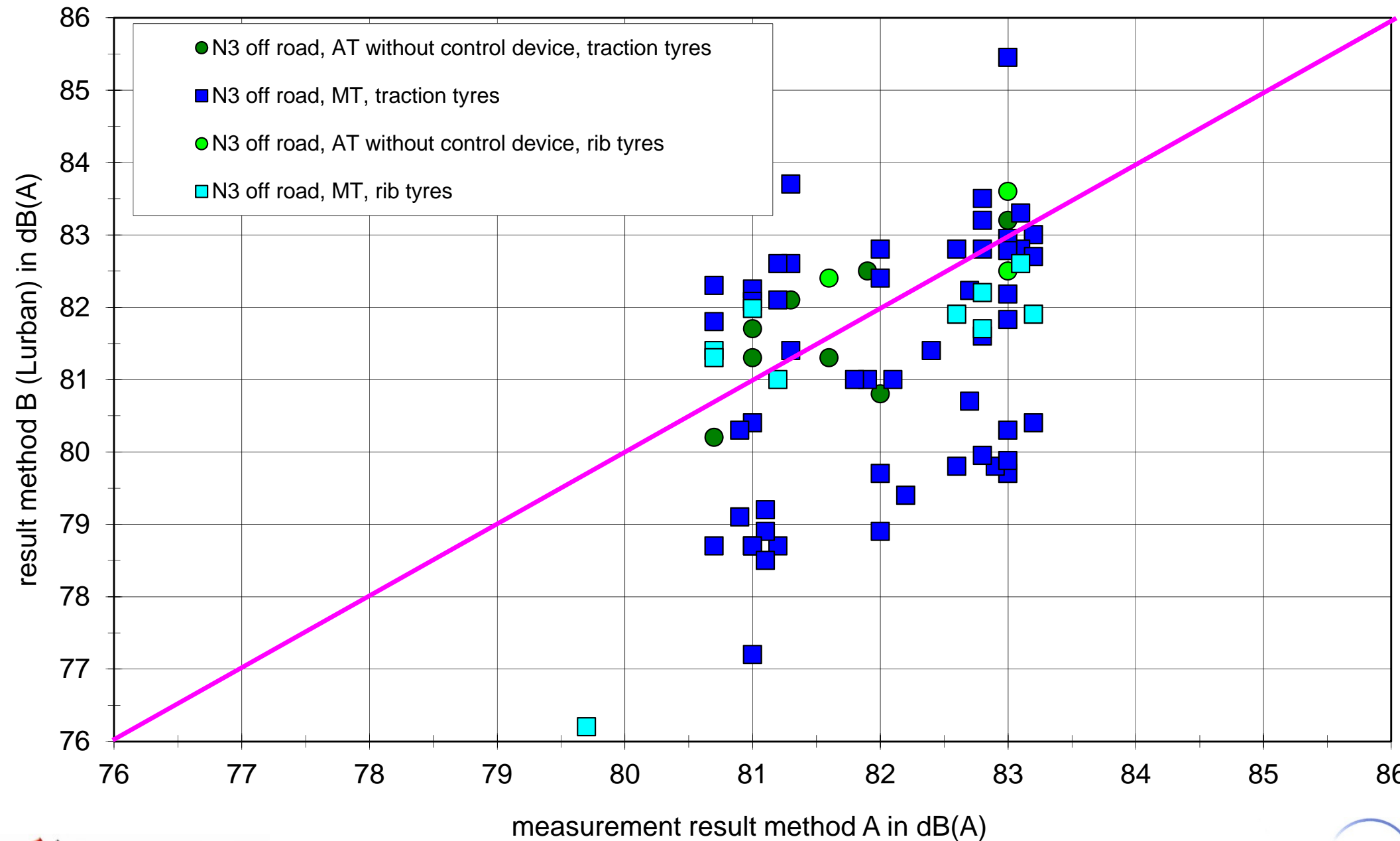
N3, method A results frequency distributions



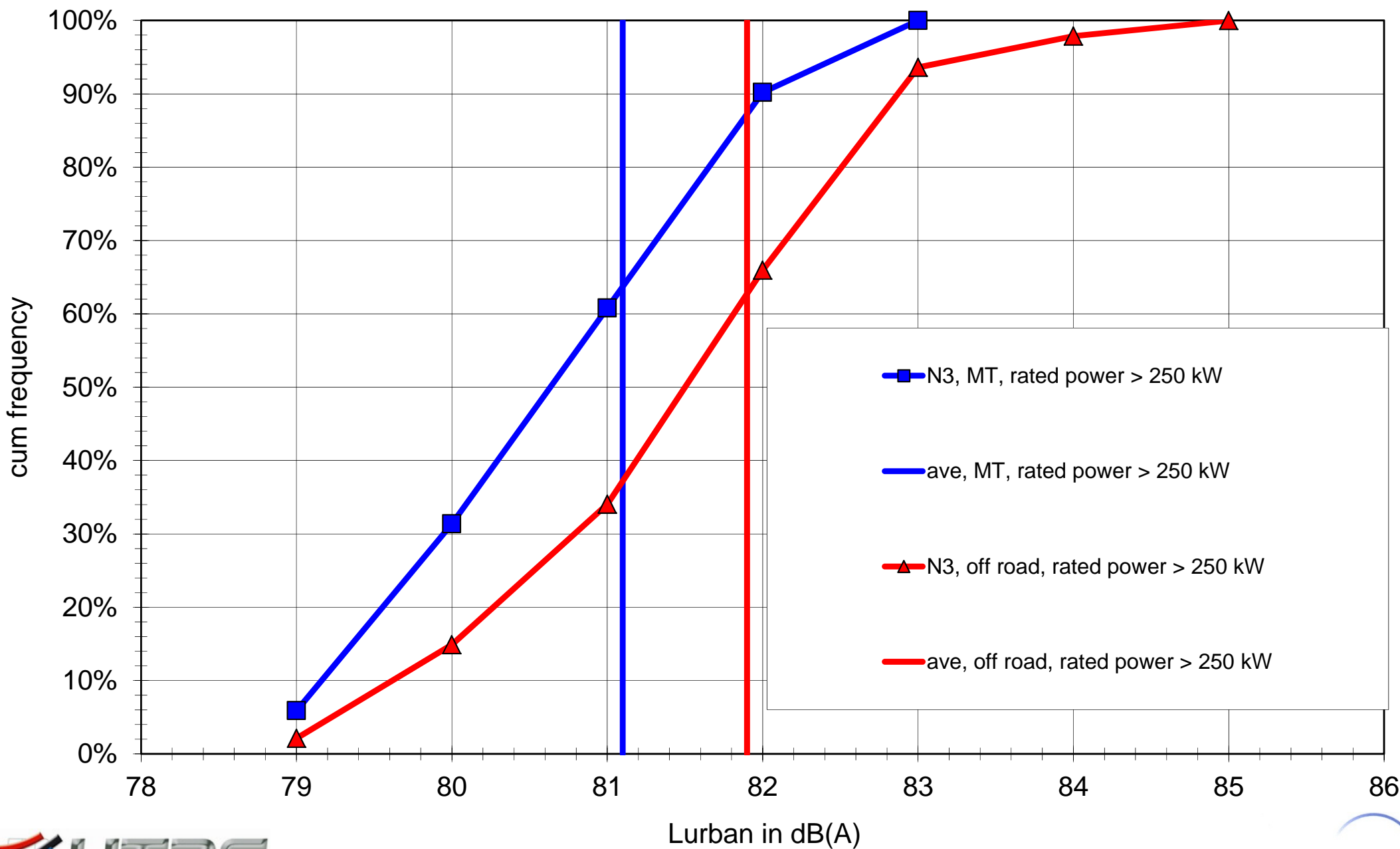
N3 off road vehicles

- The database contains 73 N3 off road vehicles with valid results. Figure 23 shows the comparison of Lurban and method A results.
- For vehicles whose results are close to the one by one line (+/- 1.5 dB) in figure 23 the differences between the transmissions types is much smaller than for on road vehicles. Another group of results is 2 to 3 dB below the one by one line. These results also need further investigation.
- The only off road subgroup with a higher sample size is the group with manual transmission and rated power values above 250 kW.
- The comparison with the corresponding on road subcategory justifies an extra allowance of 1 dB(A) for off road vehicles (figure 24). It is recommended that this allowance be applied to all N3 subgroups for reasons of consistency.

N3 off road, Lurban vs Lold



N3 and N3 or, Lurban frequency distributions



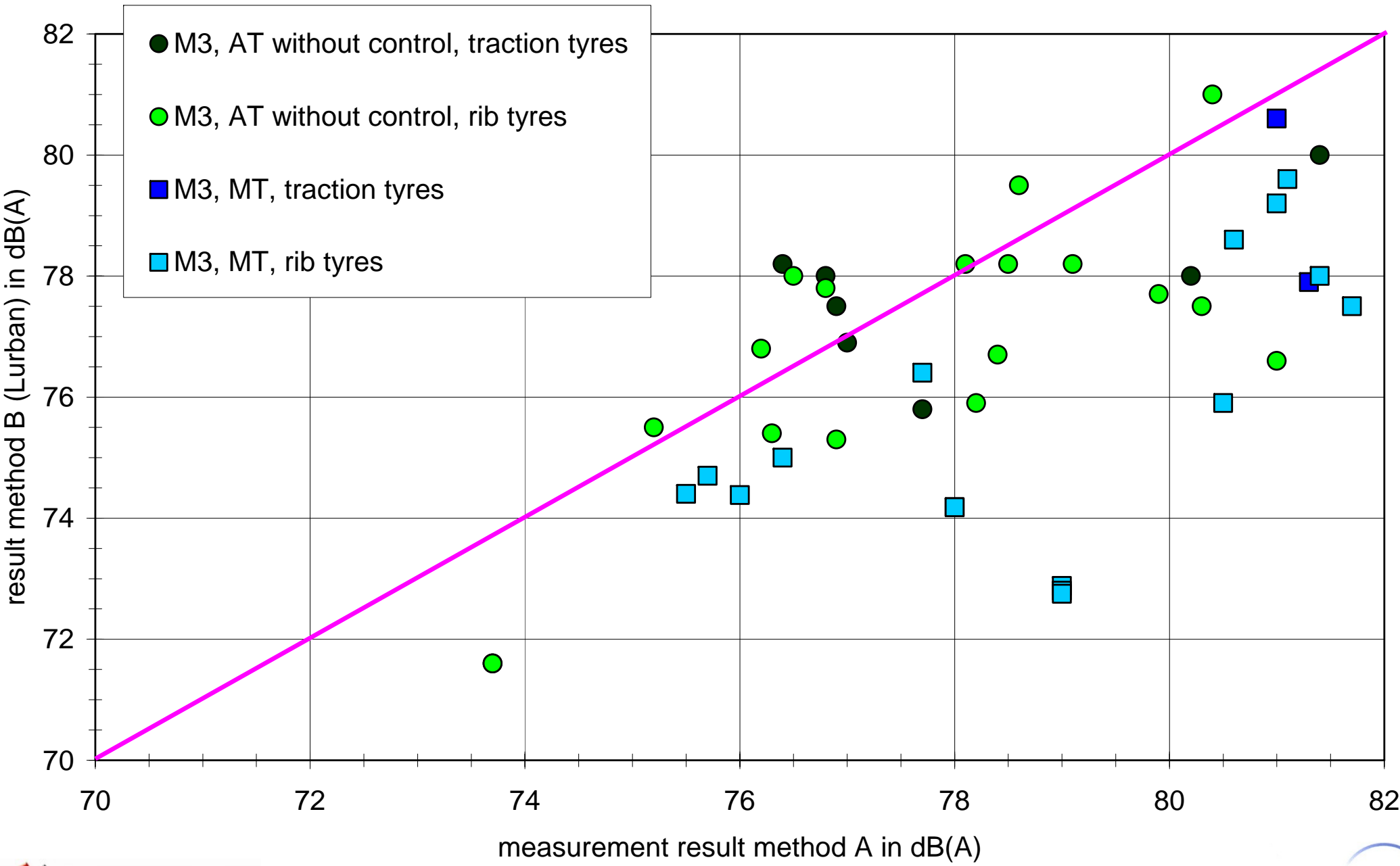
N3, proposal for subcategories and limits

- For the benefit calculation the following mixed schema was used:
 - N3-1, rated power ≤ 180 kW: 79 dB(A)
 - N3-2, 2 axles, 180 kW $<$ rated power ≤ 250 kW: 81 dB(A),
 - N3-3, 2 axles, rated power > 250 kW: 82 dB(A),
 - N3-4, more than 2 axles: 84 dB(A).
- Plus 1 dB(A) for off road vehicles.

M3 vehicles

- **M3 vehicles are used for the transportation of passengers having more than 9 seats and GVM > 5000 kg.**
- **The database contains 43 vehicles with valid results. Another 13 vehicles were added from the Circa database for the frequency distribution and average Lurban calculation.**
- **The method B test conditions are the same as for N3 vehicles except for the vehicle load.**
- **Figure 25 shows the comparison of Lurban values and method A results. A tendency for higher method B results for vehicles with automatic transmission compared to manual transmission can also be seen for M3 vehicles, but the majority of the results lies below the one by one line.**
- **The traction tyre subsample is too small to assess any tyre influence.**

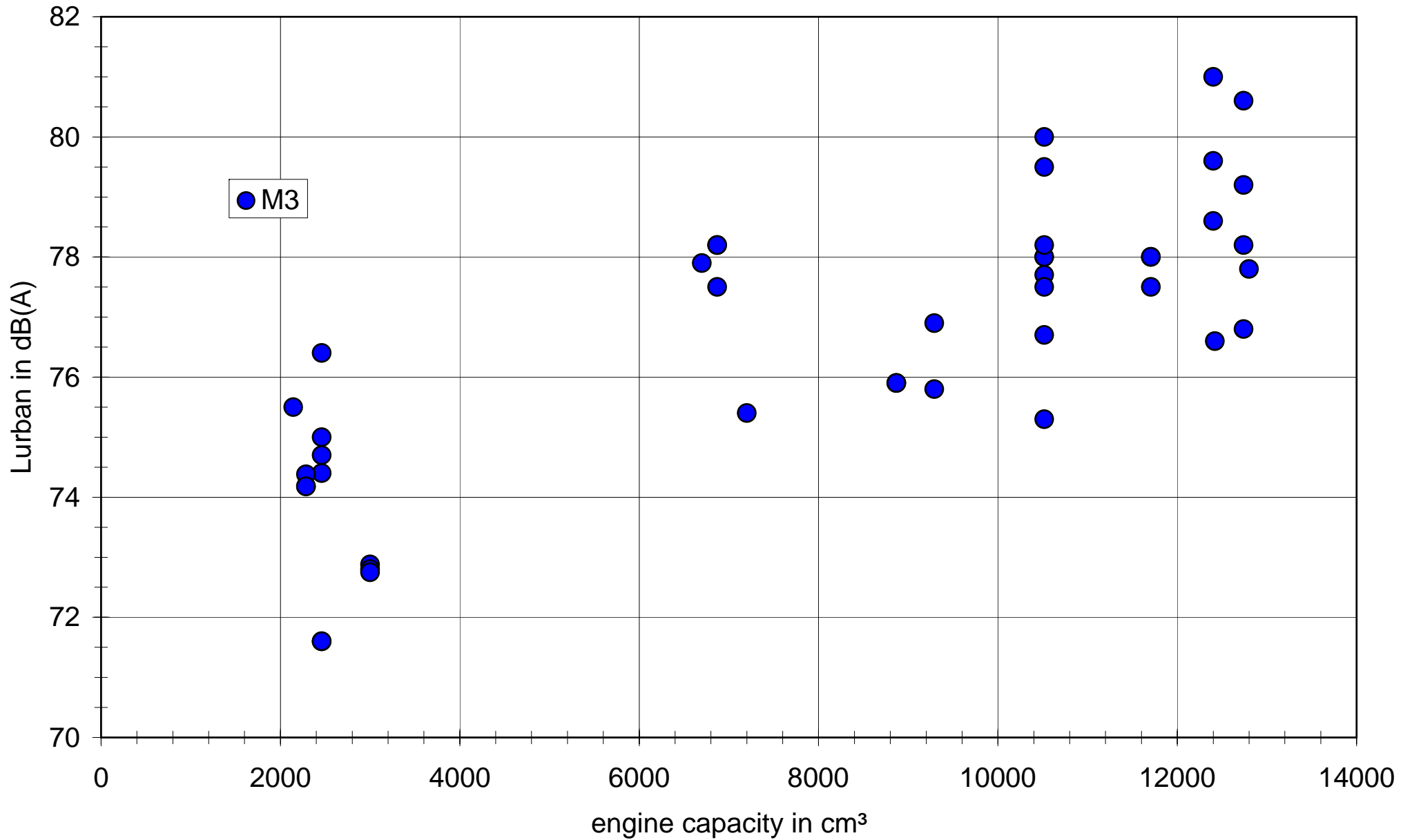
M3, Lurban vs Lold



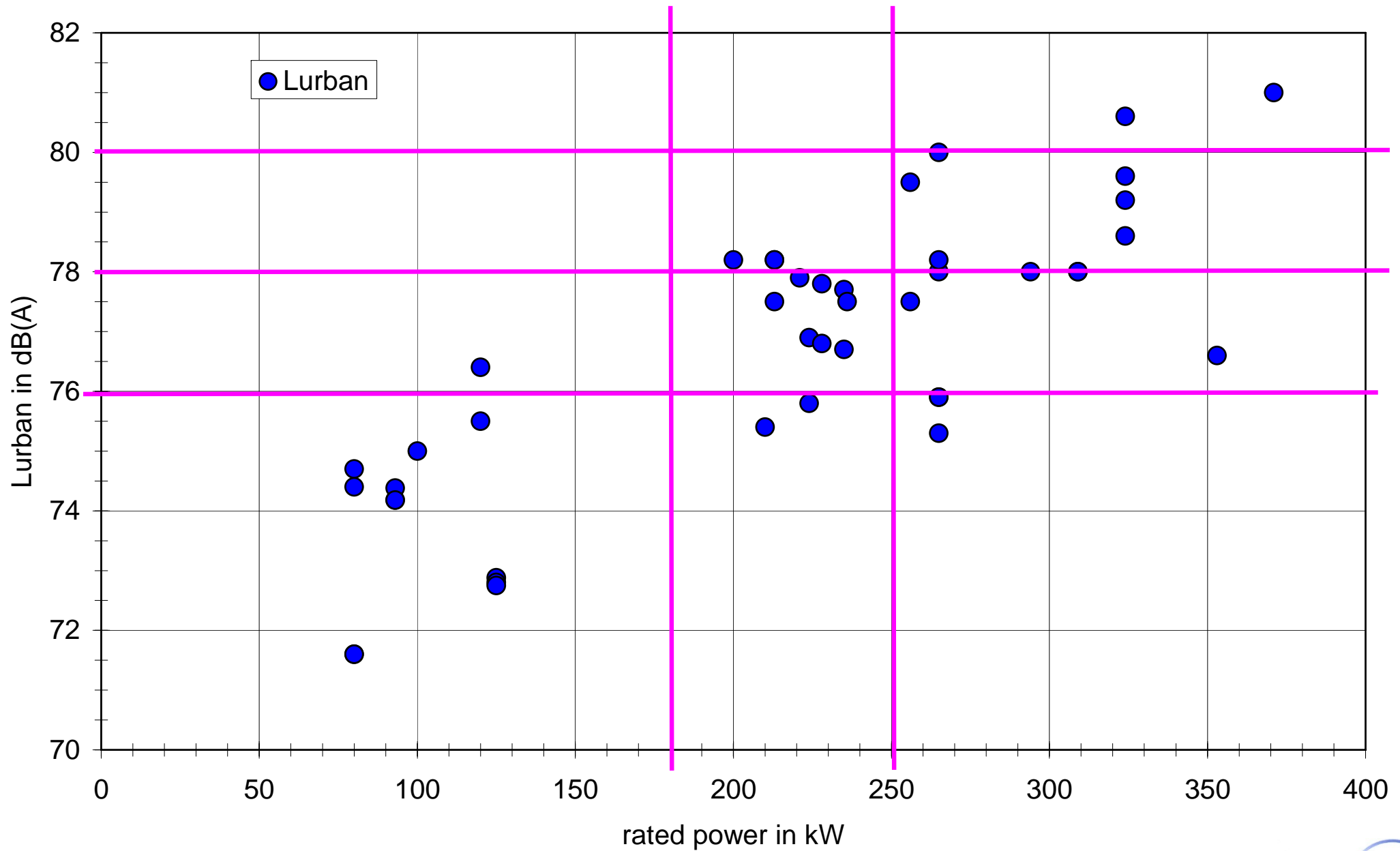
M3 vehicles

- As for N3 vehicles the average Lurban values increase with engine capacity (figure 26), but also here the correlation is poor.
- The dependency with rated power is shown in figure 27. The same rated power subcategory schema can be used as for N3 vehicles.
- Unfortunately the database contains only 3 M3 off road vehicles, all of them coming from M2-B vehicles.
- In order to be consistent with the N3 category, an extra allowance of 1 dB is proposed for M3 off road vehicles.

M3, Lurban vs engine capacity



M3, Lurban vs rated power



M3, proposal for subcategories and limits

- The results lead to the following M3 subclasses and equivalent limit value proposal:
 - M3-1, rated power up to 180 kW: 76 dB(A),
 - M3-2, 180 kW < rated power ≤ 250 kW: 78 dB(A),
 - M3-3, rated power > 250 kW: 80 dB(A).
- Plus 1 dB(A) for off road vehicles.

- All M3 vehicles with rated power values up to 180 kW have rated engine speed values above 3000 min⁻¹, while all N3 vehicles in this rated power class have rated engine speed values below 3000 min⁻¹. This explains the 3 dB difference in the limit value proposals.

M3 vehicles

- The M3-2 subcategory ($180 \text{ kW} < \text{rated power} \leq 250 \text{ kW}$) needs further explanations / comments. This category contains 15 vehicles, 12 of them are standard versions of public transport buses, all equipped with automatic transmission.
- 2 coaches with Lurban values of 80,6 dB(A) were excluded because n_{BB} was 109% of rated engine speed which is far above the upper tolerance (89%). The remaining vehicle with manual transmission is a country bus.
- The method A results for the urban buses are predominantly below the limit (5 buses with 75 dB, 2 vehicles with 76 dB and 3 vehicles with 77 dB).
- These low method A results are caused by customer requirements that are more stringent than the current legal limit values.

M3 vehicles

- Although the current method is advantageous for vehicles with automatic transmissions compared to manual transmissions, 75 to 77 dB require additional noise reduction measures compared to 80 dB versions.
- This has to be considered when further reduction steps are discussed.

Summary of proposals for subcategories and limits

- A summary of the proposed amended vehicle categorization and corresponding limit values is shown in the following table.
- Off road vehicles have a 1 dB higher limit value for all categories except for M1-1 and N1/M2-A1 vehicles, whose off-road limits are 2 dB higher than the limit values for on-road vehicles. This 2 dB should be reduced to 1 dB in future.

Summary new categories and limit value proposals

Category	Subcategory		Equivalent limit values in dB(A)	
			On Road	Off Road ¹⁾
M1	M1-1	pmr <125 kW/t	72	74
	M1-2	125 kW/t < pmr <= 150 kW/t	73	74
	M1-3	pmr > 150 kW/t	75	75
N1/M2-A	N1/M2-A1	GVM <= 2500 kg	72	74
	N1/M2-A2	GVM > 2500 kg	74	75
N2/M2-B	N2/M2-B1	rated speed > 3000 min ⁻¹	76	77
	N2/M2-B2	rated speed <= 3000 min ⁻¹	78	79
	N3-1	2 axles, P _n <= 180 kW	79	80
N3	N3-2	2 axles, 180 kW < P _n <= 250 kW	81	82
	N3-3	2 axles, P _n > 250 kW	82	83
	N3-4	> 2 axles	84	85
	M3-1	P _n < 180 kW	76	77
M3	M3-2	180 kW < P _n <= 250 kW	78	79
	M3-3	P _n > 250 kW	80	81

¹⁾ off road as defined in R.E.3 and in addition have a wading depth exceeding 500 mm and a hill climbing ability exceeding 35°

End

Thank you for your patience!