Analysis of in-use driving behaviour data, influence of different parameters

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Overview

This presentation contains the following parts

1. **Analysis of driving behaviour data delivered by vehicle manufacturers; comparison with H. Steven's existing database,**
2. **Influence of driver and vehicle,**
3. **Influence of time of the day/traffic density on driving behaviour,**
4. **Duration distributions of short trips and idle time periods.**

1. Analysis of manufacturers data

- **Data of 15 vehicles was delivered, 2 of them N1 vehicles, 14 vehicles measured in Germany, 1 in Tokyo (number 11).**
- **Table 1 shows the technical data of the vehicles.**
- **The total distance driven is 3825 km, the driving time 70,3 h. The total distance of the data collected during the last 10 years is 14728 km, the driving time 435 h.**
- **Figure 1 shows the distribution of the driving time for urban, rural and motorway operation, figure 2 contains corresponding information about the driven distance for the newly delivered data.**
- **Figure 3 shows the relations for the data collected during the last 10 years.**

Overview of vehicle data

vehicle number	engine	capacity in cm³	rated power in kW	rated speed in min-1	idling speed in min-1	kerb mass in kg	power to mass ratio in kW/t	trans-mission type	number of gears	year of first registration	vehicle category
1	Diesel	2400	66	4000	800			manual	5		N1
2	Diesel	1910	110	4000	800	1390	75.1	manual	6	2009	M1
3	Petrol	1998	147	5400	850	1365	102.1	manual	6	2008	M1
4	Petrol	2792	239	5250	700	1835	125.1	automatic	6	2009	M1
5	Diesel	2993	160	4000	700	2180	71.0	automatic	6	2005	M1
6	Diesel	2993	170	4000	700	1665	97.7	automatic	6	2006	M1
7	Petrol	1596	85	6000	800	1280	62.7	manual	5	2005	M1
8	Diesel	1994	120	4000	850	1490	76.7	manual	6	2005	M1
9	Petrol	1995	110	6200	750	1395	74.8	manual	6	2005	M1
10	petrol	1596	85	6000	700	1280	62.7	manual	5	2005	M1
11	Petrol	2994	188	6200	650	1580	113.6	automatic	6	2003	M1
12	Diesel	2500	100	3200	750			manual	6		N1
13	Diesel	2987	165	3800	700	2420	66.1	automatic	7		M1
14	Diesel	2987	173	3600	750	2175	76.9	automatic	7		M1
15	Petrol	3498	205	6000	700	2175	91.1	automatic	7		M1

Table 1

Overview of road cat. distributions

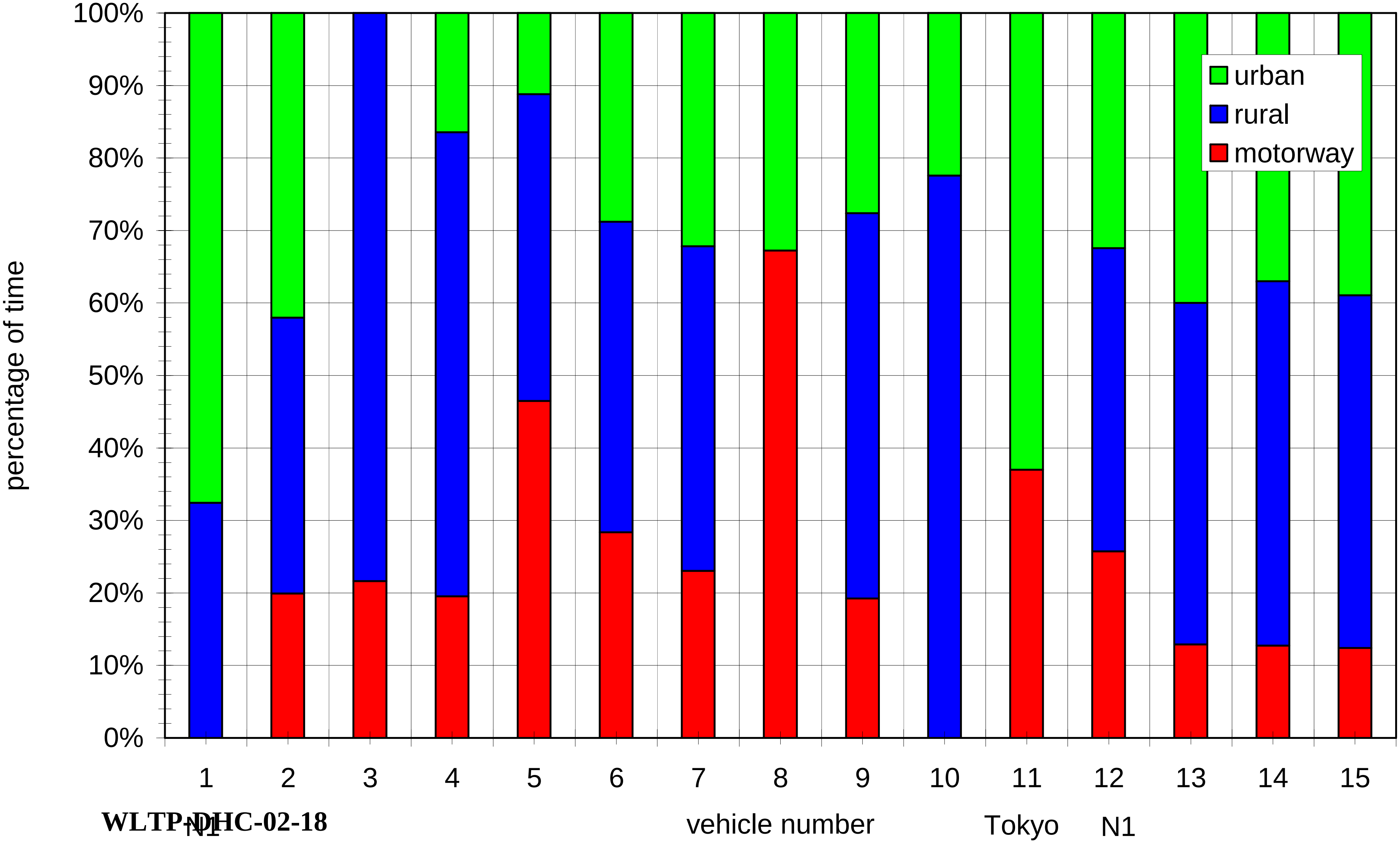

Figure 1

Overview of road cat. distributions

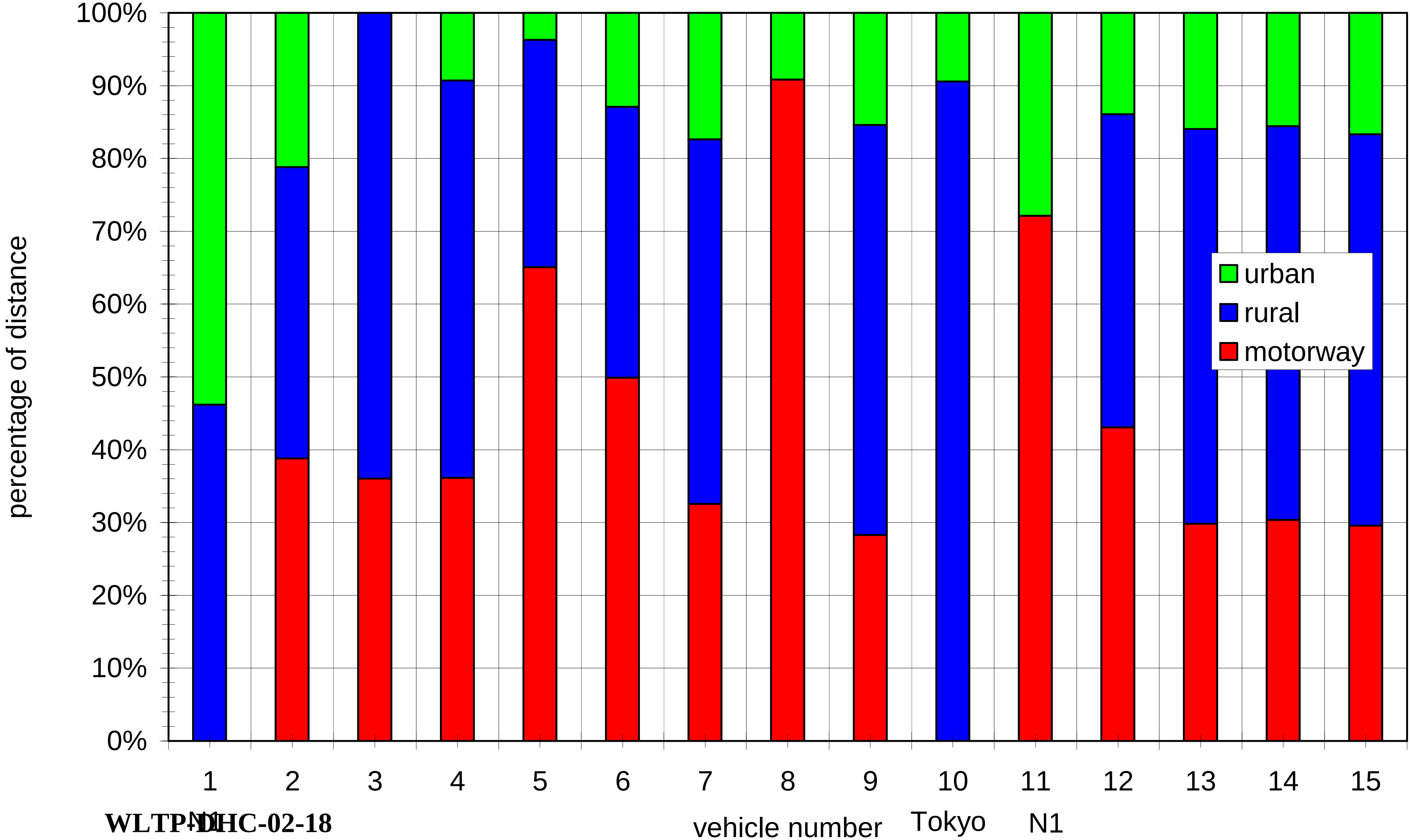

Figure 2

Overview of road cat. distributions

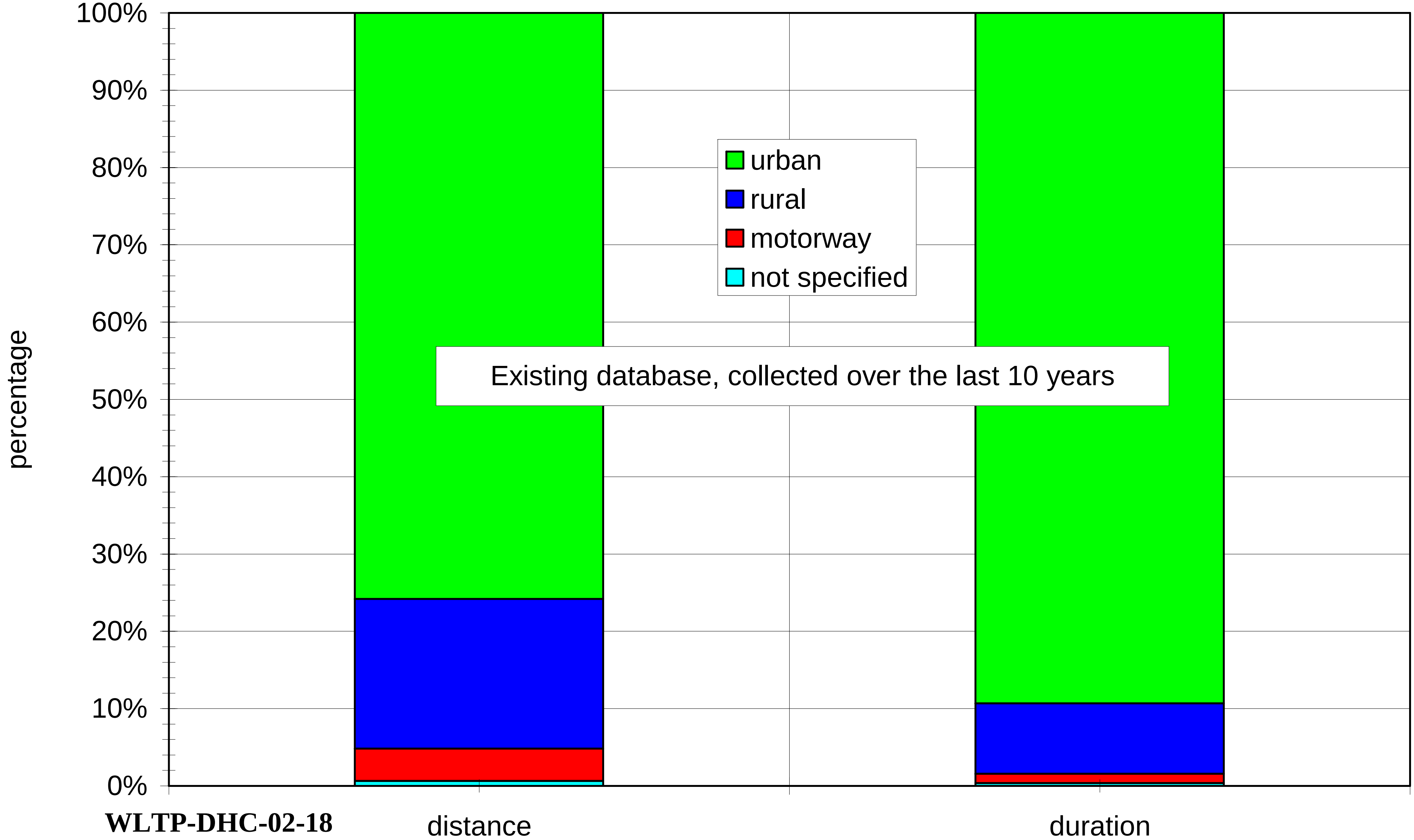

Figure 3

Overview of results

Conclusion for road cat. distributions:

- The existing data is dominated by urban operation, the new data has higher shares for rural and motorway.

Overview of vehicle speed distributions:

- Figure 4 shows the cumulative frequency distributions of vehicle speed for the individual vehicles.
- Figure 5 shows separated curves for urban, rural and motorway, aggregated over the individual vehicles.

Vehicle speed distributions

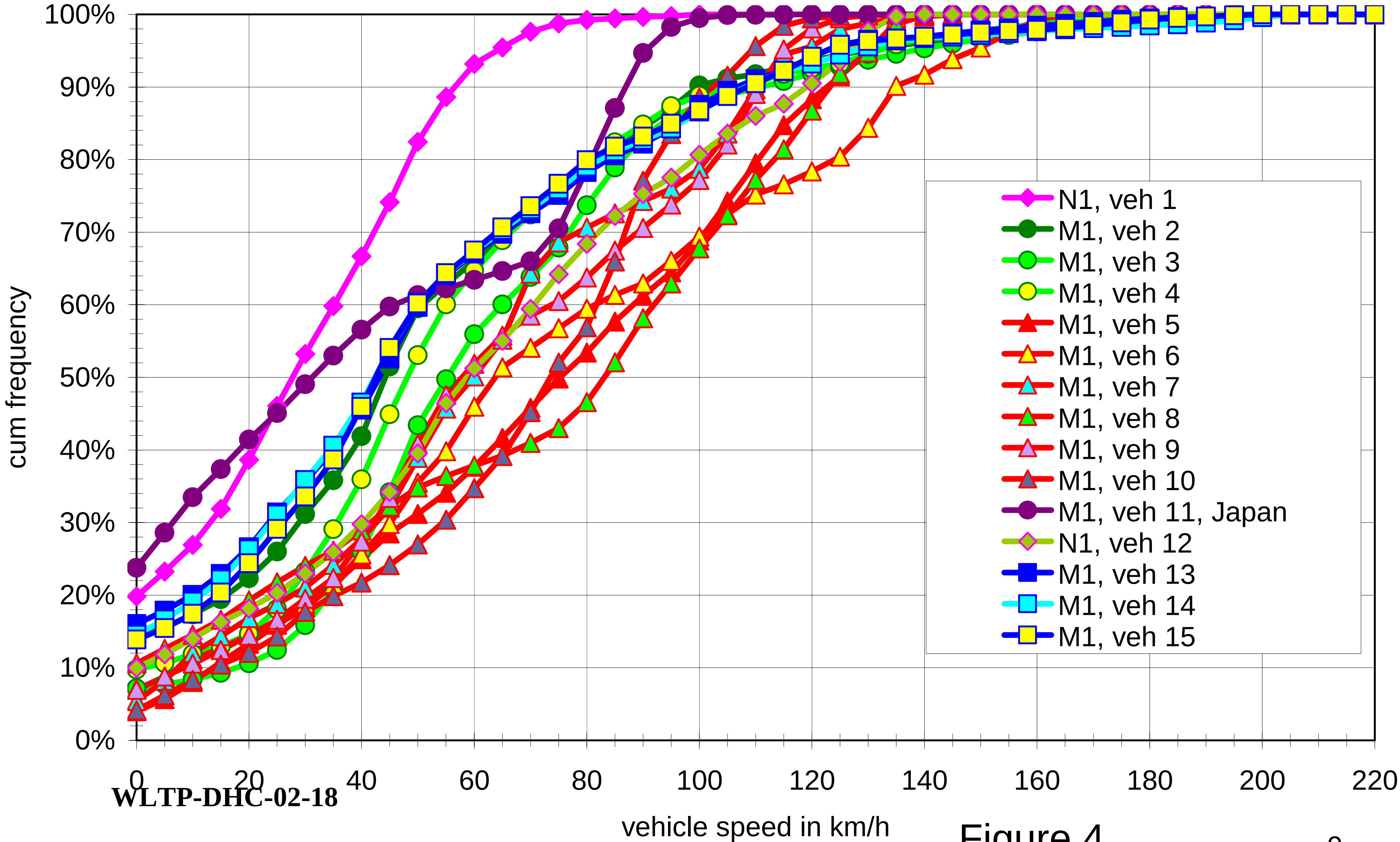

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Figure 4

Vehicle speed distributions

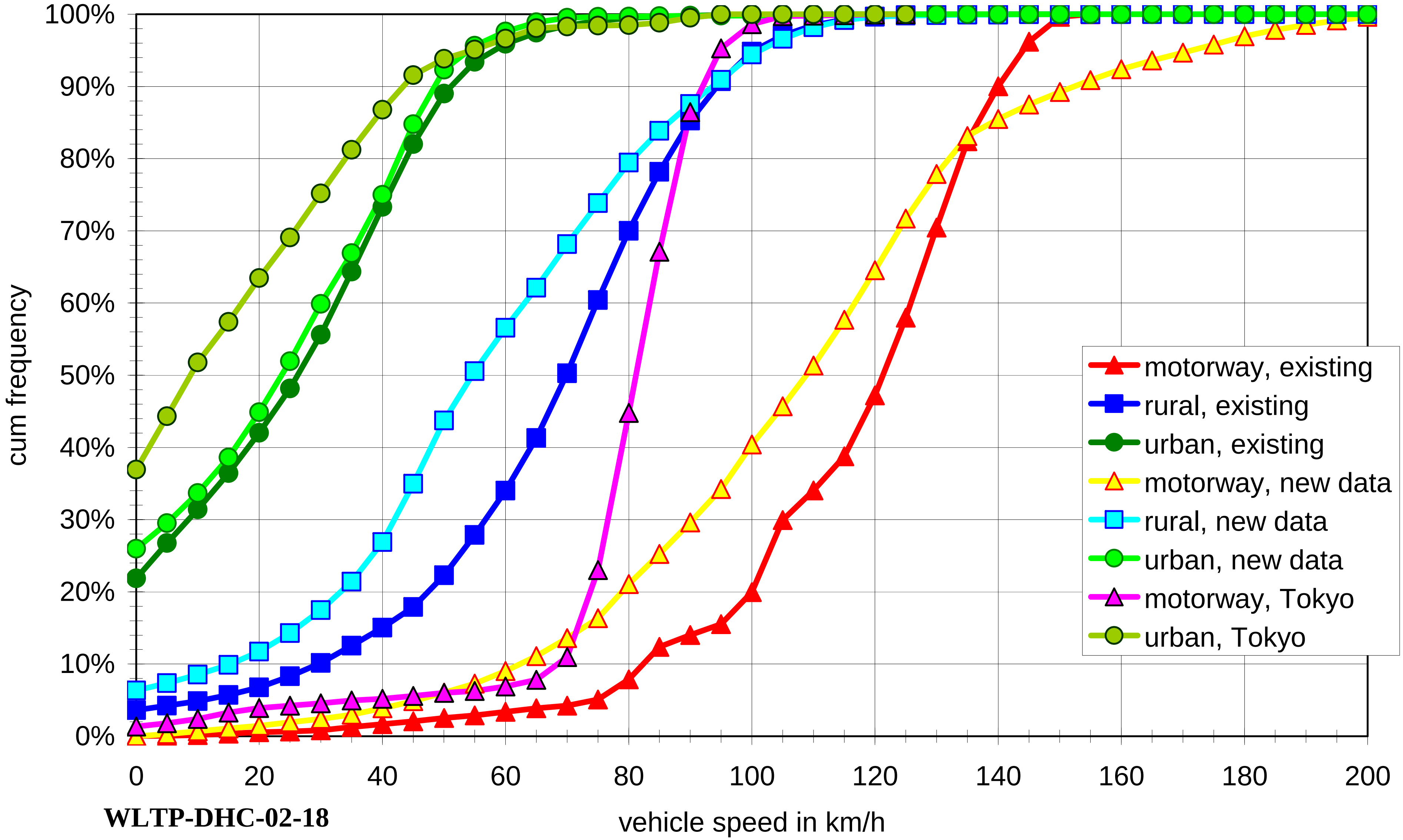

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Figure 5

Overview of results

Conclusion for vehicle speed distributions:

- **The new data show no significant difference to the existing data for urban operation.**
- **The difference for rural operation is significant, the new data tends to lower speeds.**
- **For motorway operation the new data show a broader range than the existing data.**

Overview of short trip analysis

- Figure 6 shows a comparison of the RPA values of short trips versus average speed.
- The new data extends the average speed range to operation conditions on German motorways.
- Except from that there is a good agreement between the new and the existing data.

Short trip analysis results

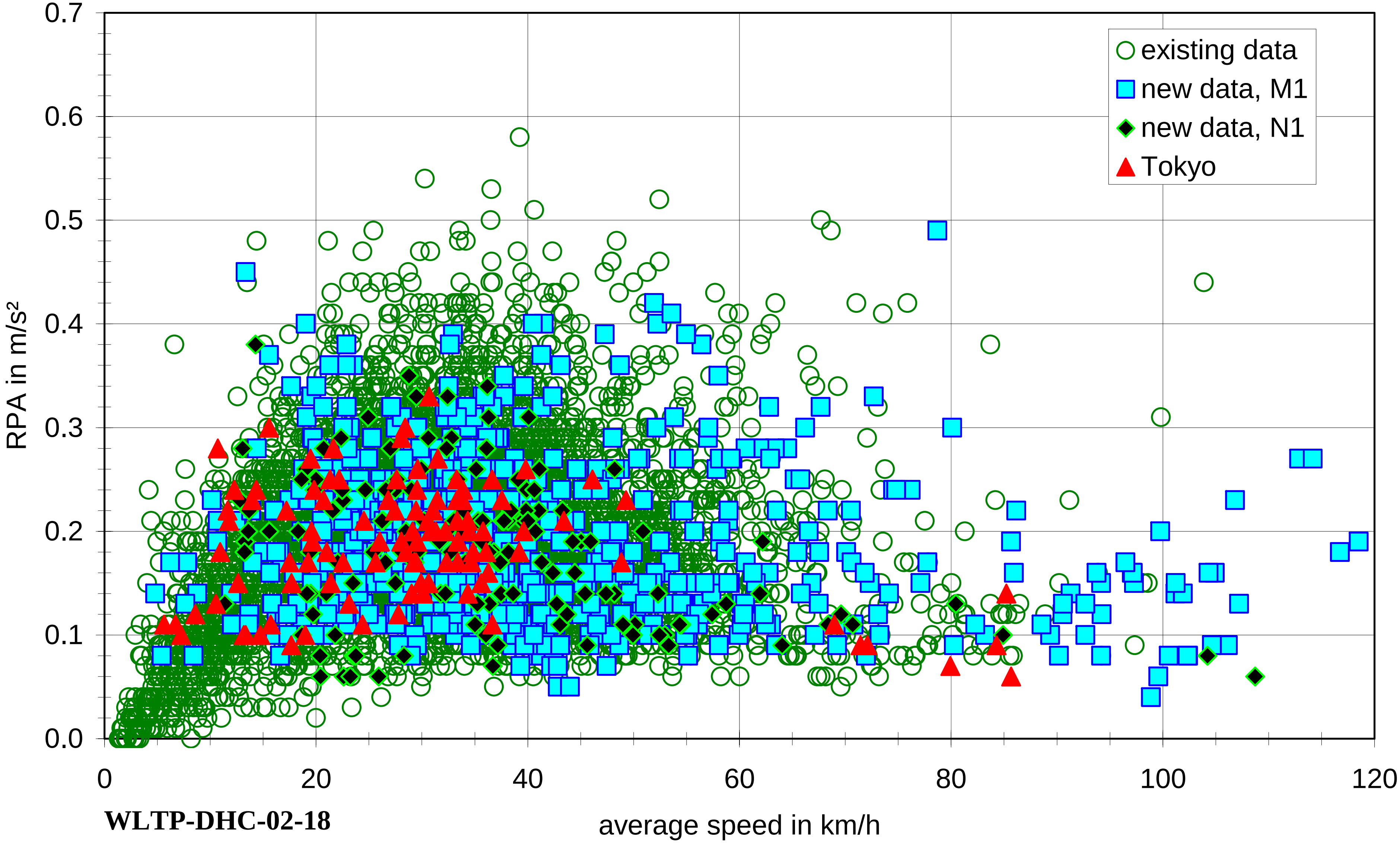

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Figure 6

Urban, rural, motorway

- Figure 7 shows the RPA and v_ave values of all short trips (existing and new data), split off into the road categories urban, rural and motorway, as far as this was possible.
- There is an extremely high overlap between urban and rural. The much less pronounced overlap between rural and motorway might be caused by the low number of motorway short trips.
- A problem that needs to be discussed is the fact, that a significant number of short trips in the database could not be assigned to one road category only. In figure 8 these "hemaphrodite" short trips are added.

Short trip analysis results

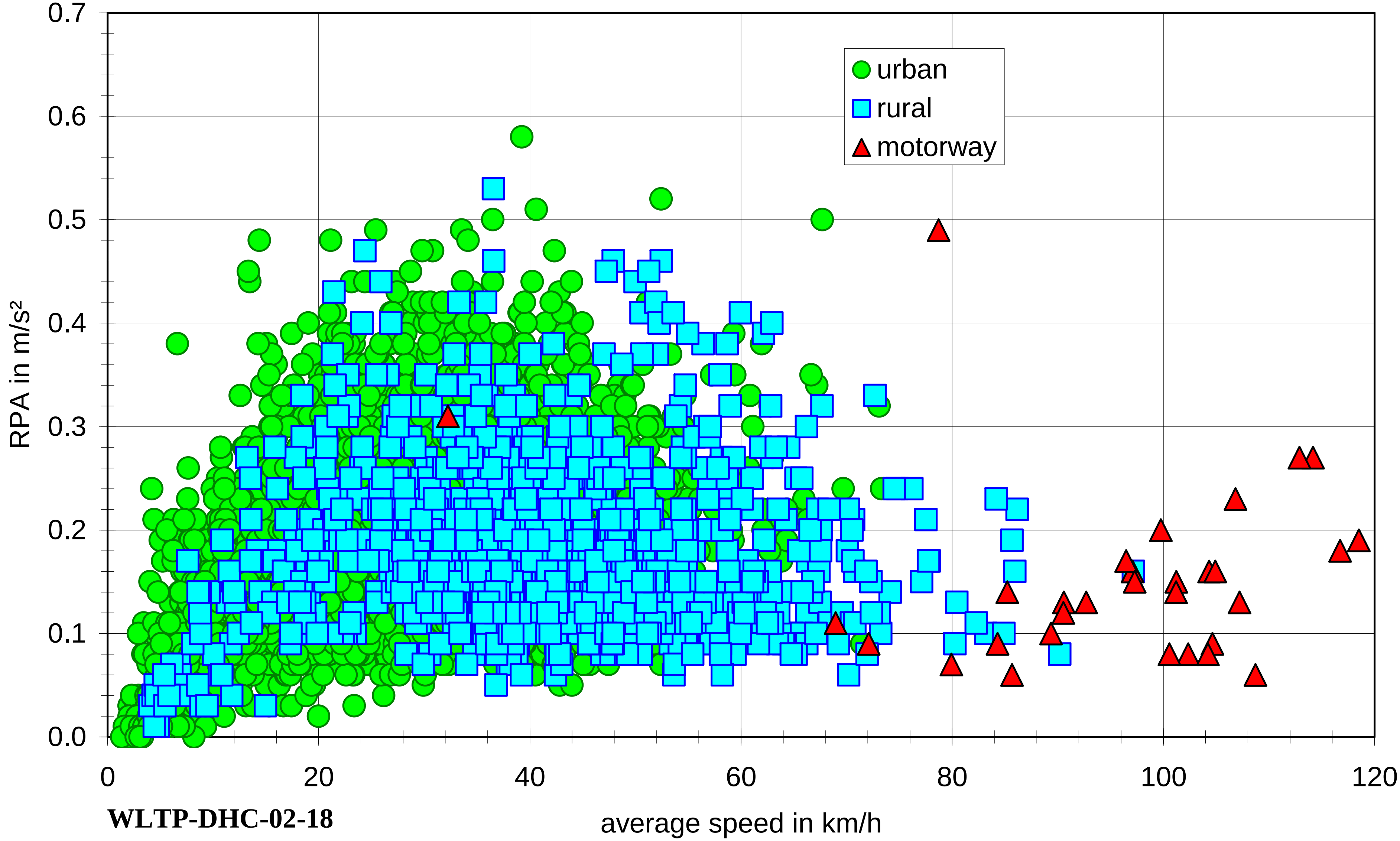

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Figure 7

Short trip analysis results

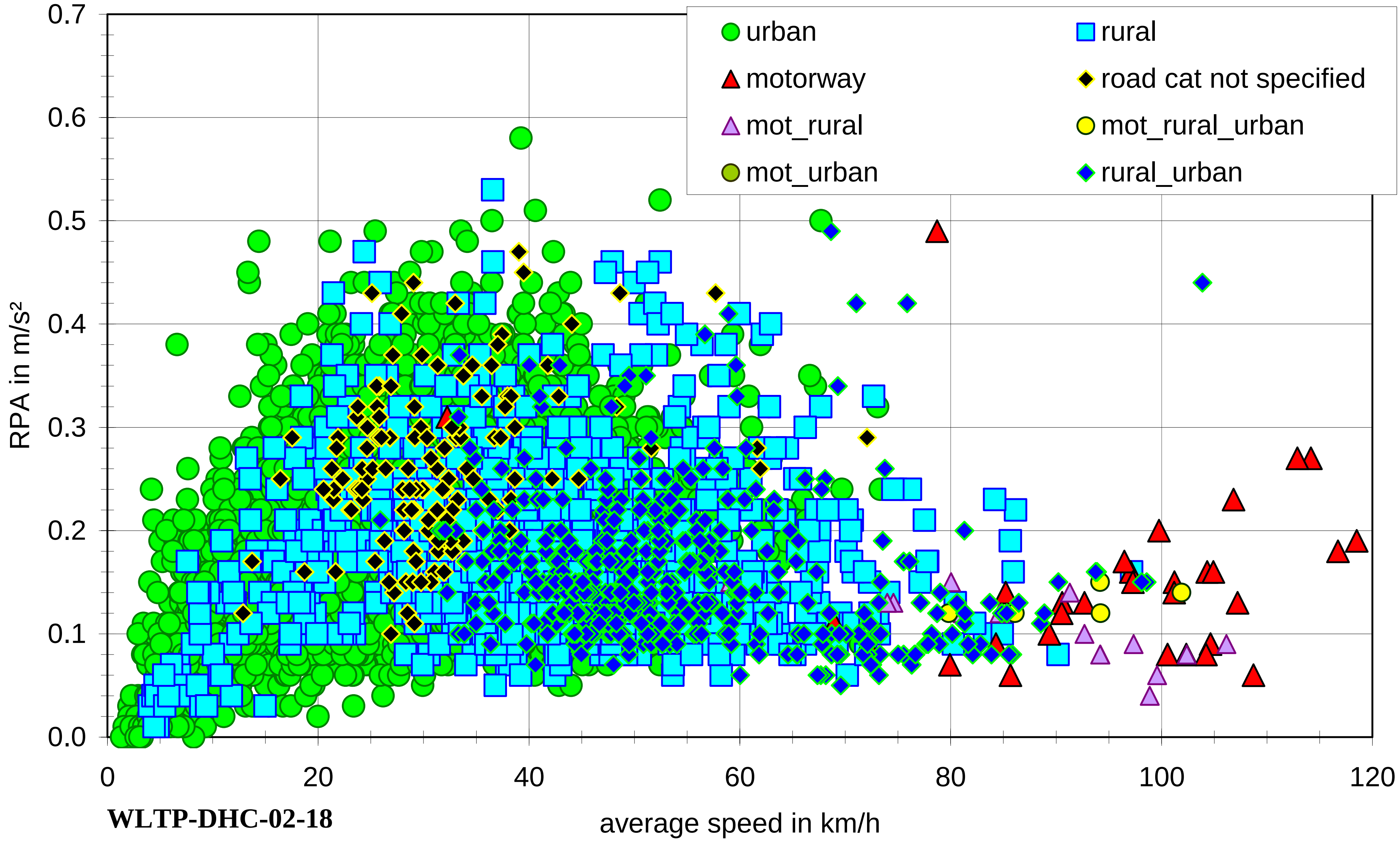

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Figure 8

Short trip analysis

Conclusions for road categories:

- **May be, there is no need for a strict separation of the in-use data with respect to road categories.**

2. Driver and vehicle influence

- **Within a research project of the German Environment Agency (see [1]) 11 different M1 vehicles were measured on 2 different circuits in the city of Aachen and the surrounding area, covering a broad variety of road types from residential streets to rural federal roads.**
- **The trips were performed with the following 3 different driving stiles:**
  - **Economic,**
  - **Normal,**
  - **High revs.**

Driver and vehicle influence

- The vehicle sample varied from low powered subcompacts to high powered sport cars.
- The most important vehicle parameter with respect to driving behaviour influence was the power to mass ratio (pmr, rated power divided by vehicle mass).
- Figure 9 shows the RPA values versus average speeds for the short trips for 3 vehicles. Vehicle 9 has a pmr value of 43,7 kW/t, the pmr value of vehicle 2 is 66,4 kW/t and vehicle 3 has a pmr value of 133,8 kW/t.

Influence of vehicle design

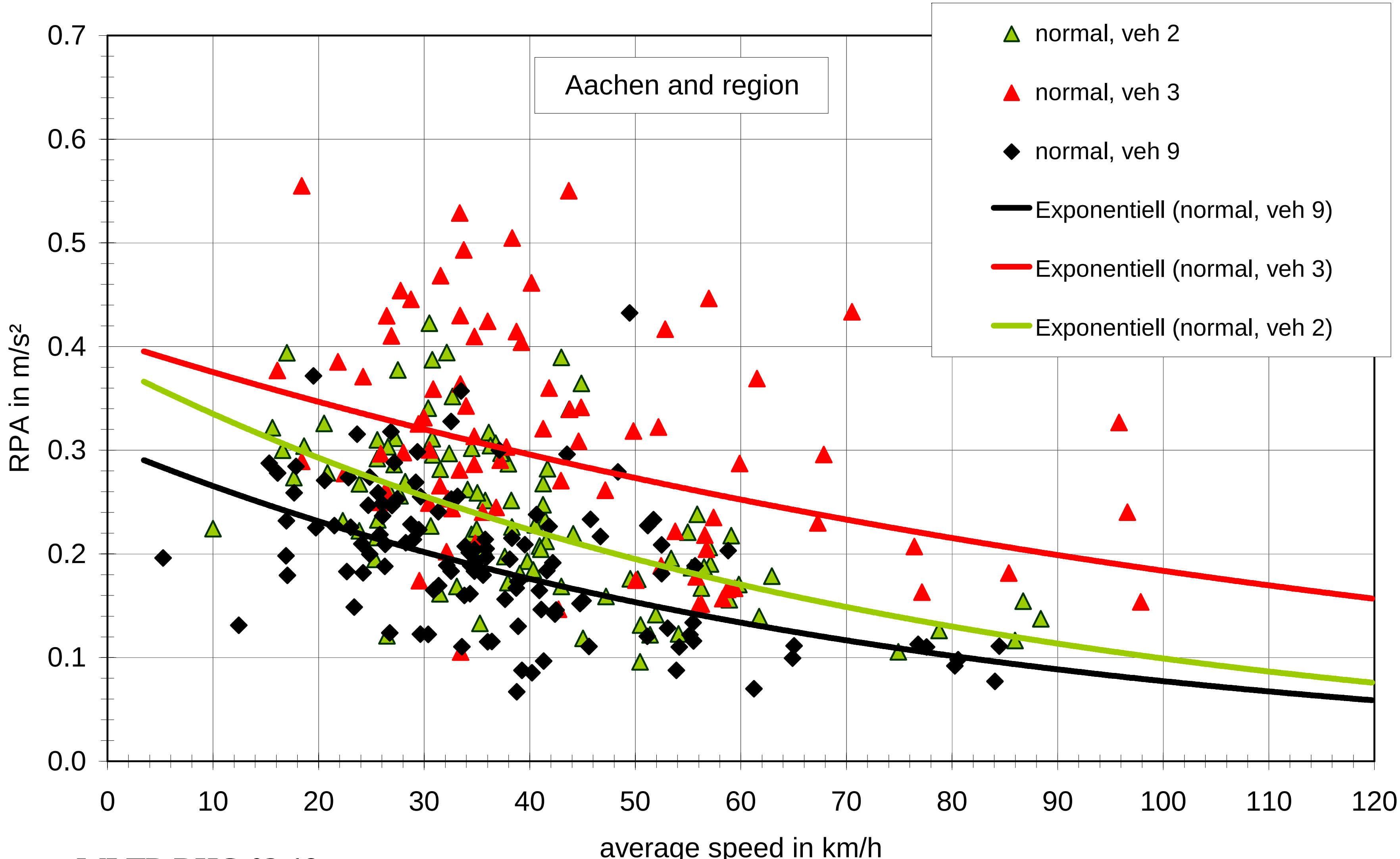

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Figure 9

Driver and vehicle influence

- **The average RPA values of all short trips per vehicle and driving behaviour are shown in figure 10 versus power to mass ratio.**
- **The RPA values of the new data could also be plotted versus power to mass ratio. These values are shown in figure 10 for comparison.**

Driver and vehicle influence

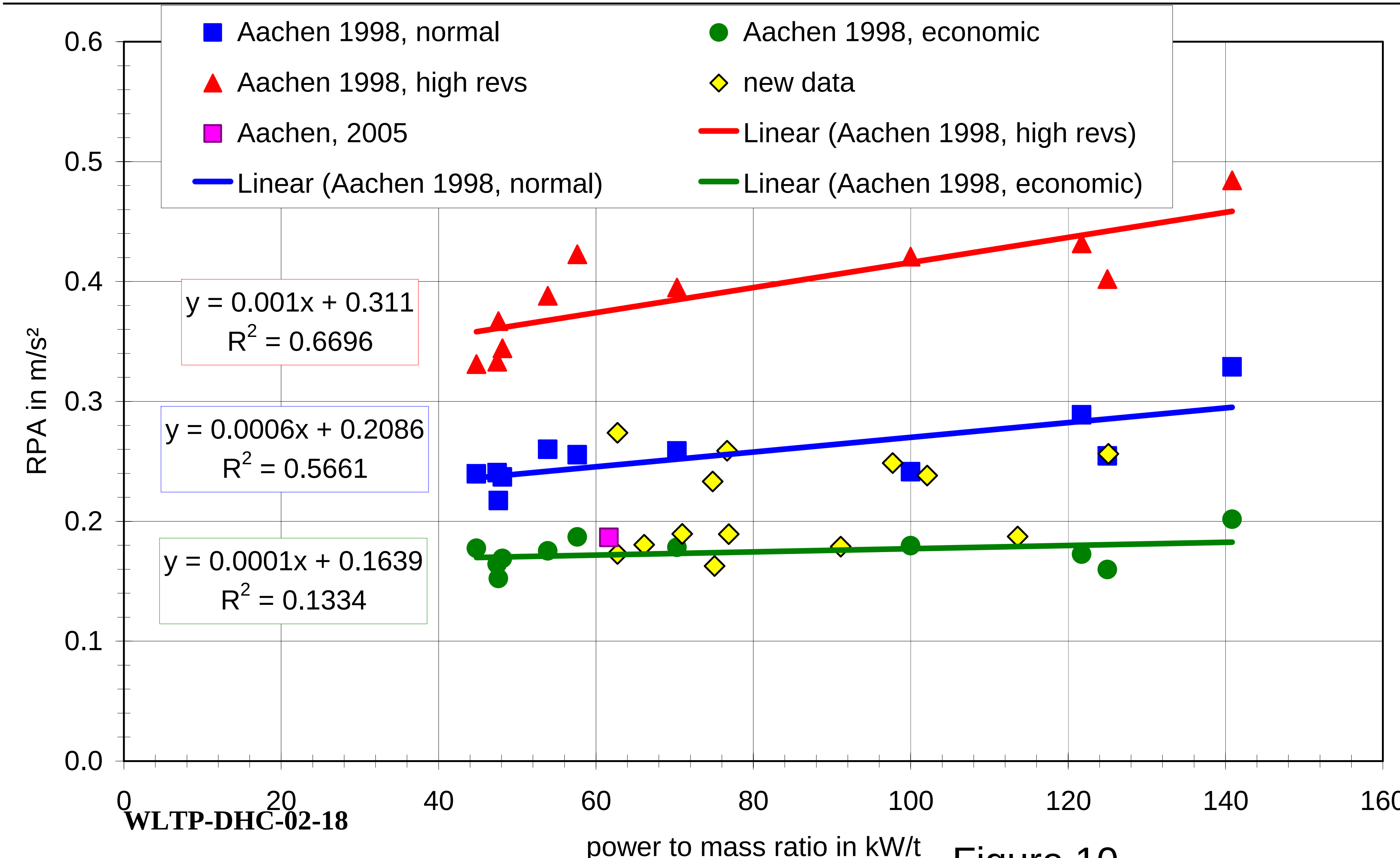

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Figure 10

Conclusions

- **The vehicle influence is significant for high revs driving behaviour but becomes insignificant for economic driving behaviour.**
- **But the differences between the 3 driving stiles are for all vehicles by far higher than the differences between the vehicles.**

3. Influence of time of day/traffic density

- In 2007 in-use driving behaviour data was measured with an average motorised car in an urban main street in Berlin (see [2]).
- The measurements were performed in time periods from 5:00 h till 9:00 h in the morning and from 12:00 h till 21:00 h in the afternoon.
- The trips were separated into different driving phases as follows:
  - Stop ($v < 1$ km/h),
  - Acceleration ($a > 0{,}278\ m/s^2$),
  - Deceleration ($a < -0{,}278\ m/s^2$)
  - Cruise (a between $-0{,}278\ m/s^2$ and $0{,}278\ m/s^2$)

Influence of time of the day/traffic density

- **Figure 11 shows the percentages of the different driving phases as function of the time of the day.**
- **The highest variance was found for the stop phases, ranging from 15% in the first morning hour to 40% in the afternoon peak hour.**
- **The lowest variance can be seen for acceleration and deceleration phases, ranging from 15% to 23%.**

Influence of time of the day/traffic density

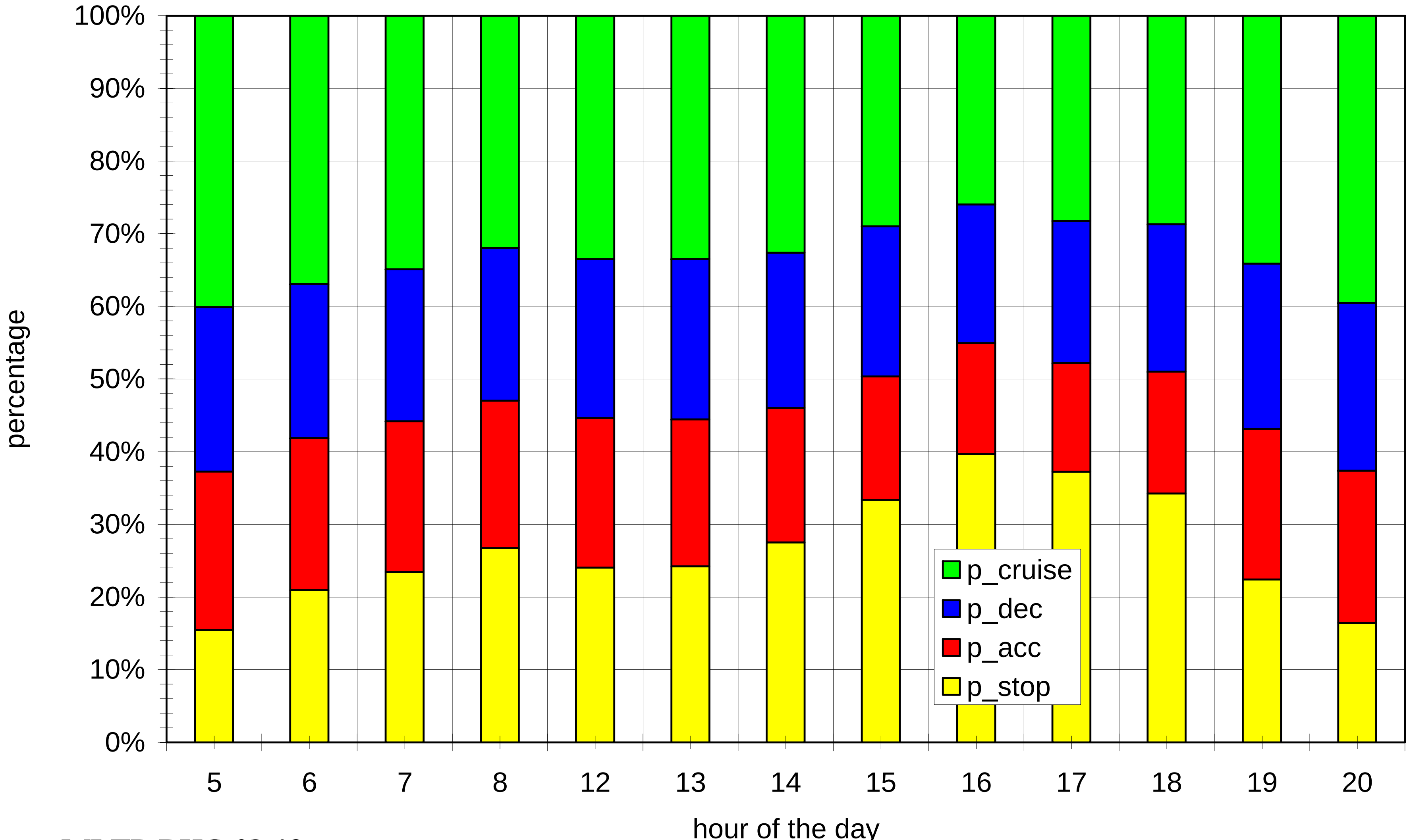

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Figure 11

Influence of time of the day/traffic density

- **Figure 12 shows the corresponding average speed and RPA values as function of the time of the day.**
- **The average speeds vary significantly with the time of the day while the RPA values remain almost on a constant level.**
- **It cannot be concluded that the RPA behaviour in this street is common. If other road types are included, the resulting trend is a decrease of the average RPA values with increasing average speed as could be seen in figure 9.**

Influence of time of the day/traffic density

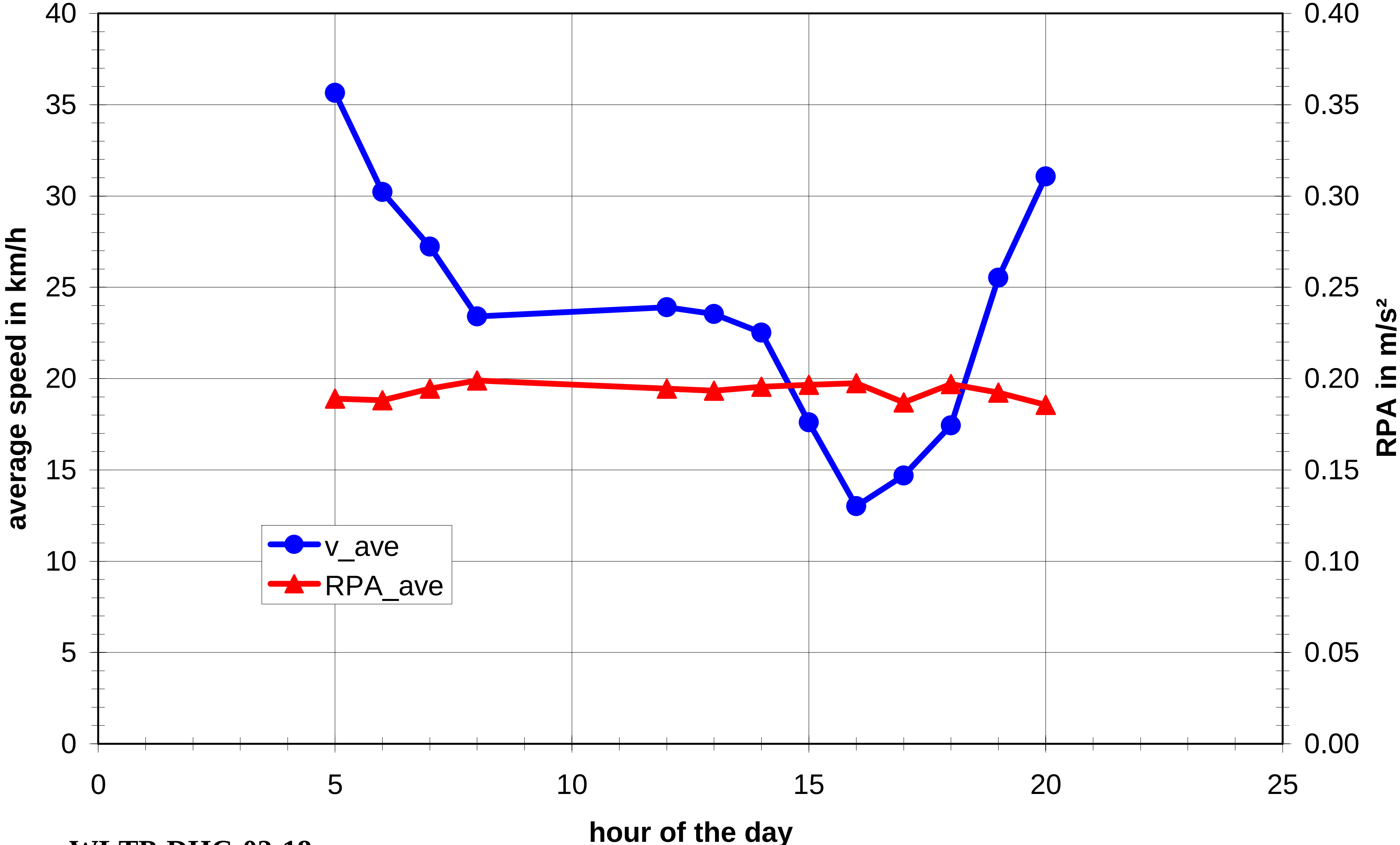

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Figure 12

Influence of time of the day/traffic density

- **In figure 13 the driving phase values from figure 11 and the corresponding average speed values from figure 12 are combined in order to examine possible dependencies.**
- **All 4 driving phases are linear correlated with the average speed.**
- **Stop and cruise phases show the highest correlation and variation ranges.**
- **The variation ranges of acceleration and deceleration phases are significantly lower.**

Influence of time of the day/traffic density

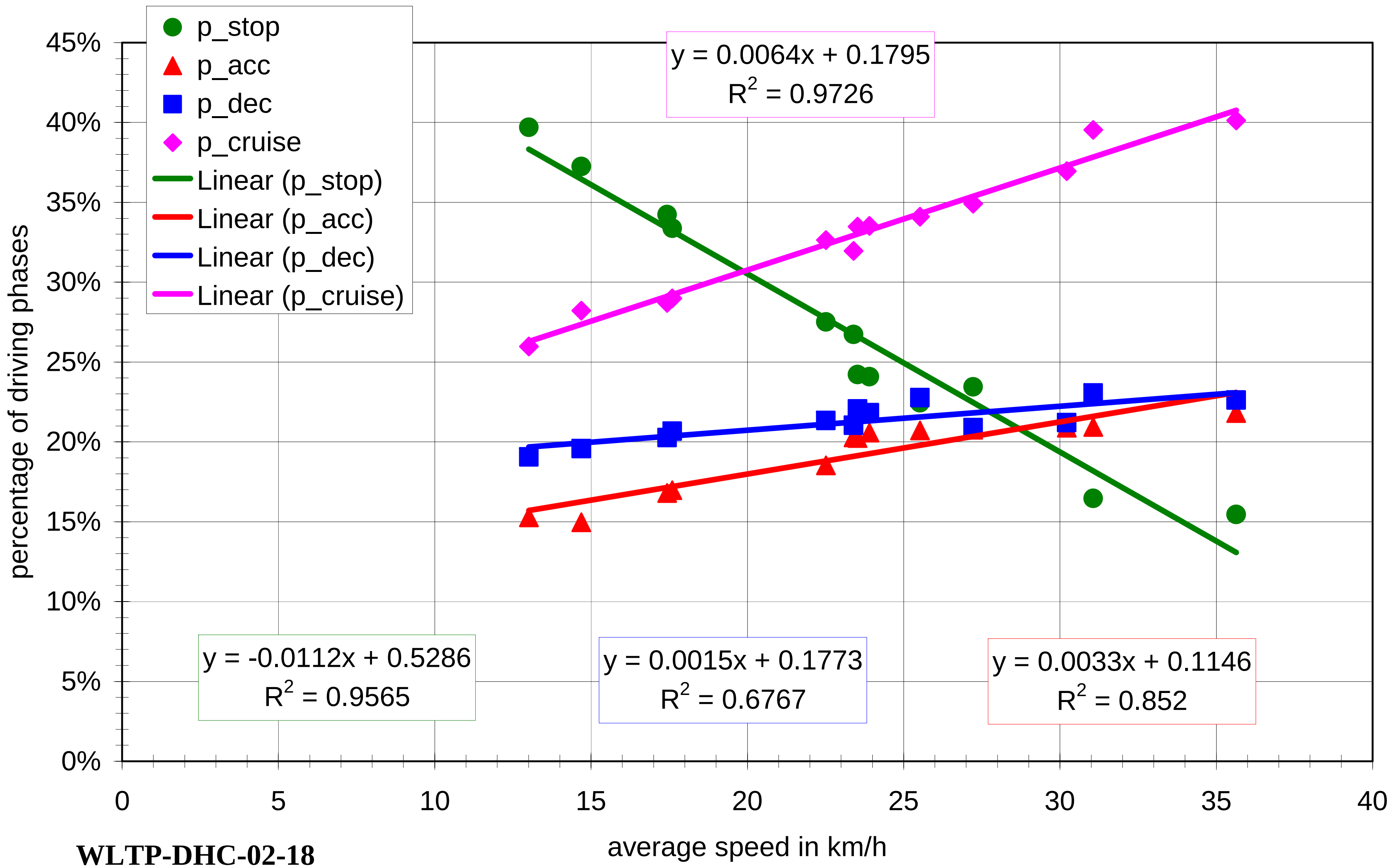

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Figure 13

Influence of time of the day/traffic density

- In addition to the in-use driving behaviour data vehicle speed/traffic density data was also be made available for further analysis as 5 minute intervals over a whole day time period.
- Figure 14 shows an example where the interval pairs in different hours are shown using different symbols.
- This figure clearly shows that the differences at different times of the day are caused by different traffic density values.
- Obviously this is the main influencing parameter together with the speed limit of the road.

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Influence of time of the day/traffic density

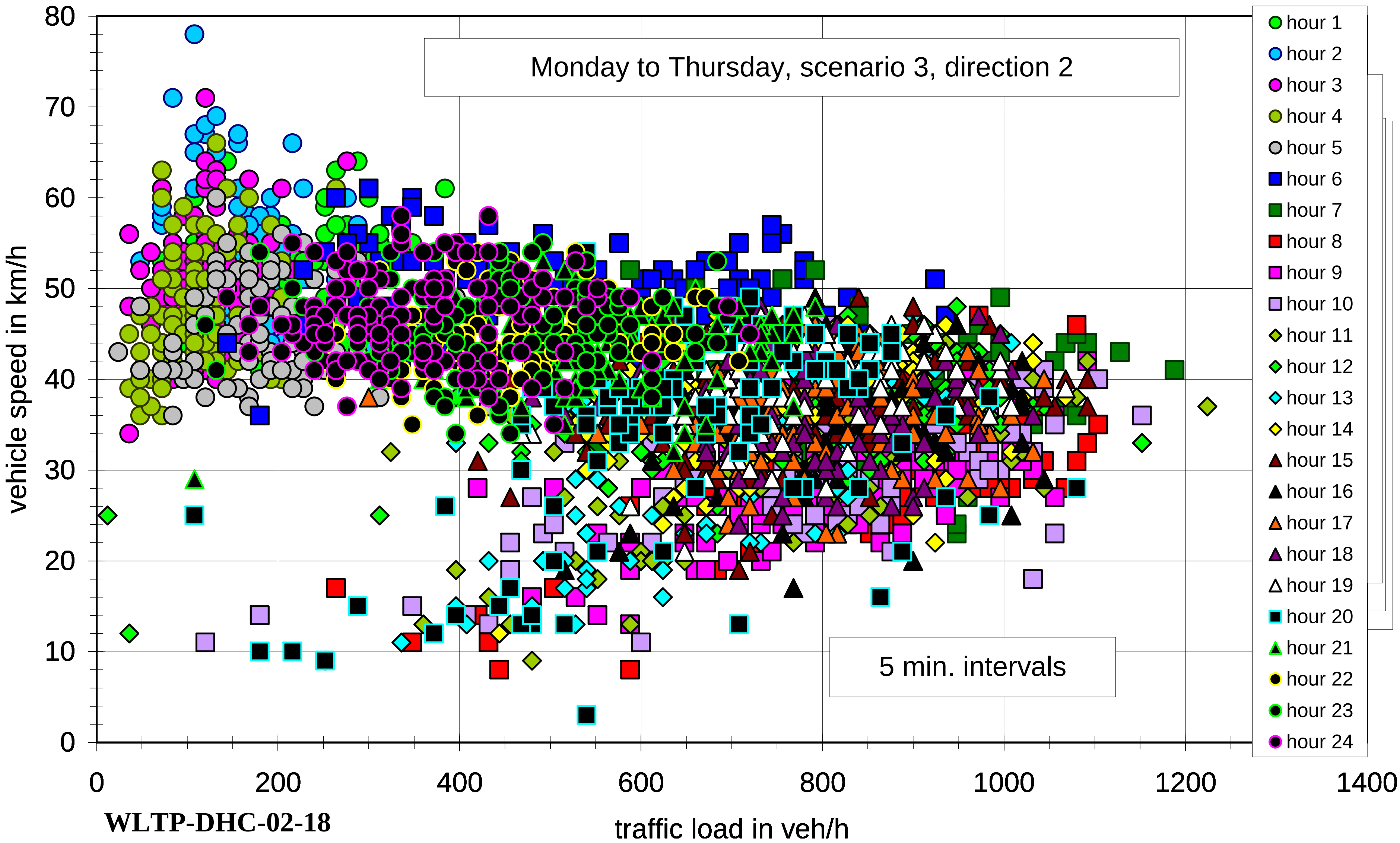

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Figure 14

Rank order of influencing parameters

The in-use driving behaviour is influenced by the following parameters:

1. **Speed limit, traffic density and composition,**
2. **Individual driving behaviour,**
3. **Area and road type,**
4. **Distances between junctions and traffic control measures at junctions,**
5. **Power to mass ratio of the vehicle.**

4. Duration distributions

- The distributions of short trip durations are shown in figure 15.
- Motorway short trips cannot be shown, because start and end phases are assigned to rural or urban operation.
- But one could include mixed trips (e.g. rural_mot, urban_mot, see figure 16)
- The question is, how to apply the proposed approach to choose appropriate short trips (duration equally spread over the whole distribution) to such steep curves as shown in the figures.

Distributions of short trip durations

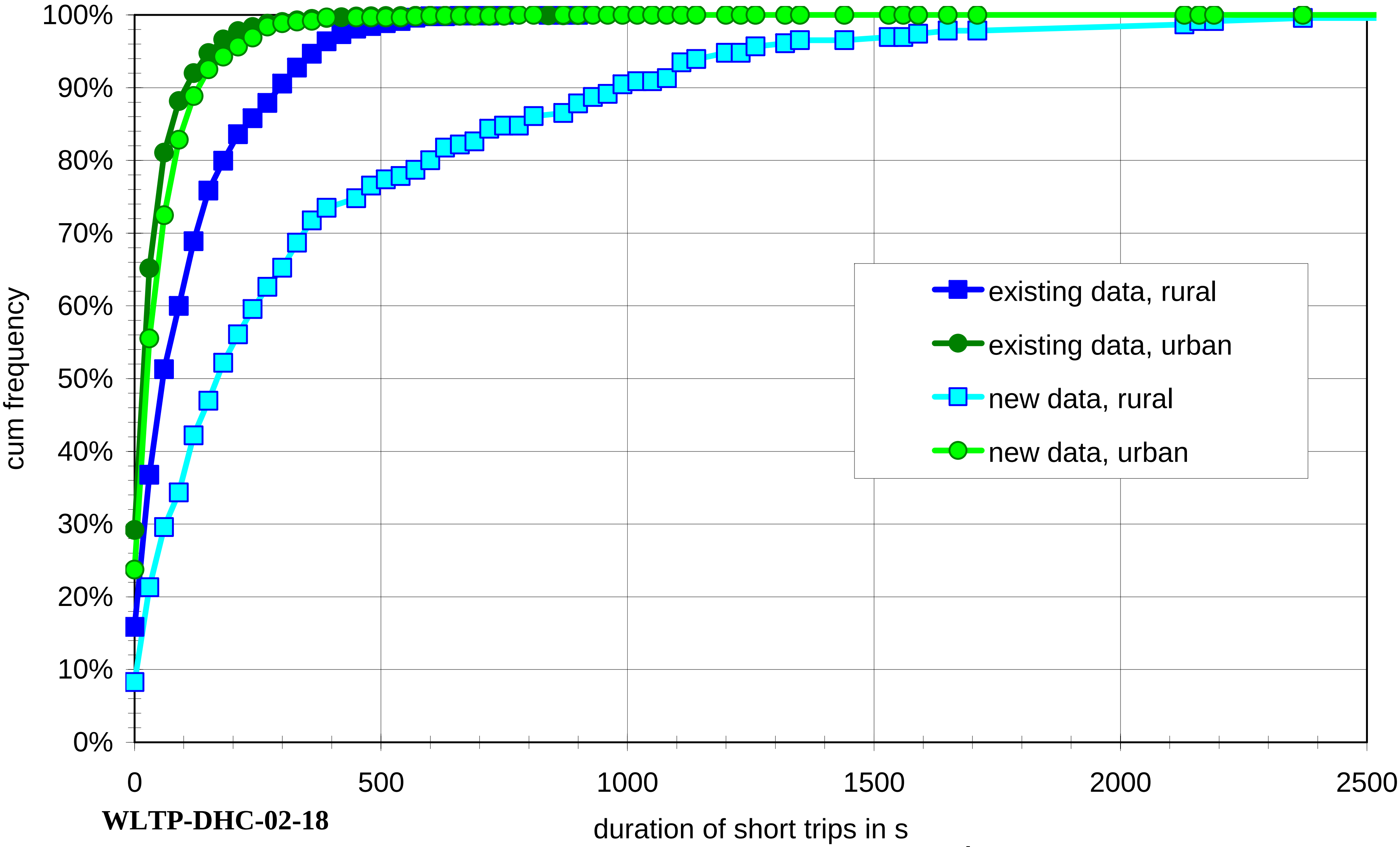

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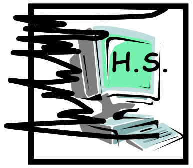
Figure 15

Distributions of short trip durations



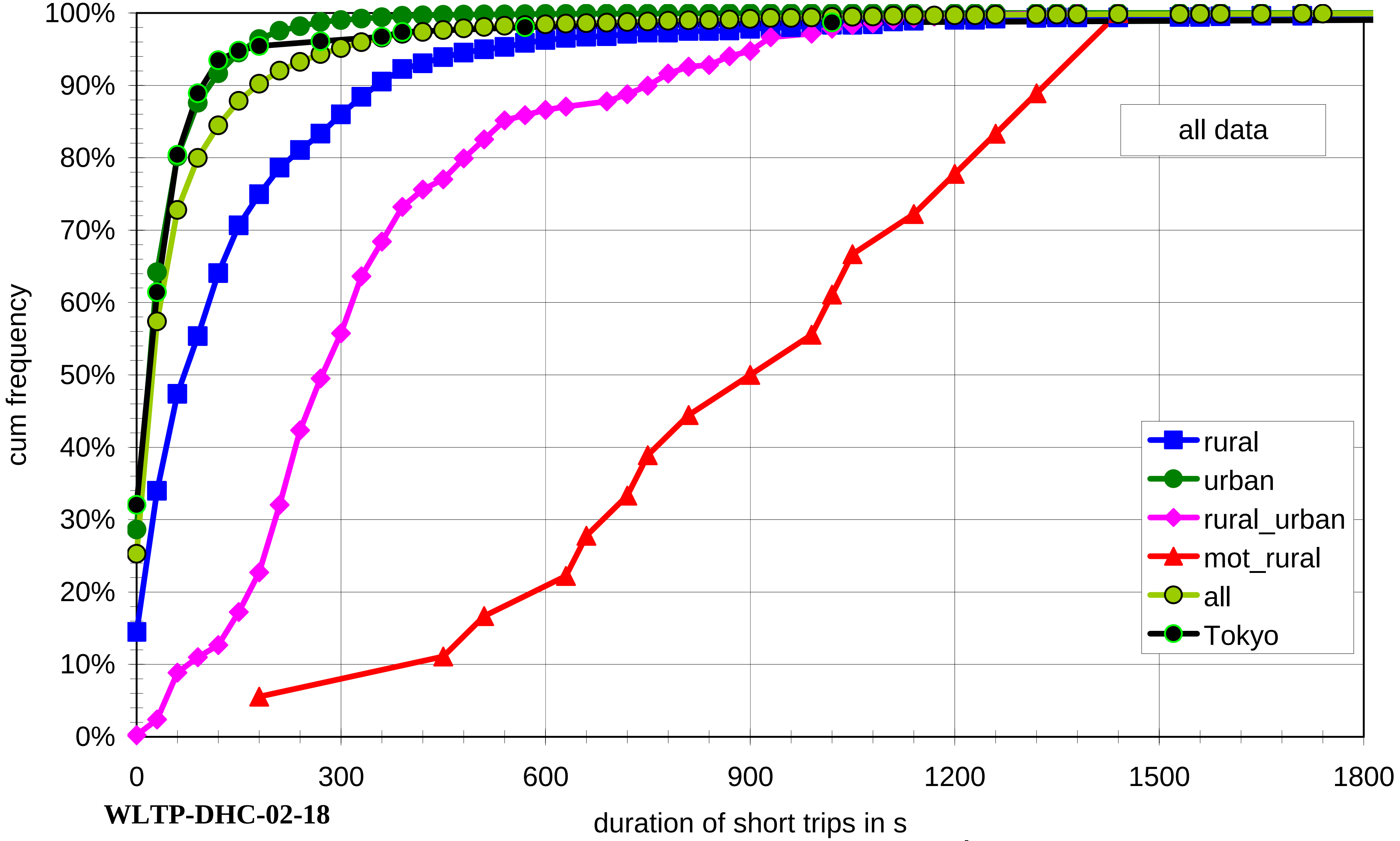


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Figure 16

Duration distributions

- Figure 17 shows corresponding distributions of stop phase durations. The short trip duration distributions show insignificant differences between existing and new data for urban operation but significant differences for rural operation. The new data consists of a significant part of longer short trips than the existing data.
- Differences for the stop duration distributions between existing and new data as well as between urban and rural operation are insignificant.
- The question remains, how to apply the proposed approach to choose appropriate idle time sections to such steep curves as shown in the figure.

Distributions of stop phase durations

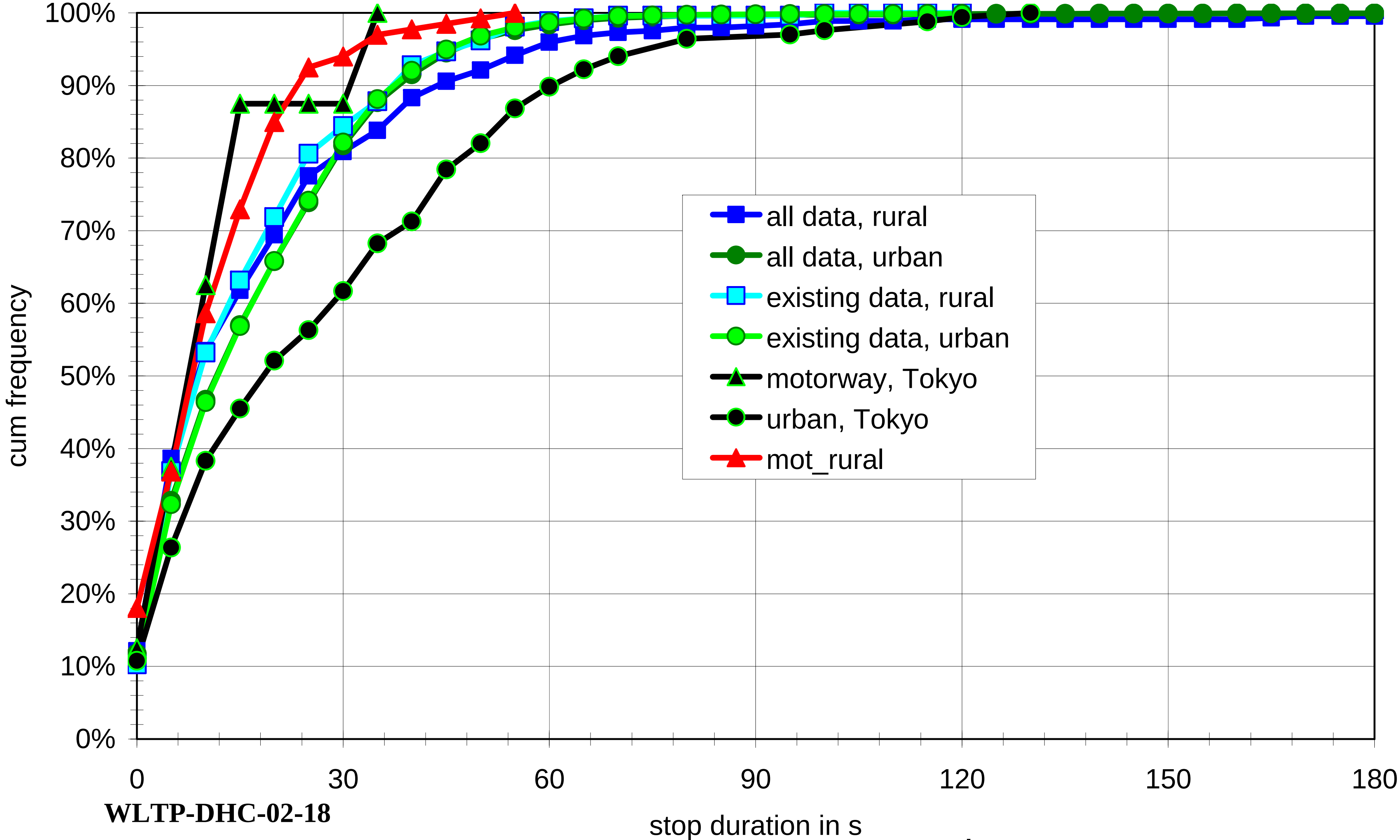

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Figure 17

Equal duration per cycle part

WMTC approach:

- **cycle length = 600 s per part (urban, rural, motorway).**
- **Results of in-use data analysis for urban, rural, motorway for percentage of idle (stop) time on total driving time:**
  - **Urban: 26%, equals 156 s,**
  - **Rural: 3%, equals 18 s,**
  - **Motorway: 1%, equals 6 s**

This means for the urban part:

- **10 short trips (140 s, 80 s, 60 s, 45 s, 25 s, 15 s, 10 s, 10 s, 10 s, see figure 18) result in a total driving time of 430 s, which is pretty close to the required 444 s.**

Distribution of short trip duration

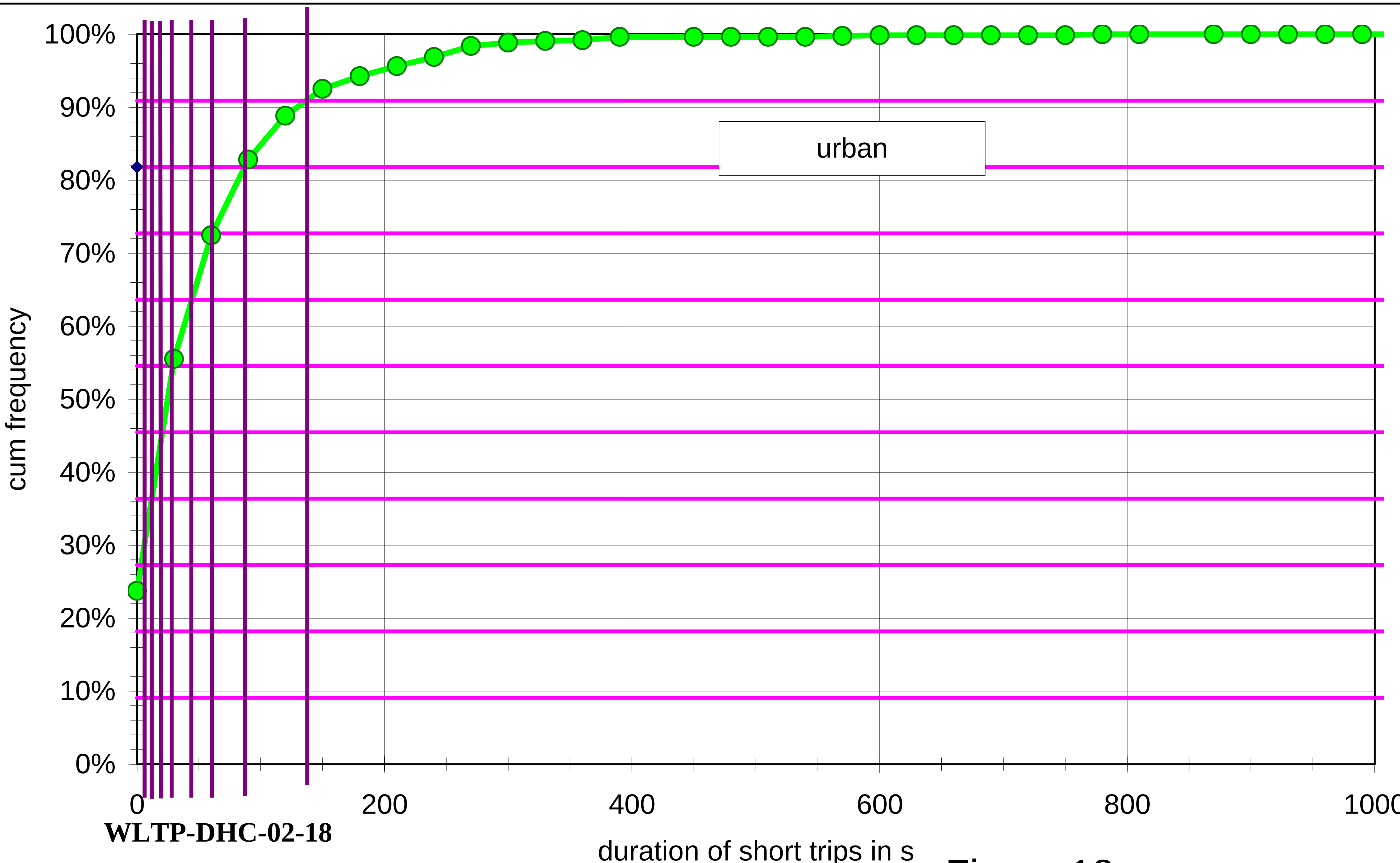

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Figure 18

Stop phase frequency distributions

- The same approach applied to the corresponding stop duration frequency distribution shown in figure 19 requires 11 stop sections which together add up to 174 s, which is also not too far away from the target idling time.

Distribution of stop phase duration

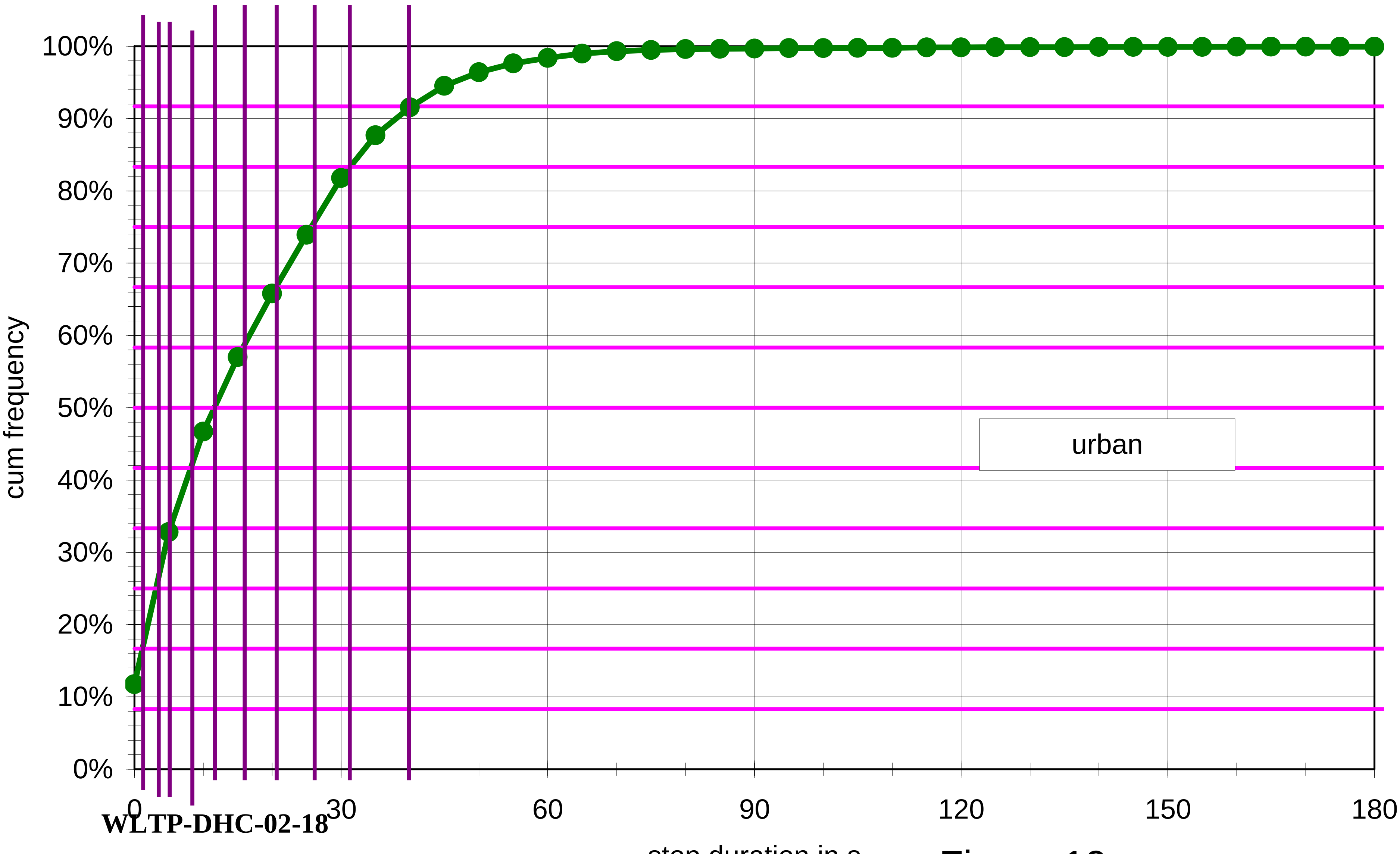

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Figure 19

Equal duration per cycle part

Rural part:

- ➢ **Urban: 26%, equals 156 s,**
- ➢ **Rural: 3%, equals 18 s,**
- ➢ **Motorway: 1%, equals 6 s**

- **The trip percentage of 97% or 582 s cannot be fulfilled (see figure 20). 2 short trips result in a driving time of 405 s, 3 short trips in a driving time of 720 s.**
- **The stop percentage of 3% or 18 s for rural can not be fulfilled (see figure 21). 2 short trips would result in an idling time of 32 s, 3 short trips would result in an idling time of 52 s.**

Distributions of short trip duration

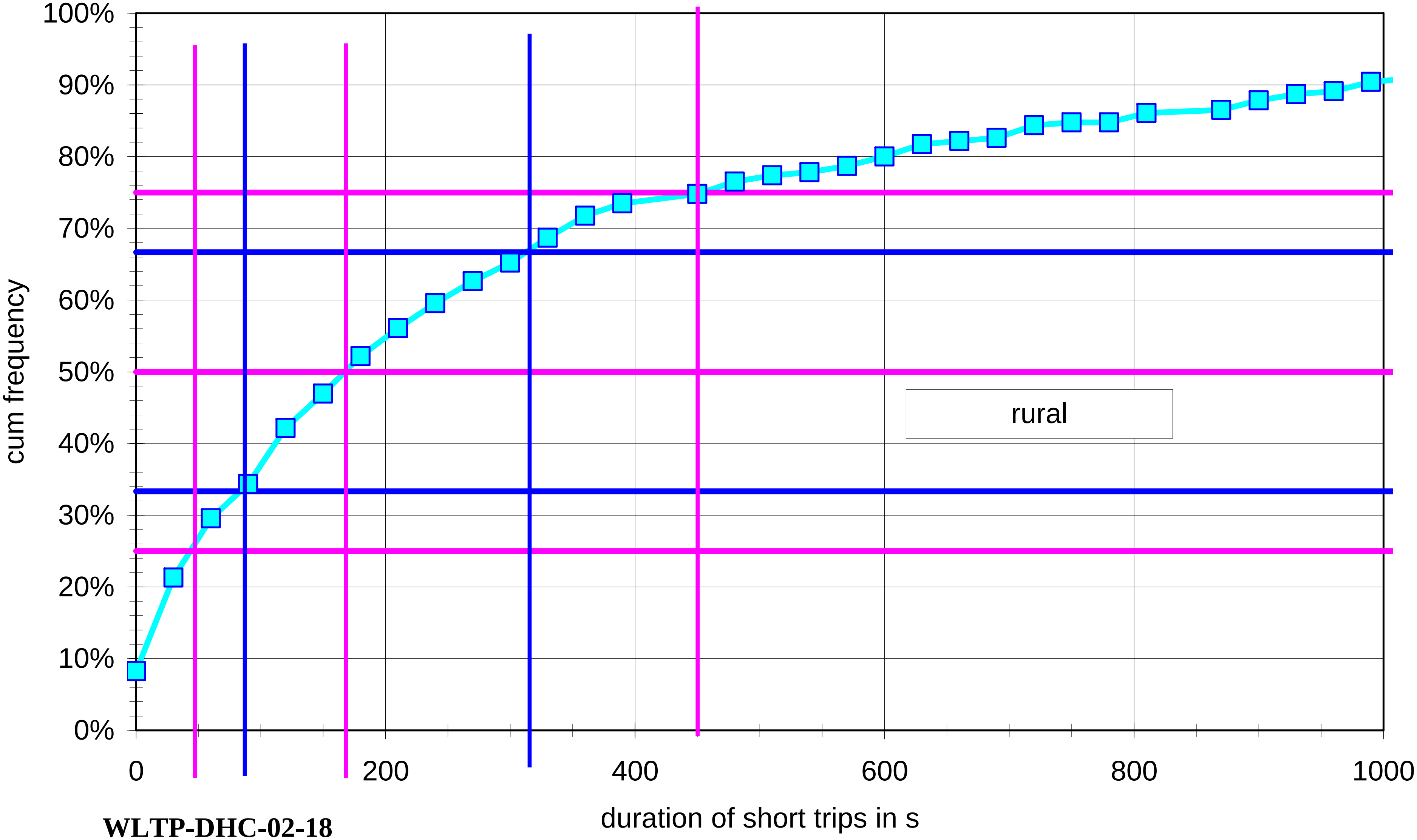

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Figure 20

Distributions of stop phase durations

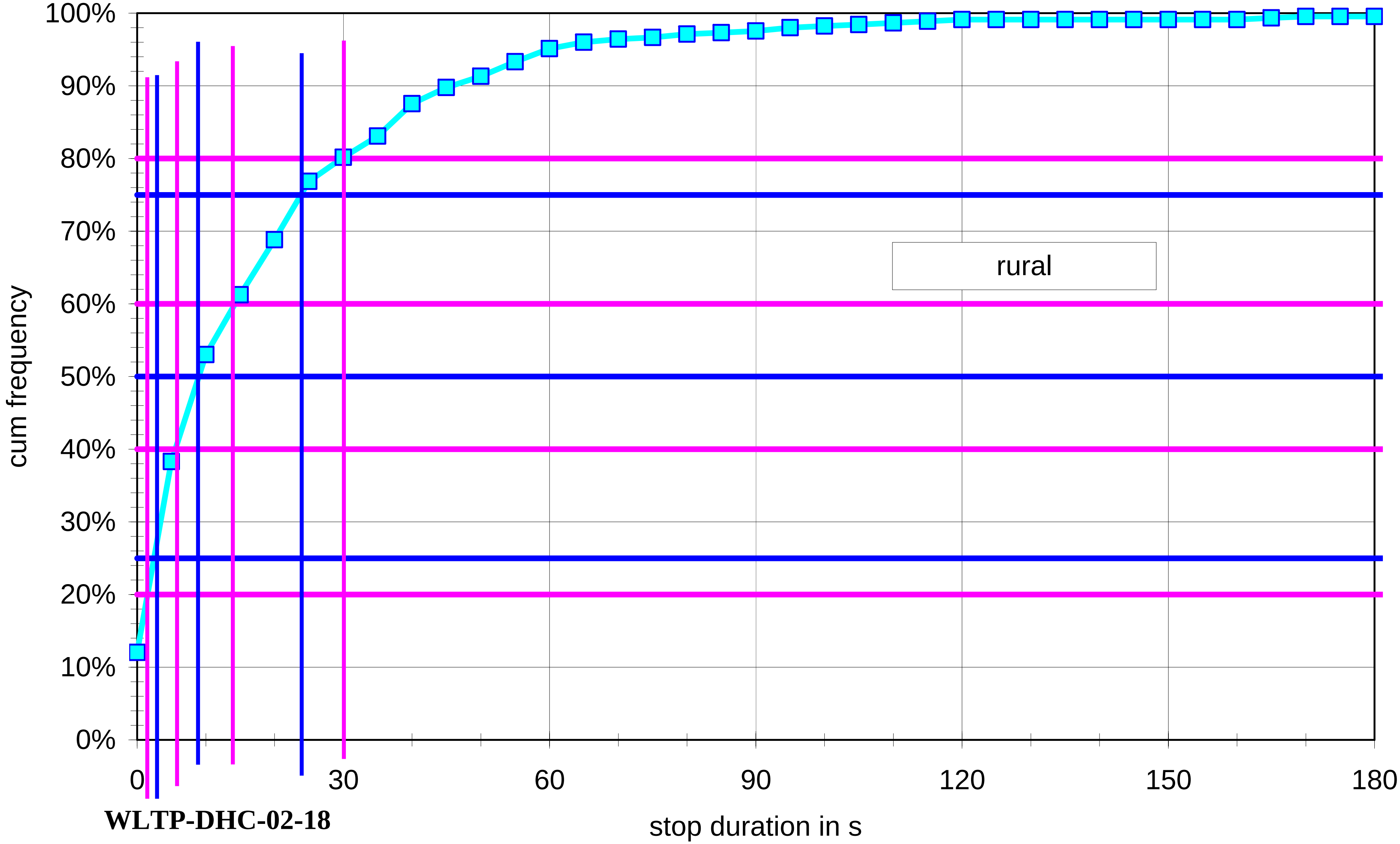

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Figure 21

Cycle part distances according to mileage percentages

Alternative approach:

- The distances of the cycle parts are chosen according to the total mileage percentage.
- Taking Germany as an example because the percentages are known:
  - ➢ Motorway 31%,
  - ➢ Rural 42%,
  - ➢ Urban 27%
- This approach has the advantage that the final result can be calculated without weighting factors.
- The stop time percentages are the same as for the previous example.

Cycle part distances according to mileage percentages

- **In addition the average speeds and the number of short trips per km should be known.**
- **A corresponding analysis leads to the following results:**
  - **Motorway** **100 km/h, 0,1 short trip per km,**
  - **Rural** **68 km/h, 0,4 short trips per km,**
  - **Urban** **26,5 km/h, 1,9 short trips per km**
- **The original average speed for motorways was 117 km/h. This value is lowered to 100 km/h in order to consider that nearly all other regions have speed limits on motorways.**

Cycle part distances according to mileage percentages

- **Such an analysis would lead to the following results for the current available data:**

road category / cycle part	mileage percentage	average speed in km/h	short trip duration in s	stop time duration in s	total duration in s	distance in km	average number of short trips per km	number of short trips
motorway	31%	100	255	3	258	7.1	0.1	1
rural	42%	68	509	25	534	9.6	0.4	4
urban	27%	26.5	840	168	1008	6.2	1.9	12
		sum	**1604**	**196**	**1800**	**22.9**		

- **12 short trips for the urban part, chosen from the short trip duration frequency distribution would result in a driving time of 515 s (see figure 22) which is far too low compared to the above shown table.**

Distributions of short trip duration

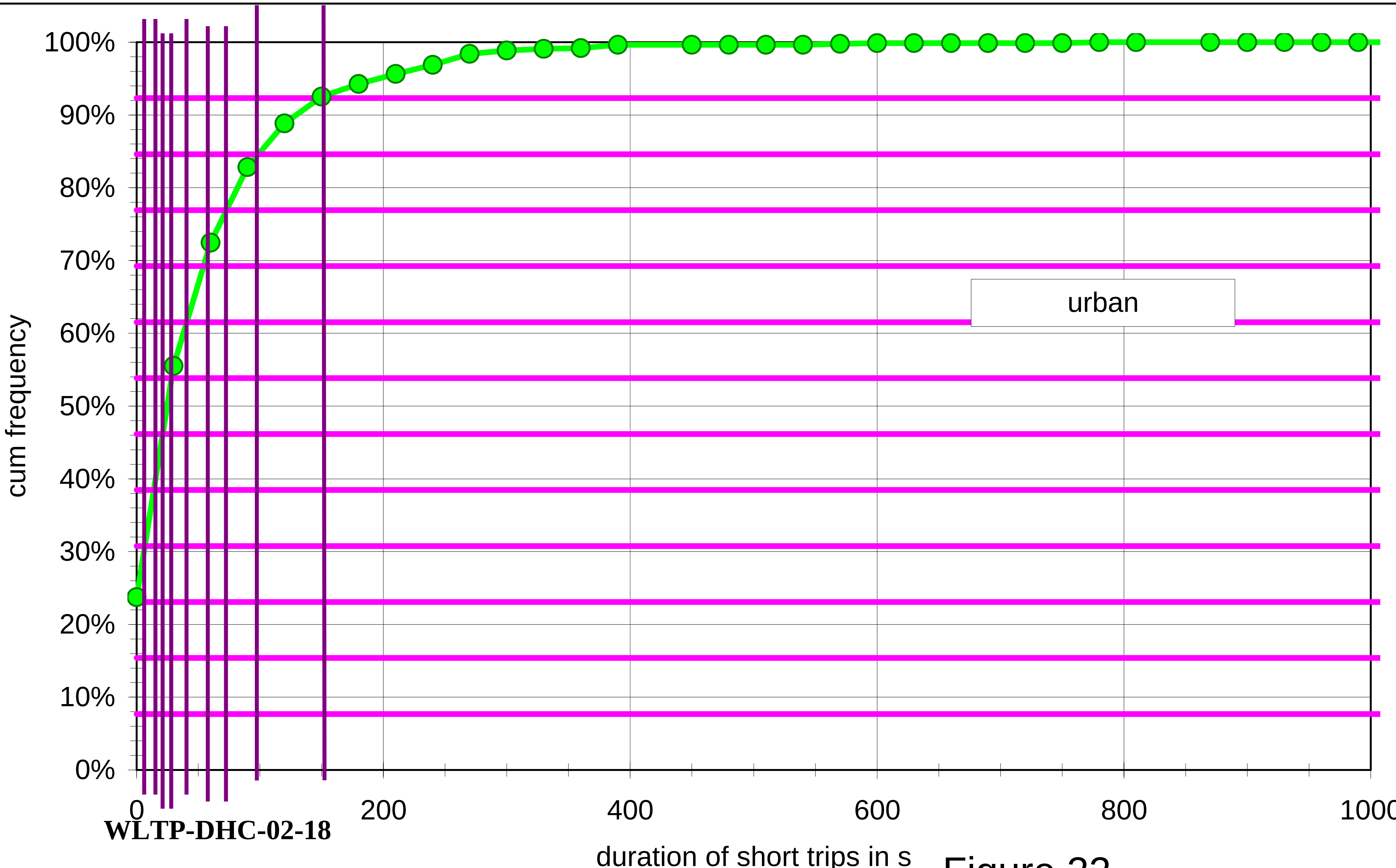

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Figure 22

Conclusions

- **With the proposed approach for the selection of short trips and idle time sections it is not possible to match the results with average speeds and idle time percentages.**
- **In either case one has to make compromises in order to assure practicability and cost efficiency.**

References

[1] Investigations on Improving the Method of Noise Measurement for Powered Vehicles, by order of the German Environment Agency, December 1998

[2] Analysis of in-use driving behaviour measurement results in an urban main street (Berlin, Leipziger Straße) with respect to noise and exhaust emissions, performed within the frame of the research project „IQmobility“, by order of the city of Berlin, March 2008.