Comparison of different gearshift prescriptions

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Introduction

- **Concerning the gearshift prescriptions for vehicles with manual transmissions the following proposals were used during validation 1:**
  - ✓ **The Japanese proposal, which defines shiftpoints as function of vehicle speed and acceleration separately for the categories M1and N1. For a given cycle this results in fixed vehicle speeds. N1 vehicles shift gears at lower vehicle speeds than M1 vehicles.**
  - ✓ **The Steven 1 proposal is based on normalised engine upshift speeds as function of the power to mass ratio of the vehicle (see figure 1). The shift speeds are the same for each gear.**
- **Both proposals were based on analyses of the gearshift behaviour in the WLTP in-use data.**

Introduction

- The Advantage of the Japanese prescriptions is the simplicity and easy implementation into drivers aids of test benches and that no vehicle specific input data is needed.
- The disadvantages are that different gearbox designs in terms of numbers of gears cause differences in average engine speeds against the trend in real traffic and that driveability problems could occur for low powered vehicles, especially for N1 vehicles.
- In addition to that, prescriptions for 4speed and 7speed gearboxes are missing because of lack of in-use data.
- The advantage of the Steven 1 proposal is the independency from the gearbox design, the disadvantage is the need of vehicle specific input data like power to mass ratio, rated speed, idling speed and transmission ratios. Driveability problems could also occur depending on the transmission design.

Normalised upshift speeds during acc

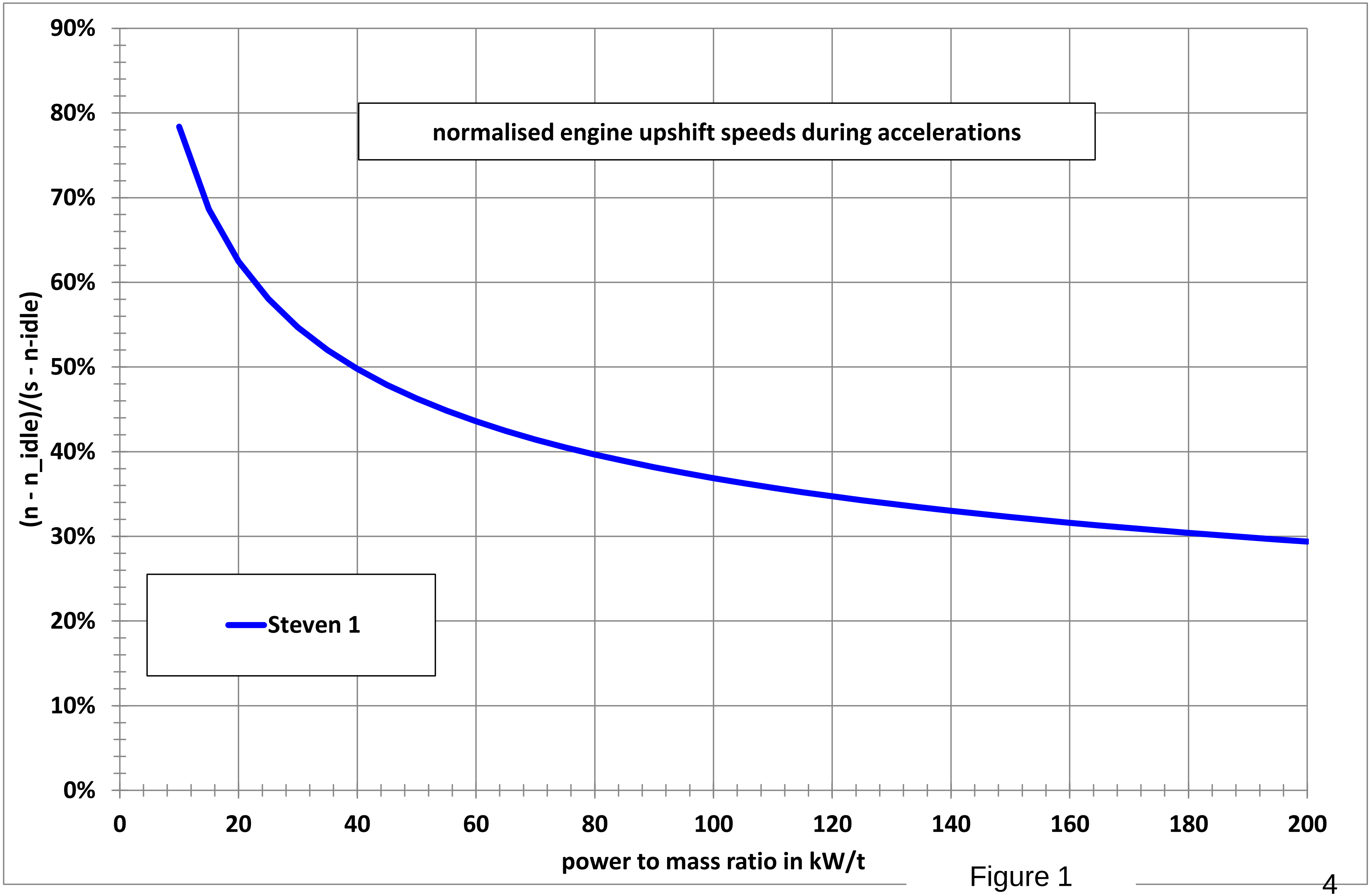

Figure 1

Further development

- After validation 1 the WLTC was modified. The maximum accelerations were limited but the average dynamics were increased in order to bring the positive acceleration distributions closer to the database distributions.
- These modifications increased the risk for gearshift related driveability problems for both proposals.
- This problem was partly reduced again by the Steven 2 proposal which still uses the engine speed curve as shown in figure 1 but varies the shift speeds depending on the actual v*a values and checks the available engine power on the basis of an average full load normalised power curve.

Further development

- The addition of the v*a component was taken over from the analysis results of Eva Ericsson.
- The check of the available engine power adds the vehicle mass as an additional and important parameter.
- Eva Ericssons results have more influencing parameter than just v*a, like vehicle category and engine type.
- Since it is difficult to implement them all into test bench compatible prescriptions and since some of them are vehicle design parameter that reflect the current situation (or more likely the situation 10 - 5 years ago) but may change in future, they are not included in this comparison.

Further development

- With respect to future developments one of the vehicle manufacturers developed gearshift prescriptions that are purely based on the individual acceleration performance of a vehicle under test.
- The full load power curve, the driving resistance coefficients f0, f1 and f2 and the gear ratios are needed as input data.
- The author got the task to merge this proposal with the Steven 2 proposal. The result is named Steven 3.
- A calculation tool based on ACCESS was prepared and distributed to the members of the DHC group.

Further development

- **In order to allow sensitivity calculations, different full load power curves can be chosen as default values as well as fixed f0. f1 and f2 values depending on vehicle mass.**
- **Of course, both parameters can alternatively be defined as input values.**
- **The vehicle database contains all vehicles with manual transmissions from the in-use database that had reliable second by second engine speed values and in addition artificial “model” vehicles for parameter variations like rated engine speed, transmission ratios, pmr, number of gears.**

Further development

- As an improvement compared to the Steven 2 proposal the Steven 3 proposal requires the test mass as input parameter, so that the influence of the current proposals for test mass modifications can be assessed.
- A further parameter that was added is called “safety margin for Pwot”. This is a factor that reduces the actual full load power values for the calculation of the available power in order to take into account the differences between stationary and transient engine conditions.
- ~~This parameter can also be used to represent different driving stiles in terms of engine speed use.~~

Comparison of results

- The further comparison focusses on the Japanese proposal and the Steven3 proposal and is based on average normalised engine speeds for WLTC version 4. The normalisation is related to the span between idling speed and rated engine speed.
- $n\_norm = (n - n\_idle)/(s - n\_idle)$

Comparison for vehicles of in-use DB

- Figure 2 shows the average normalised engine speeds (n_norm_ave) for the Japanese proposal and the Steven 2 and 3 proposals versus power to mass ratio (rated power divided by kerb mass + 100 kg, named pmr) for all manual transmission vehicles in the WLTP in-use database. Stop periods are excluded.
- Figure 3 shows the same results but versus the vehicle speed in highest gear at rated engine speed (v_s_max) which is an important transmission design parameter and to a certain extend correlated with pmr (see figure 4). Stop periods are excluded.
- The full load power curve used for the calculations is shown in figure 5. The resulting power values were reduced by 15% as safety margin.

Average n_norm vs pmr for WLTC

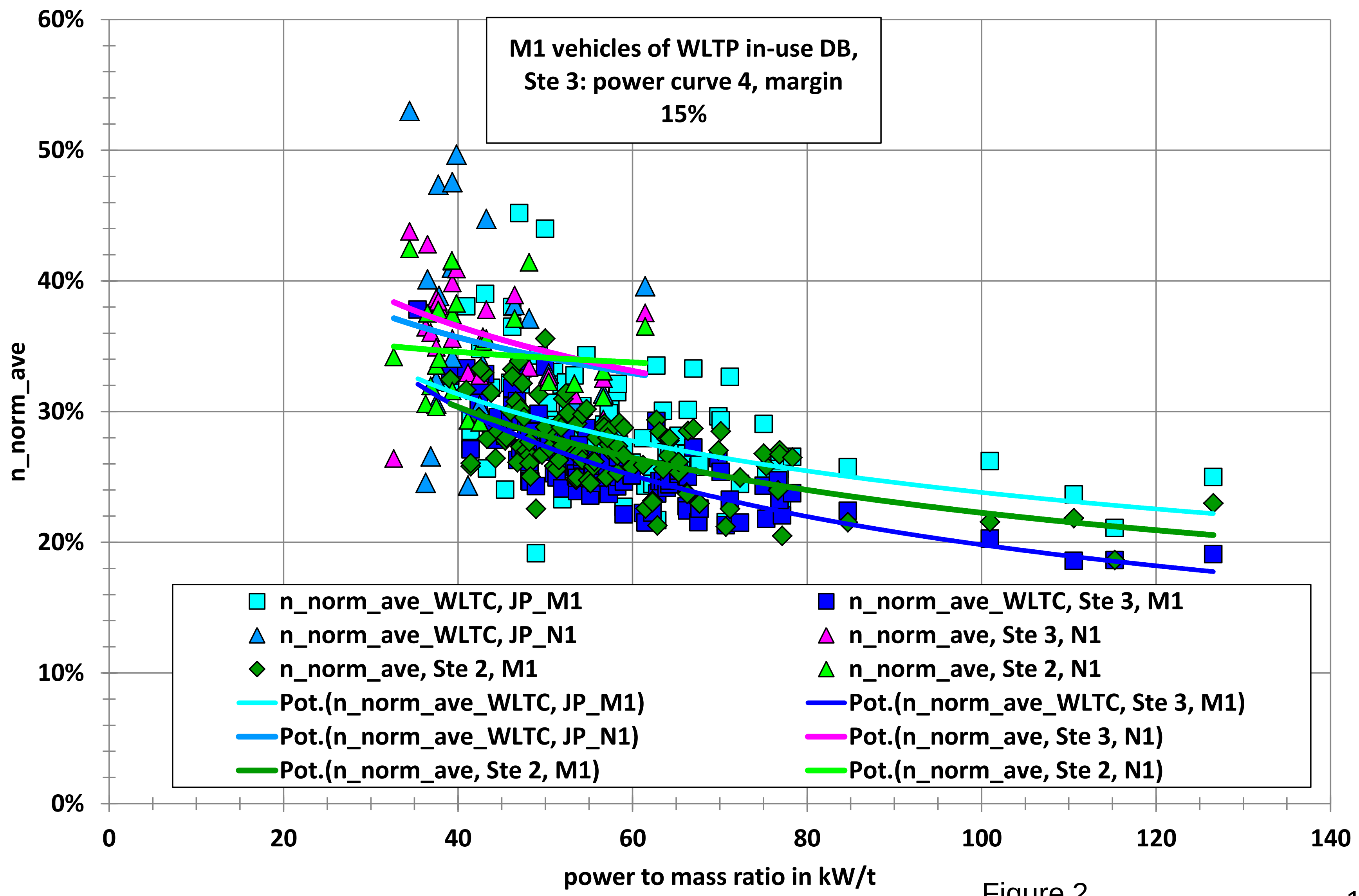

Figure 2

Aver. n_norm vs v_s_max for WLTC

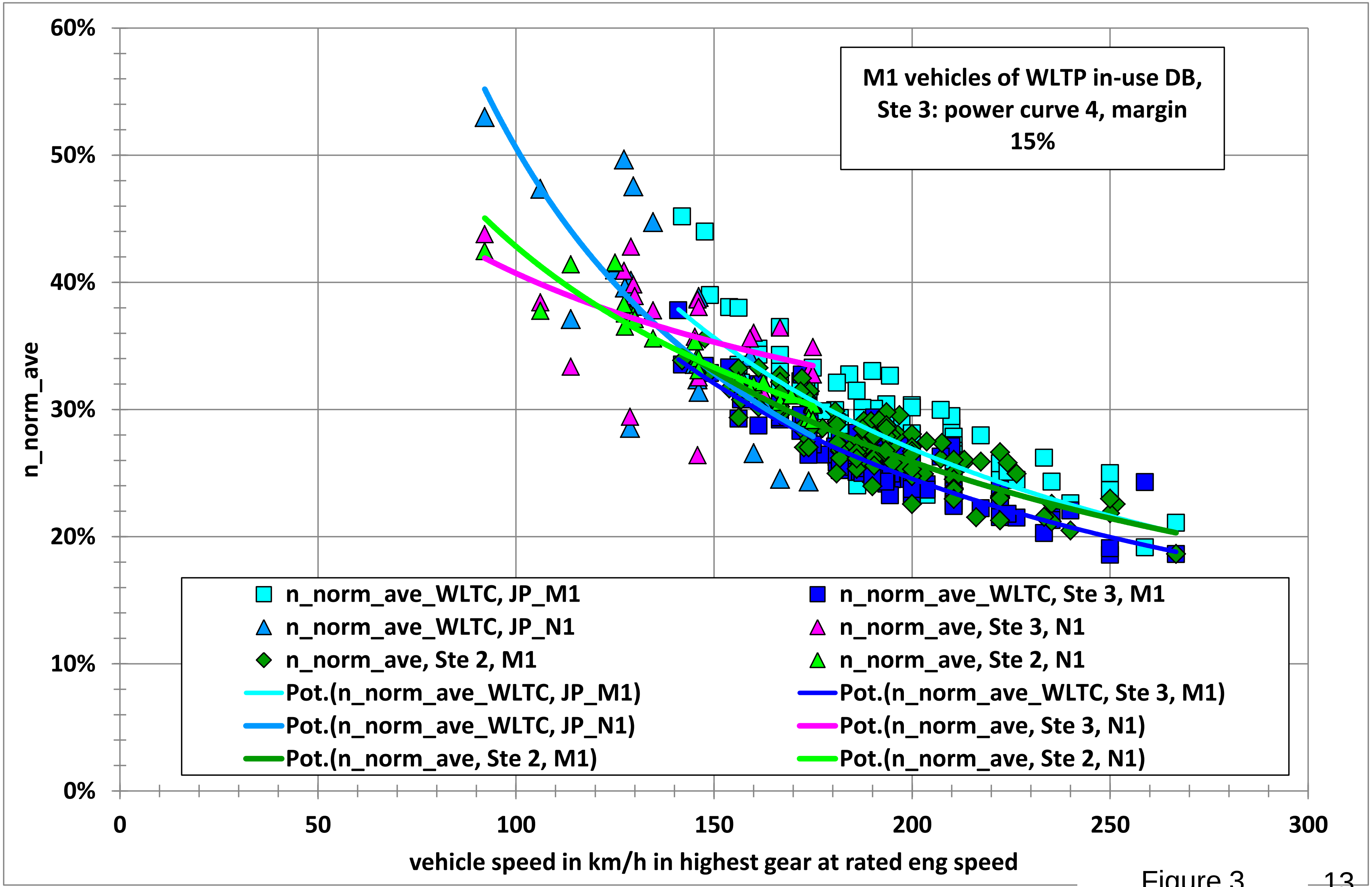

Figure 3

v_s_max versus pmr

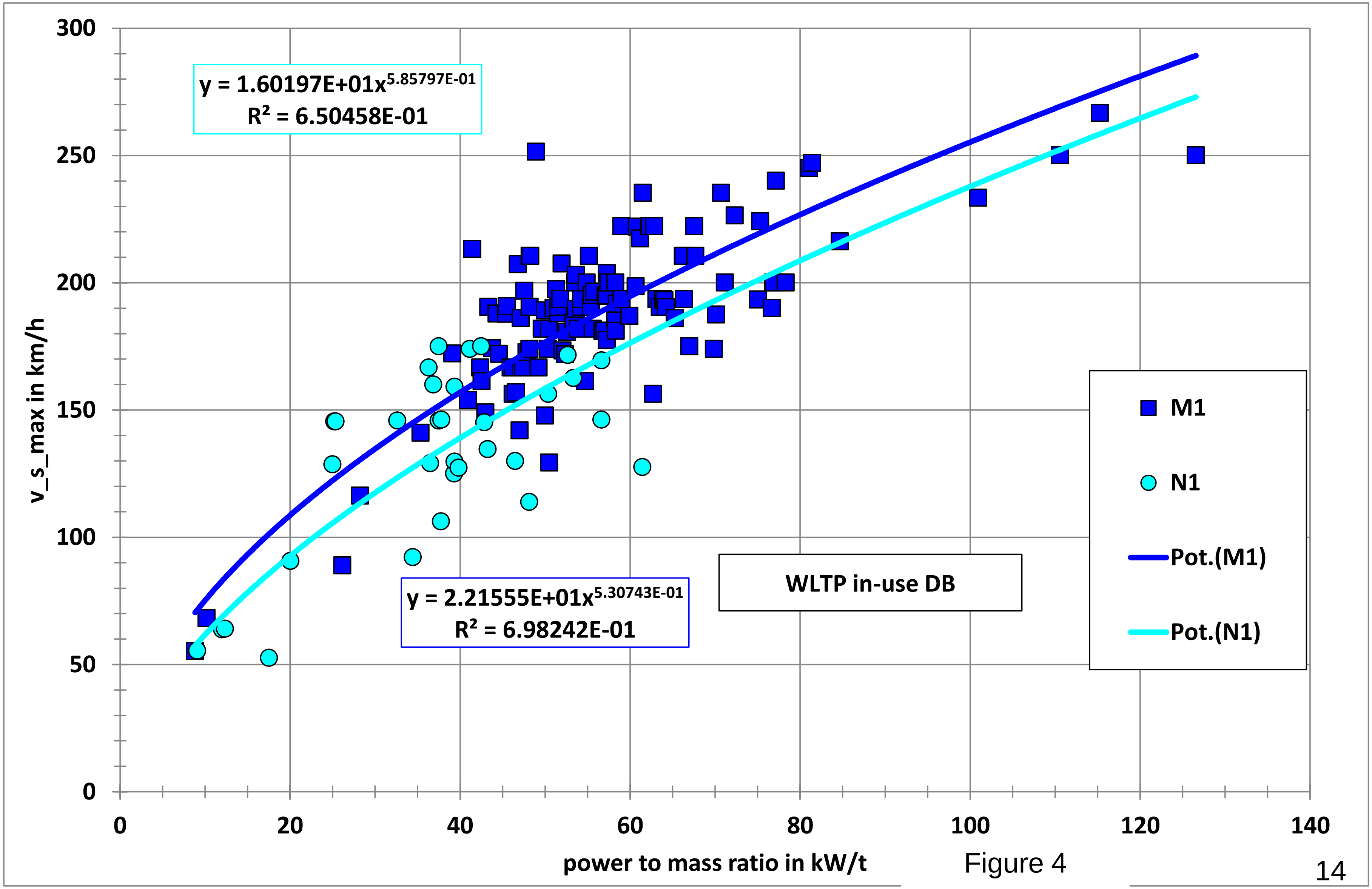

Figure 4

Normalised power curve used

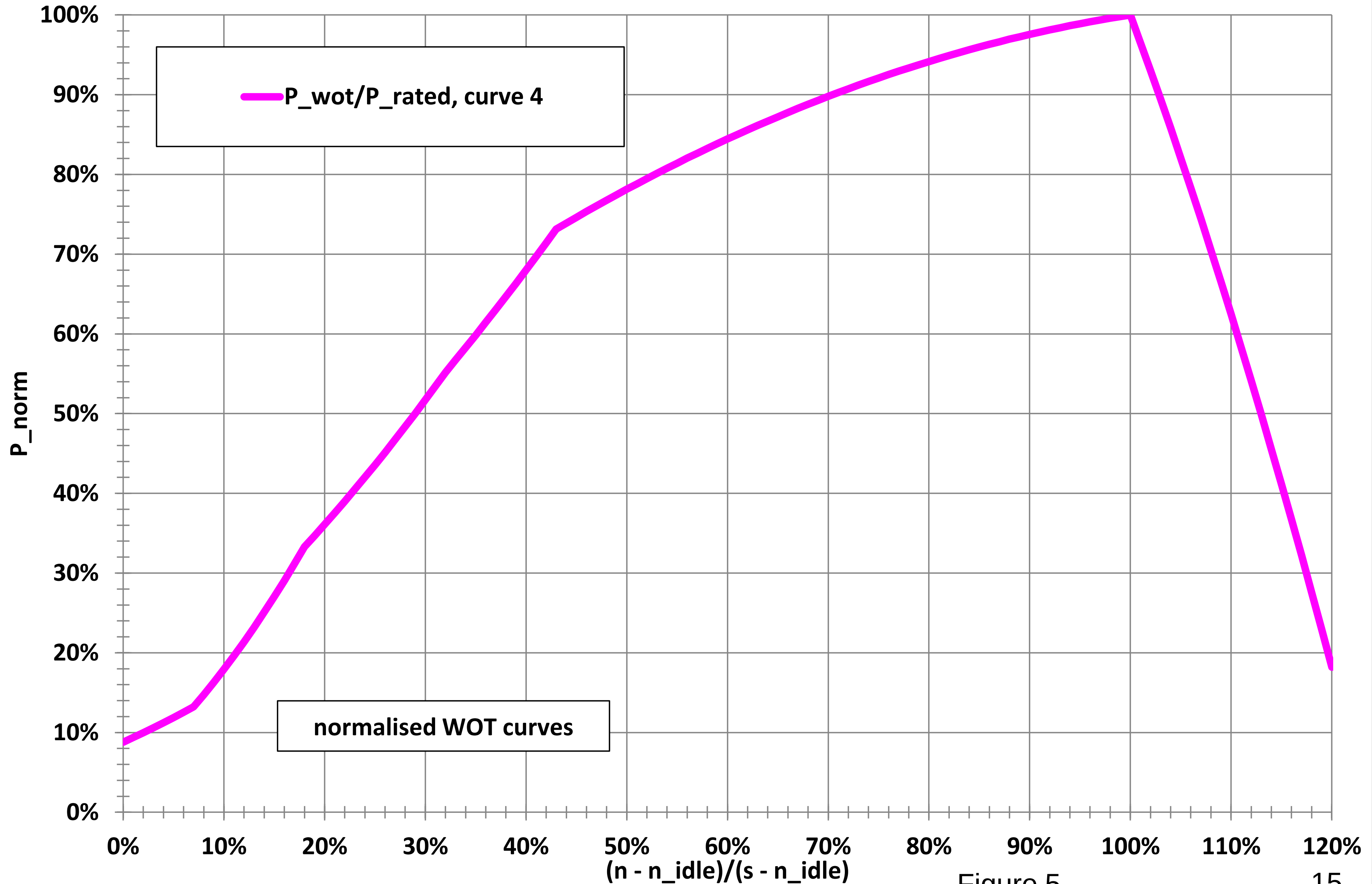

Figure 5

Comparison for vehicles of in-use DB

- **Figure 6 shows the average normalised engine speeds (n_norm_ave) for the in-use data, the Japanese proposal and the Steven 3 proposal versus power to mass ratio for all manual transmission vehicles in the WLTP in-use database with pmr > 33 kW/t.**
- **The n_norm_ave values for the in-use data were calculated as follows: The average engine speeds were calculated for low, medium, high and extra high speed short trips separately and then averaged using the durations of the WLTC as weighting factors.**
- **In all cases stop periods are disregarded.**

Average n_norm vs pmr

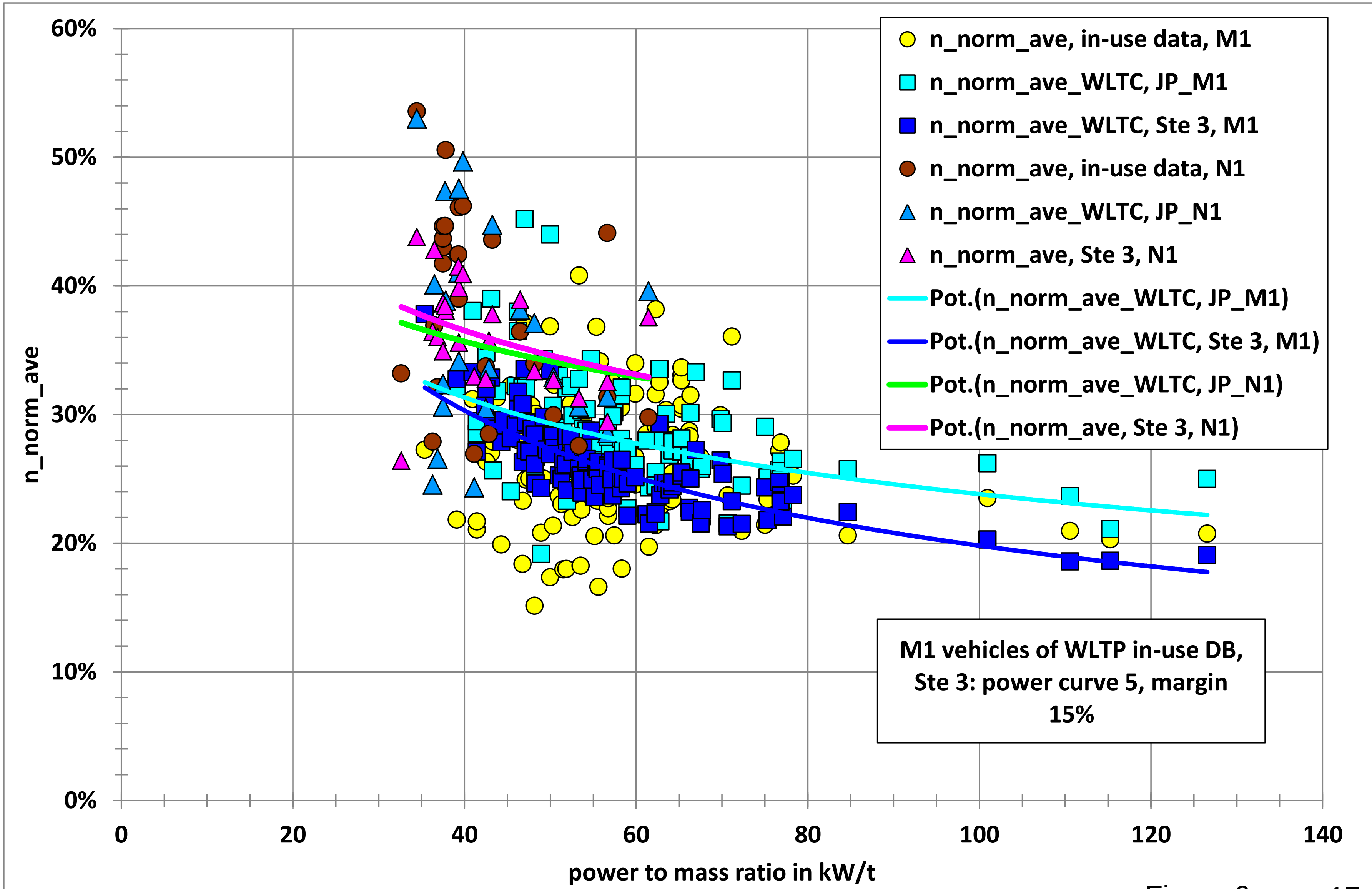

Figure 6

Comparison for vehicles of in-use DB

- **Figure 7 shows the average normalised engine speeds (n_norm_ave) for the Steven 3 proposal versus power to mass ratio for two different safety margins.**
- **The effect of an increase of the safety margin decreases with increasing power to mass ratio.**
- **The influence of different power curves shows the same tendency.**
- **The reason is that for vehicles with high pmr values the variations in the available power caused by these parameters normally do not lead to values below the requested power.**

Average n_norm vs pmr

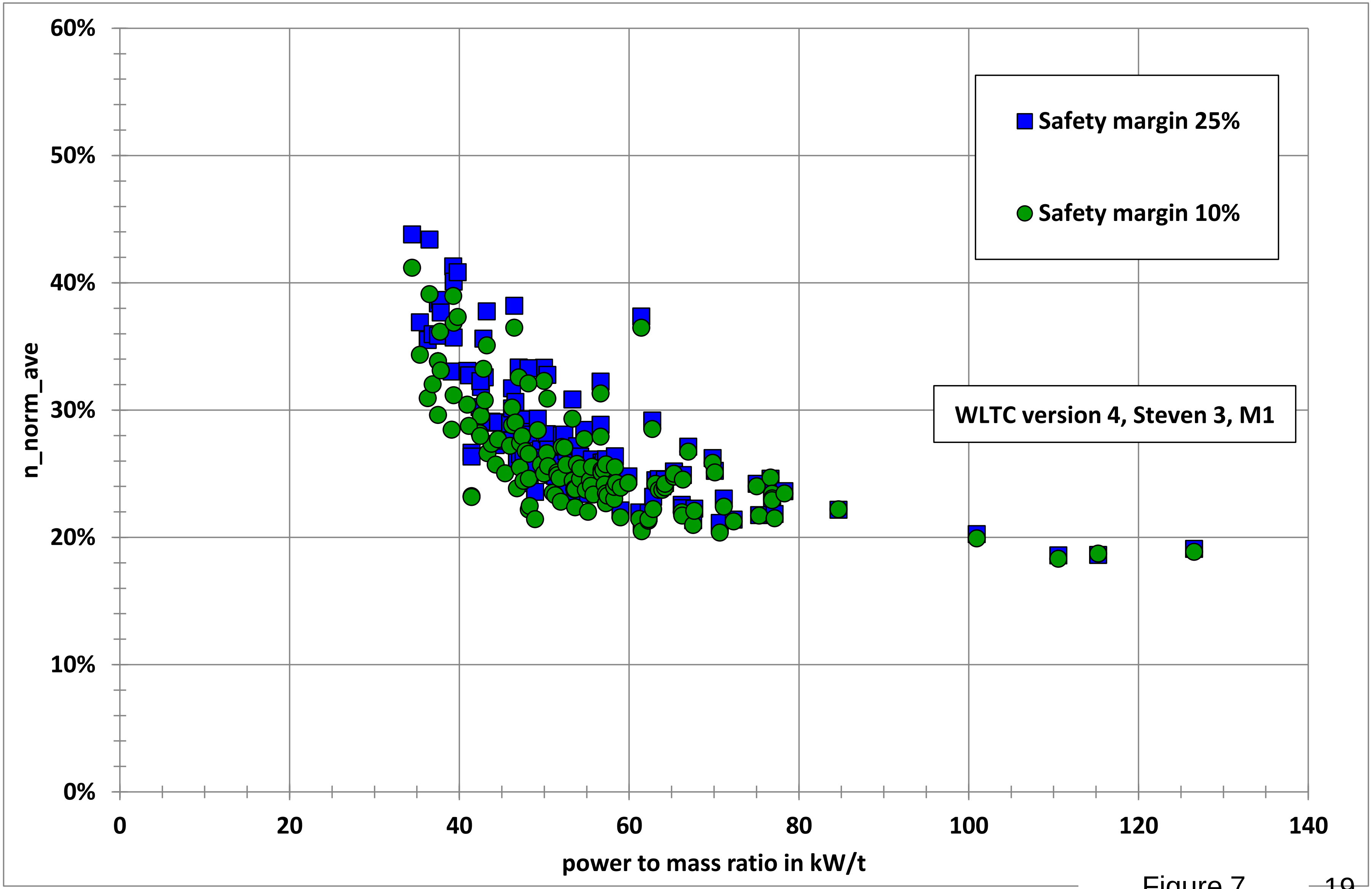

Figure 7

Conclusions

- The following conclusions can be drawn:
  - ✓ There is a correlation between pmr and v_s_max but the individual deviations from the regression curve can be in the order of +/- 18% in terms of v_s_max.
  - ✓ As one would expect, N1 vehicles have on average lower v_s_max values at the same pmr values than M1 vehicles.
  - ✓ The correlation of the average engine speed is better for v_s_max than for pmr and better for the Steven proposals than for the Japanese proposals.

Conclusions

- ✓ **For high pmr values the Steven 3 proposal has lower average speeds than the Steven 2 proposal. The reason is that the minimum normalised engine shift speed in the Steven 2 proposal is set to 33%, while there is no equivalent limit in the Steven 3 proposal.**

Comparison for model vehicles

- In order to enable a better assessment of influencing parameters like rated engine speed, number of gears etc. “model” vehicles were defined for different power to mass ratio values with fixed v_s_max values from the M1 regression curve of figure 4.
- The rated engine speed was varied between 3200 min^{-1} and 8000 min^{-1}, the number of gears between 5 and 7, in one pmr class between 4 and 7.
- The results are shown in figure 8 and figure 9.

n_norm_ave vs pmr for model veh.

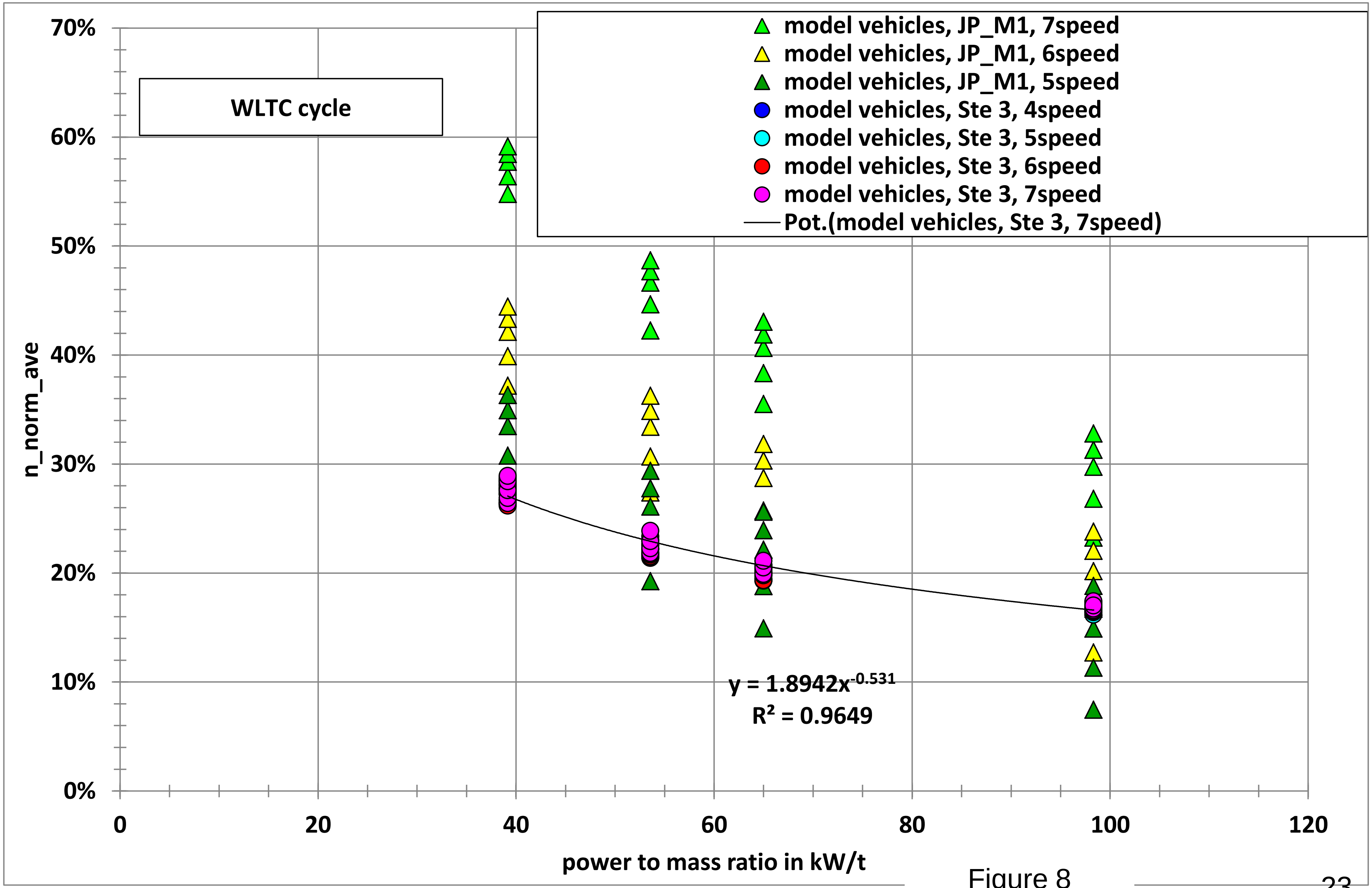

Figure 8

n_norm_ave vs v_s_max for model veh.

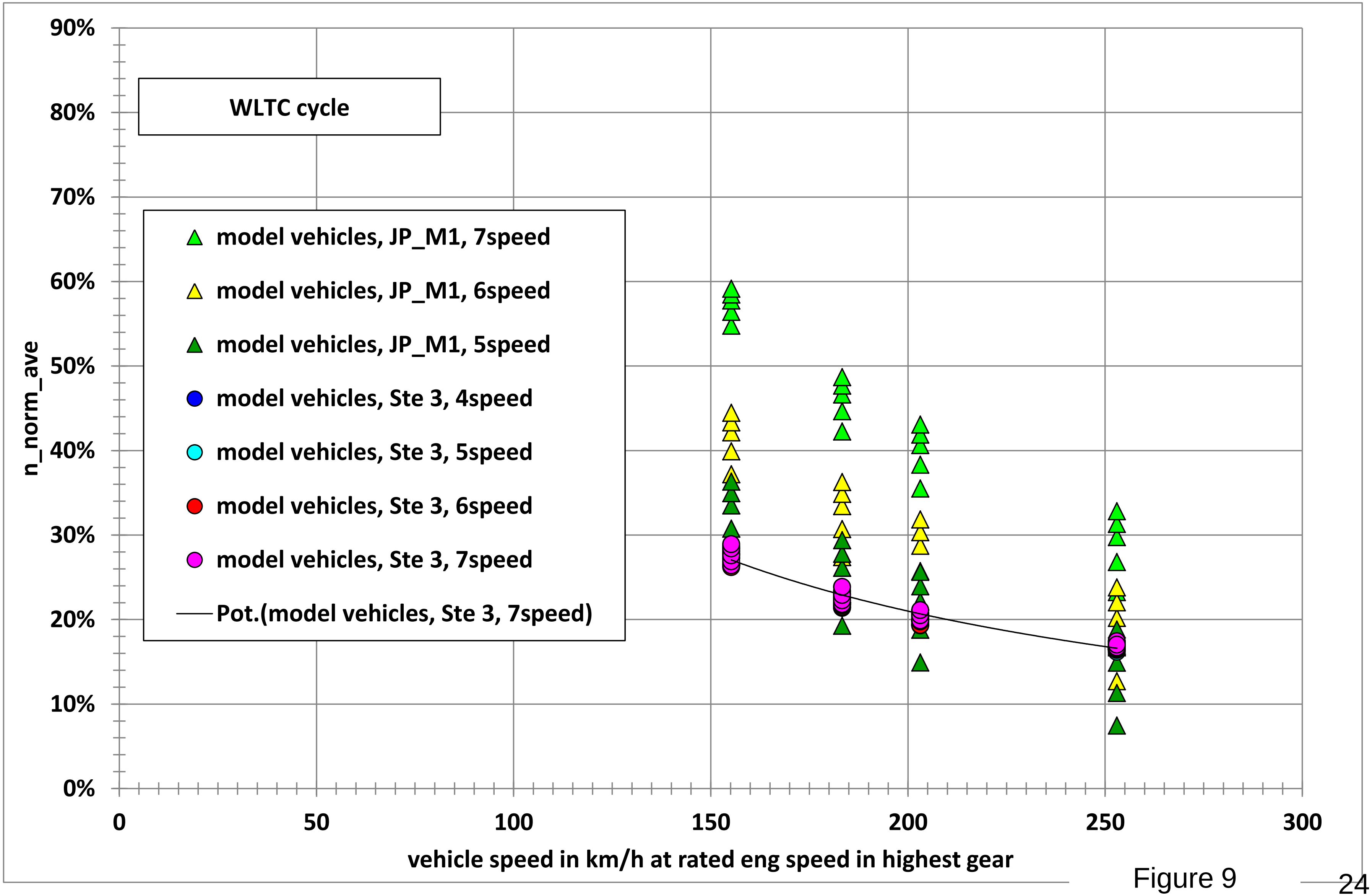

Figure 9

Comparison for model vehicles

- **The wide variation ranges for the Japanese proposal are mainly caused by different numbers of gears and to a lower extend by different rated speed values.**
- **The influences of these parameters are separately shown in figures 10 and 11.**
- **Figure 12 shows the influence of different v_s_max values for vehicles with 5 speed gearboxes, pmr of 40 kW/t and rated engine speed of 4000 min^{-1}.**

Influence of rated speed

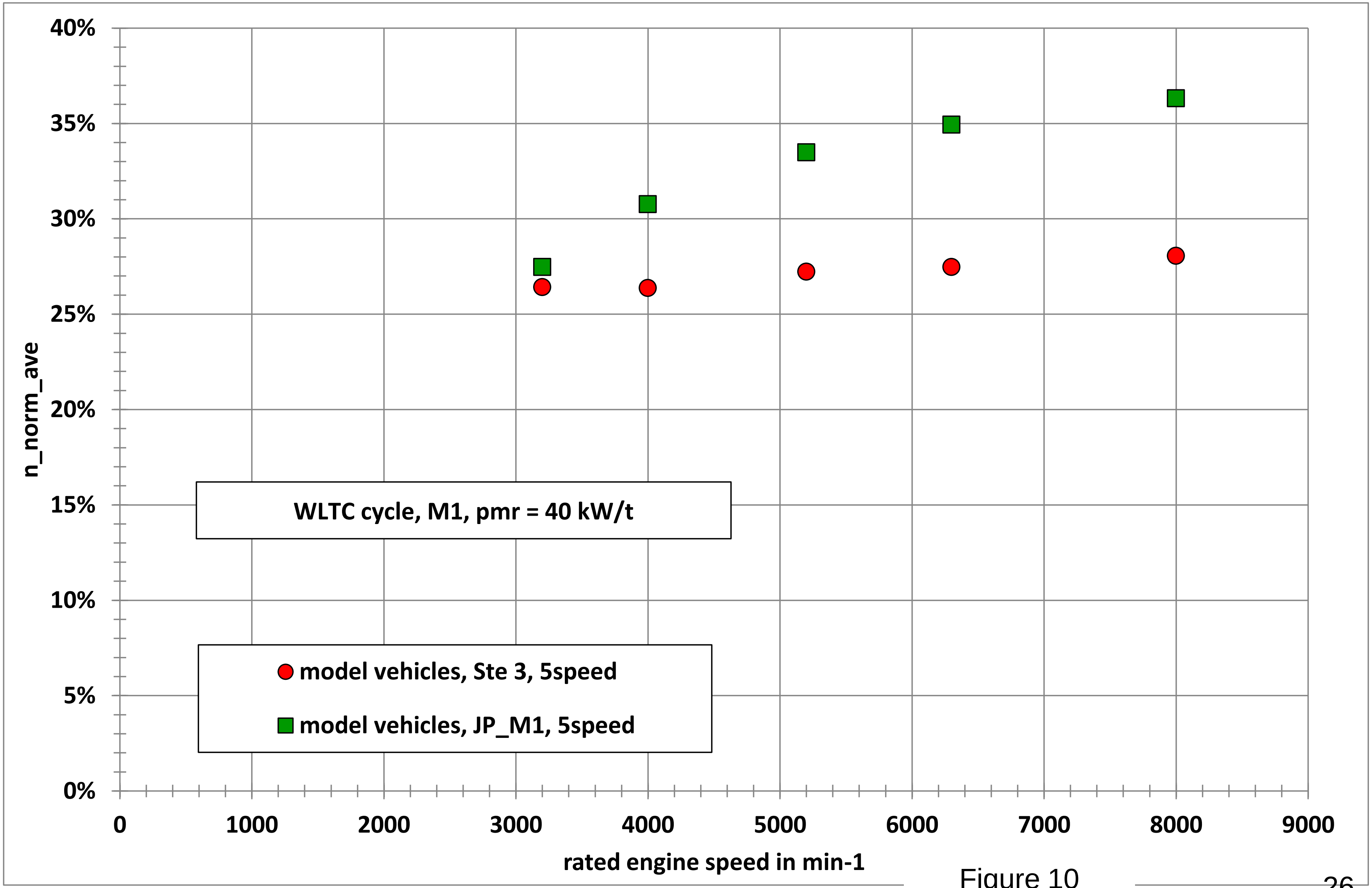

Figure 10

Influence of number of gears

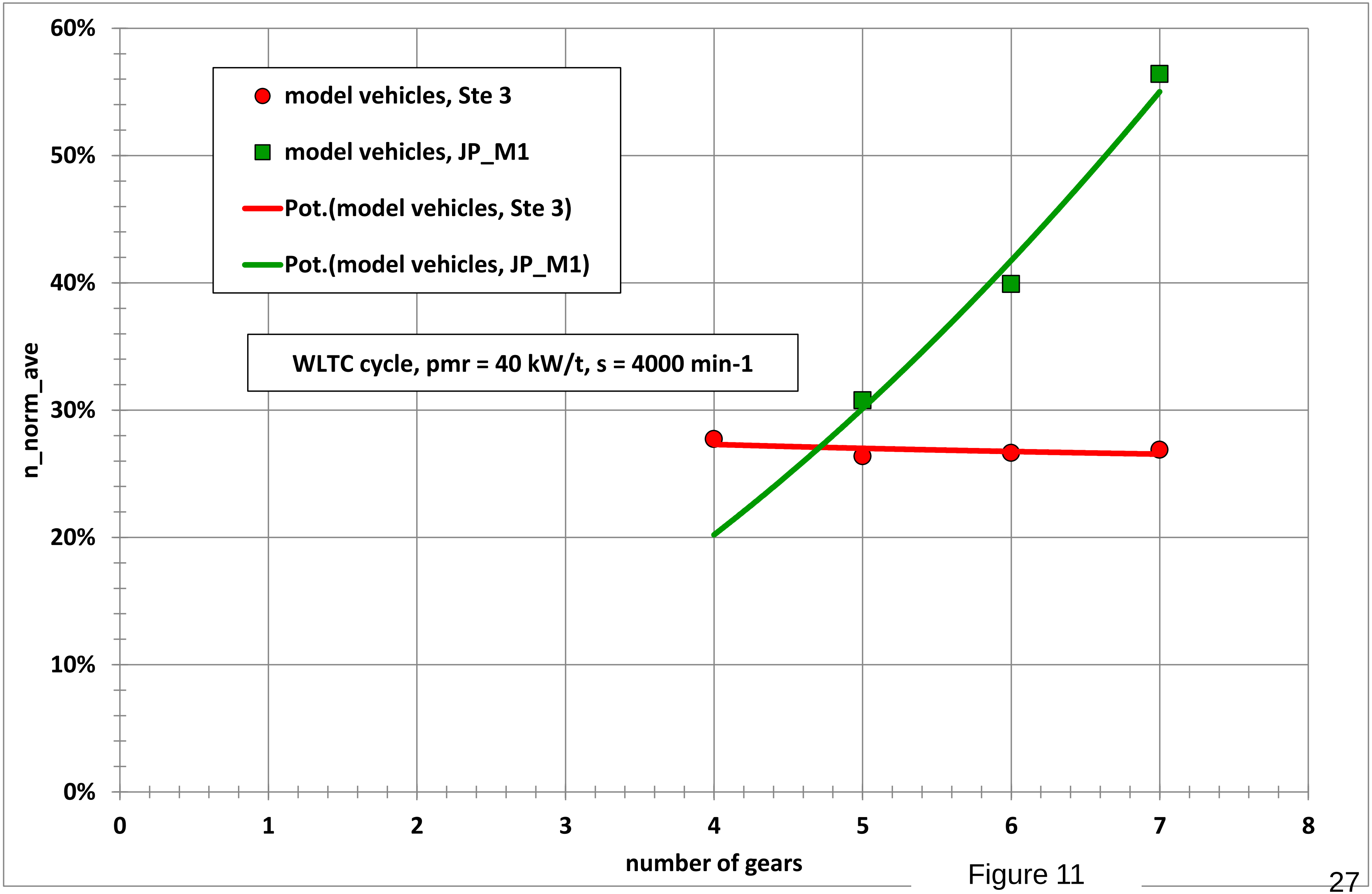

Figure 11

Influence of v_s_max

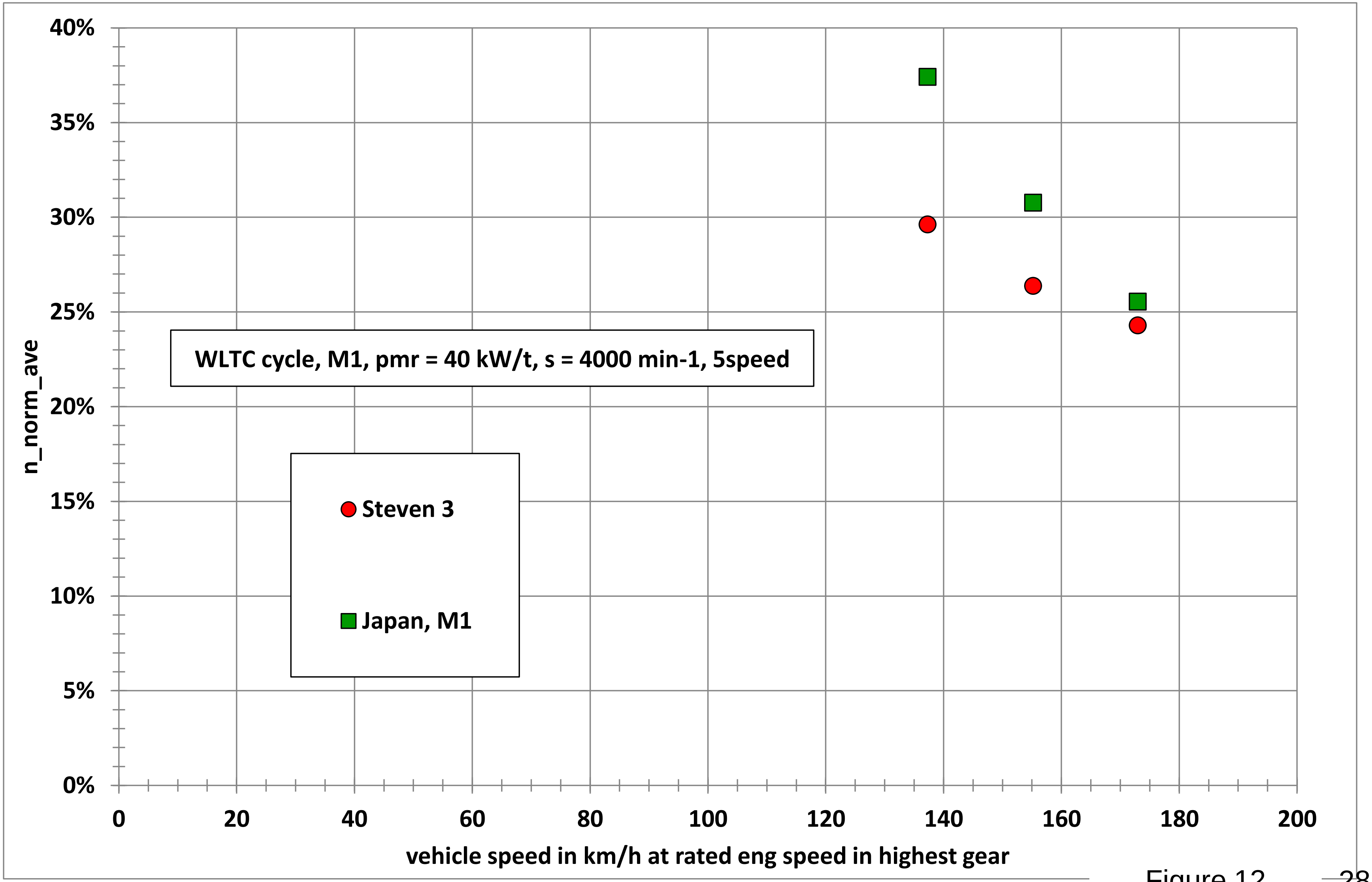

Figure 12

Conclusions

- The following conclusions can be drawn:
  - ✓ The fixed vehicle speed proposal is very sensitive with respect to engine and gearbox design (rated speed, number of gears, gear ratio of highest gear.
  - ✓ The trends for rated speed and number of gears are not in line with practical use. The trend for the gear ratio of the highest gear is too exaggerated.
  - ✓ The Steven 3 proposal is almost insensitive for rated speed and number of gears and shows a much lower influence of the gear ratio in highest gear.
  - ✓ For practical application some parameter of the Steven 3 proposal need to be fixed.

Summary

- Concerning the gearshift prescriptions for vehicles with manual transmissions the following proposals were used during validation 1:
  - ✓ The Japanese proposal (fixed vehicle speeds)
  - ✓ The Steven 1 proposal
- Both proposals were based on analyses of the gearshift behaviour in the WLTP in-use data.
- After validation 1 the WLTC was modified. The maximum accelerations were limited but the average dynamics were increased in order to bring the positive acceleration distributions closer to the database distributions.
- These modifications increased the risk for gearshift related driveability problems for both proposals.

Summary

- **This problem was partly reduced again by the Steven 2 proposal which adds the v*a component taken over from the analysis results of Eva Ericsson. The check of the available engine power adds the vehicle mass as an additional and important parameter.**
- **These prescriptions were all based on the WLTP in-use data that reflect the current situation (or more likely the situation 10 - 5 years ago) but may change in future.**
- **With respect to future developments one of the vehicle manufacturers developed gearshift prescriptions that are purely based on the individual acceleration performance of a vehicle under test.**
- **The full load power curve, the driving resistance coefficients f0, f1 and f2 and the gear ratios are needed as input data.**

Summary

- The author got the task to merge this proposal with the Steven 2 proposal. The result is named Steven 3.
- The comparison, shown in this presentation leads to the following conclusions:
- The fixed vehicle speed proposal is quite sensitive with respect to the design of engine and transmission. The influences are not always in line with practical use.
- The Steven 3 proposal is quite neutral against the above mentioned influences and more in line with practical use.
- A big advantage is the consideration of the vehicle mass as influencing parameter.

End

Thank you for your attention!