Working paper number WLTP-DHC-03-03

Application of the development approach described in WLTP-DHC-02-05 on ACEA's EU database

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Introduction

- **The methodology to develop the WLTP drive cycle is described in WLTP-DHC-02-05 (30.10.2009).**
- **This methodology was developed and agreed following a full discussion at the 1. DHC subgroup meeting (held in September 2009).**
- **The work comprises four work streams:**

  a) In-use data collection

  b) Determination of weighting factors

  c) Data analysis and drive cycle development

  d) Validation/confirmation testing

Introduction

- **Work streams c and d will be an iterative process; validation/confirmation testing will undoubtedly result in modifications being made to the early versions of the drive cycle until the final drive cycle is agreed.**

Method for developing drive cycle

- **The WLTC drive cycle will be developed based on combination of collected in-use data and suitable weighting factors.**
- **It is proposed to follow the method used in developing the worldwide harmonized motorcycle emissions certification procedure (WMTC), i.e., aggregating in-use data according to road type (urban, rural and motorway) and processing data pertaining to these road types separately in order to produce drive cycles phases that are road type specific.**
- **These drive cycle phases will then be combined to yield the final drive cycle.**

Initial data analysis

- **Raw in-use data will initially be analysed according to road type (urban, rural and motorway) and region (e.g. Japan, Europe, India, etc), i.e. all urban data from Japan will be analysed independently to all urban data from India.**
- **A global unified distribution will be developed for each road type by combining the appropriate regional in-use data with the appropriate weighting factors.**
- **Initially, it is proposed to generate unified speed–acceleration distributions and to use these to compare the representativeness of the drive cycle phases.**

Determination of test cycle length

- **For WLTC, it is proposed to follow the WMTC method and develop a drive cycle that contains individual phases relating to urban, rural and motorway driving.**
- **As a first step, it will be necessary to decide the length/duration of each drive cycle phase.**
- **The number of short trips and idle periods in each section will be determined by the average short trip and idle period durations, as determined from analysis of the in-use data.**

Development of the drive cycle

The first step will be to identify short trips and idle periods that will be considered for the drive cycle.

- Cumulative frequency graphs based on the short trip and idle databases will be derived and from these it will be possible to select short trips and idle periods of suitable length (distance/time) to be included in the drive cycle phase.
- It is agreed that all drive cycle phases will begin and end with an idle period.

Development of the drive cycle

The 2. step is as follows:

- **Selected short trips and idle periods will be combined to develop candidate drive cycle phases.**
- **The speed–acceleration distributions of these candidate drive cycle phases will be compared with the relevant unified speed–acceleration distributions using a chi-squared analysis.**
- **The final drive cycle phase will be chosen as the combination of short trip and idle periods that minimises the difference between the speed–acceleration distributions of the drive cycle phase and the unified distribution.**

Composition of ACEA's EU database

- **Up to end of February 2010 the database consisted of data from Graz (2007), Aachen (2005), Berlin (2007), Malmö, Naples (2002) and vehicle manufacturers (from 2004 on).**
- **By the end of February additional in-use driving behaviour data from Switzerland was delivered, collected in 2008 from customer vehicles.**
- **This data contains GPS information as well as information about the road type and speed limit.**
- **This data was added to the existing database and previous analysis steps were repeated in order to show the consequences on the database and candidate cycle.**

Composition of EU database

- **The driving time, stop percentage and average speeds are shown in the following table:**

status of database	road category	time in h	stop time	distance in km	time share	distance share	stop percentage	average speed in km/h
without CH	motorway	42.7	0.5	4,391	14.7%	36.4%	1.1%	102.9
	rural	55.4	3.3	3,121	19.1%	25.9%	6.0%	56.3
	urban	192.3	44.8	4,535	66.2%	37.6%	23.3%	23.6
	sum	**290.4**	**48.6**	**12,047**	**100.0%**	**100.0%**	**16.7%**	
with CH	motorway	216.1	2.9	21,527	22.3%	48.3%	1.3%	99.6
	rural	142.0	7.9	8,029	14.7%	18.0%	5.6%	56.5
	urban	610.4	155.6	15,025	63.0%	33.7%	25.5%	24.6
	sum	**968.5**	**166.4**	**44,580**	**100.0%**	**100.0%**	**17.2%**	

Table 1

Vehicle speed distributions

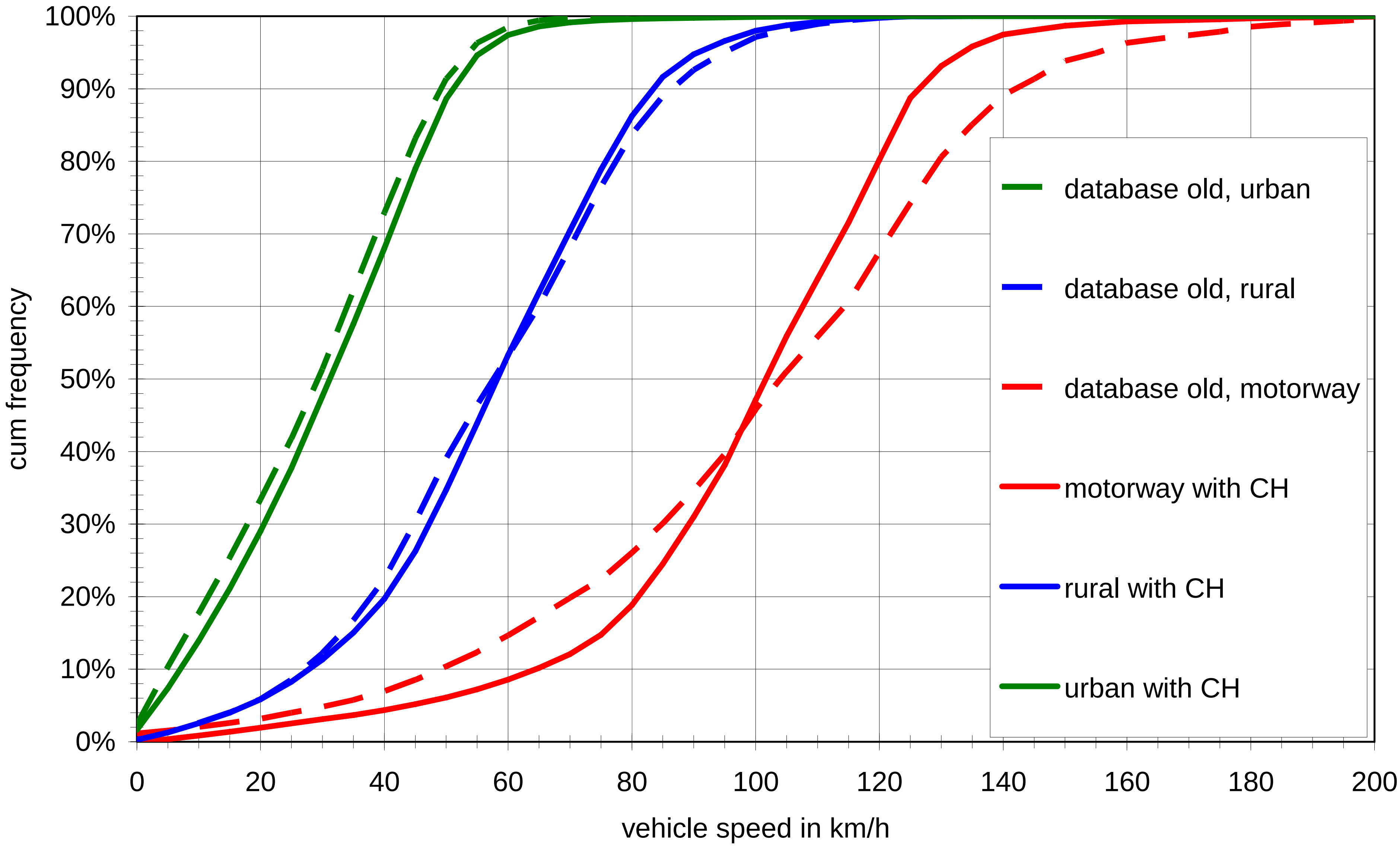

Figure 1

RPA vs average speed

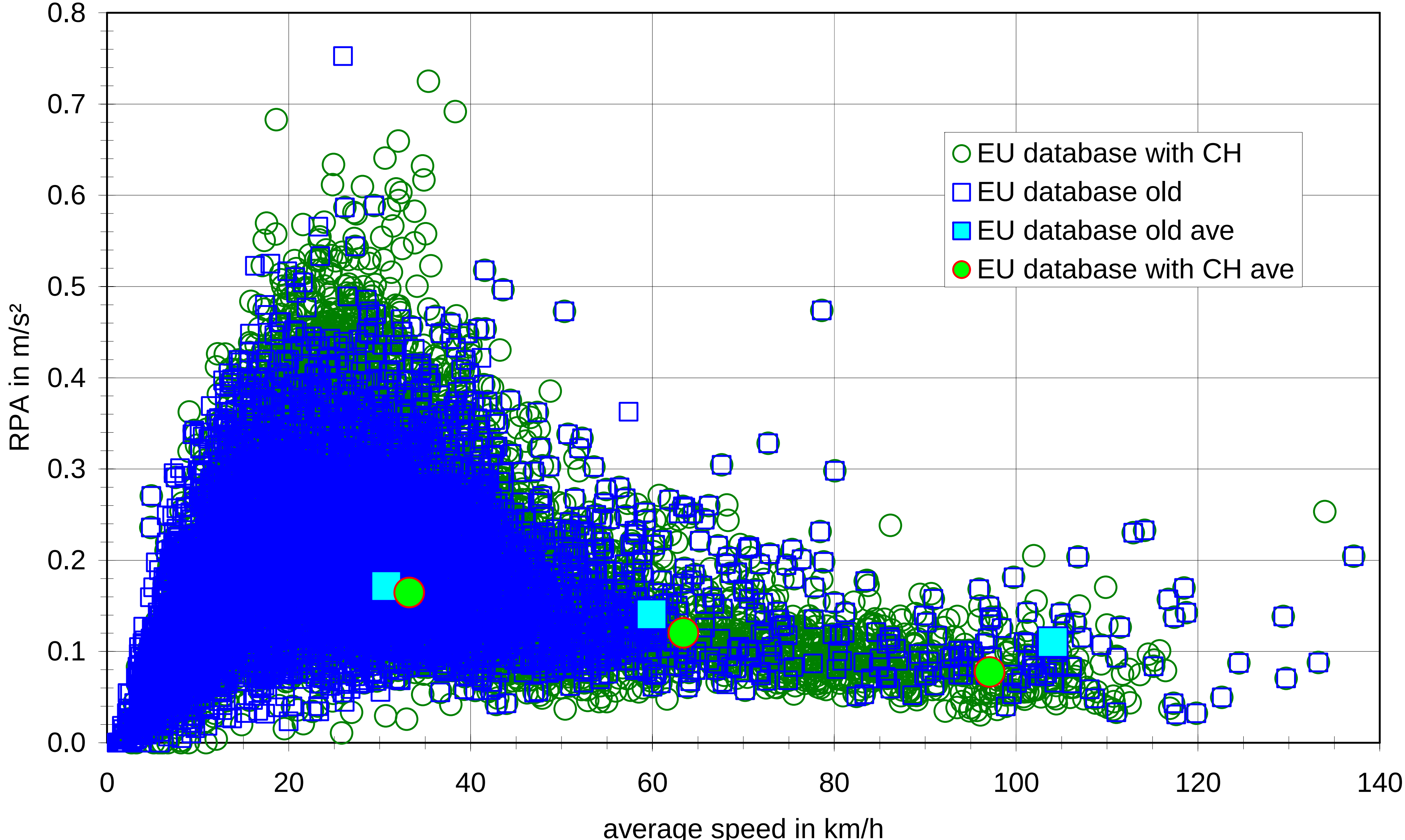

Figure 2a

RPA vs average speed

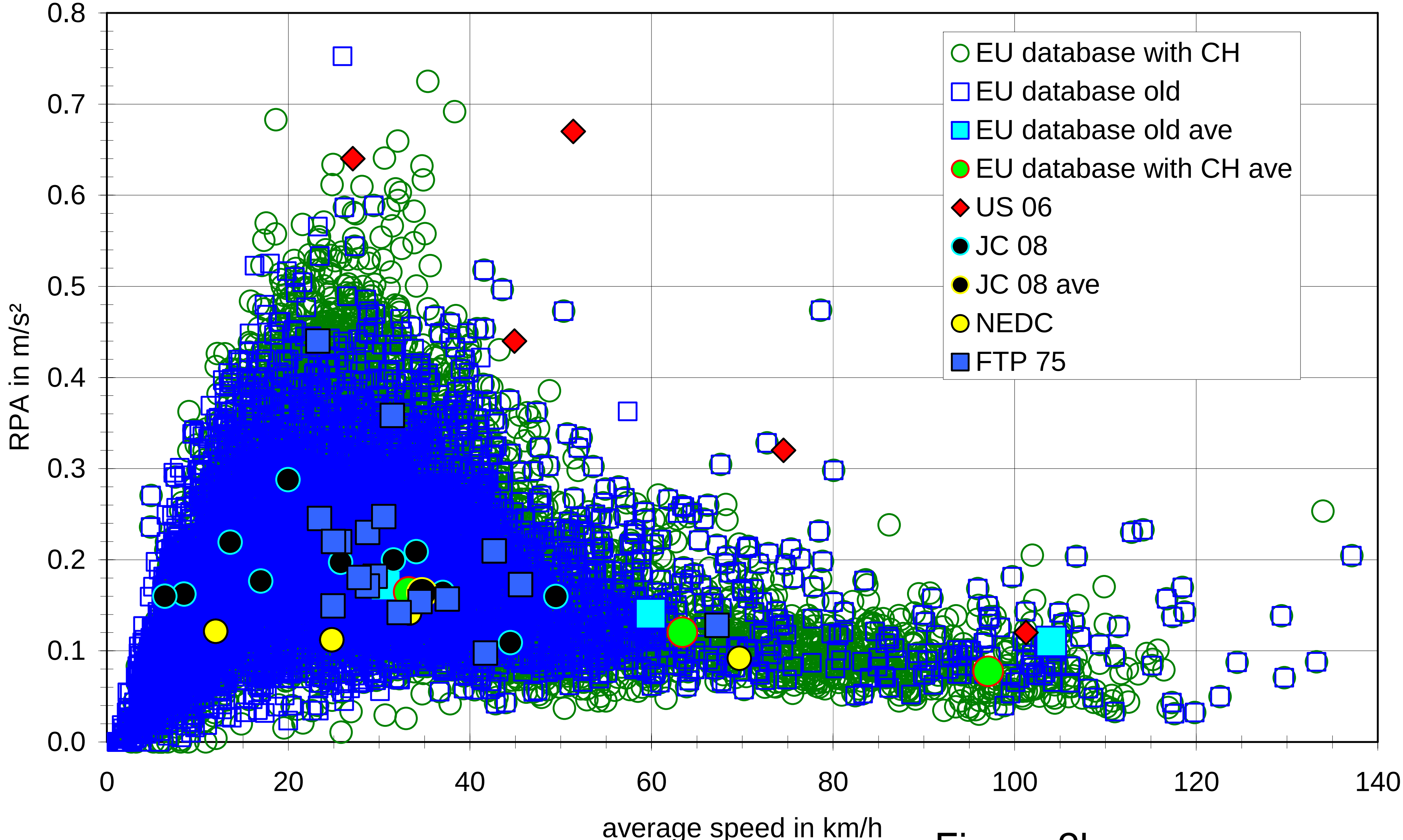

Figure 2b

Composition of EU database

- The following numbers of short trips could be used for the cycle development:

without / with CH

- Motorway: 138 / 761,
- Rural 565 / 1641,
- Urban: 6869 / 21166.

- Average stop phase (idling time) duration:
  - Urban 19 s / 24 s,
  - Rural 22 s / 24 s,
  - Motorway 19 s / 26 s.

Application on ACEA database, 1. step

- **Percentage of stop phases:**

  without / with CH

  - **Urban 23,3% / 25,5%,**
  - **Rural 6,0% / 5,6%,**
  - **Motorway 1,1% / 1,3%.**

Application on ACEA database, 1. step

- **Setting the subcycle duration to 600 s results in the following number of stops/total idling time/driving time:**

status of database	road category	cycle length	stop phases	stop time	number of stops	drive time	v_ave short trips
		s		s		s	km/h
without CH	motorway	600	1.1%	7	2	593	104.1
	rural	600	6.0%	36	2	564	59.9
	urban	600	23.3%	140	7	460	30.7
with CH	motorway	600	1.3%	8	2	592	100.9
	rural	600	5.6%	34	2	566	59.9
	urban	600	25.5%	153	6	447	33.0

Table 2

Application on ACEA database, 1. step

New database

- **Figure 1 shows the stop duration derivation for the new database resulting in 6 stop phases for the urban part.**

Application on ACEA database, 1. step

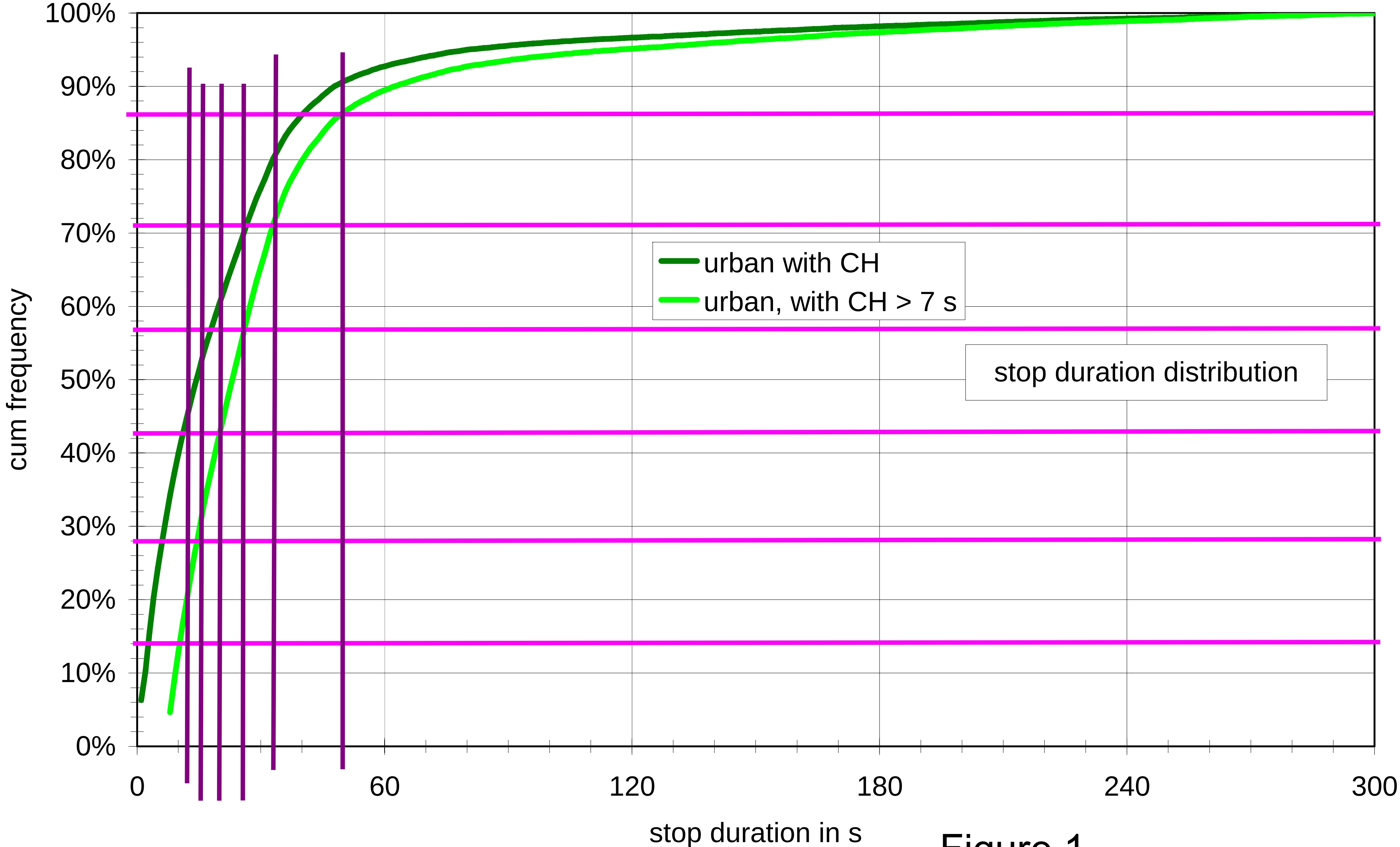

Figure 1

Application on ACEA database, 1. step

- **For the new database including the CH data the above described approach resulted in the following stop phases:**
  - **48 s, 33 s, 26 s, 20 s, 15 s, 11 s.**
- **An alternative approach based on the ratio between the required total stop time (153 s) and the stop time resulting from the original stop time distribution in figure 4 (103 s) led to the following stop phases for the urban part:**
  - **57 s, 40 s, 25 s, 16 s, 9 s, 6 s.**

Application on ACEA database, 1. step

- The length of the 5 short trips for the urban part are derived from the short trip duration distribution using the same approach as for the stop phases (see figure 2).
- The durations of the short trips derived from the original distribution curve sum up to 210 s.
- The driving times for the short trips derived from figure 7 sum up to the required driving time of 447 s, if all short trips below 50 s are disregarded. This results in the following short trip length for the urban part:
  - 143 s, 101 s, 79 s, 67 s, 57 s.

Application on ACEA database, 1. step

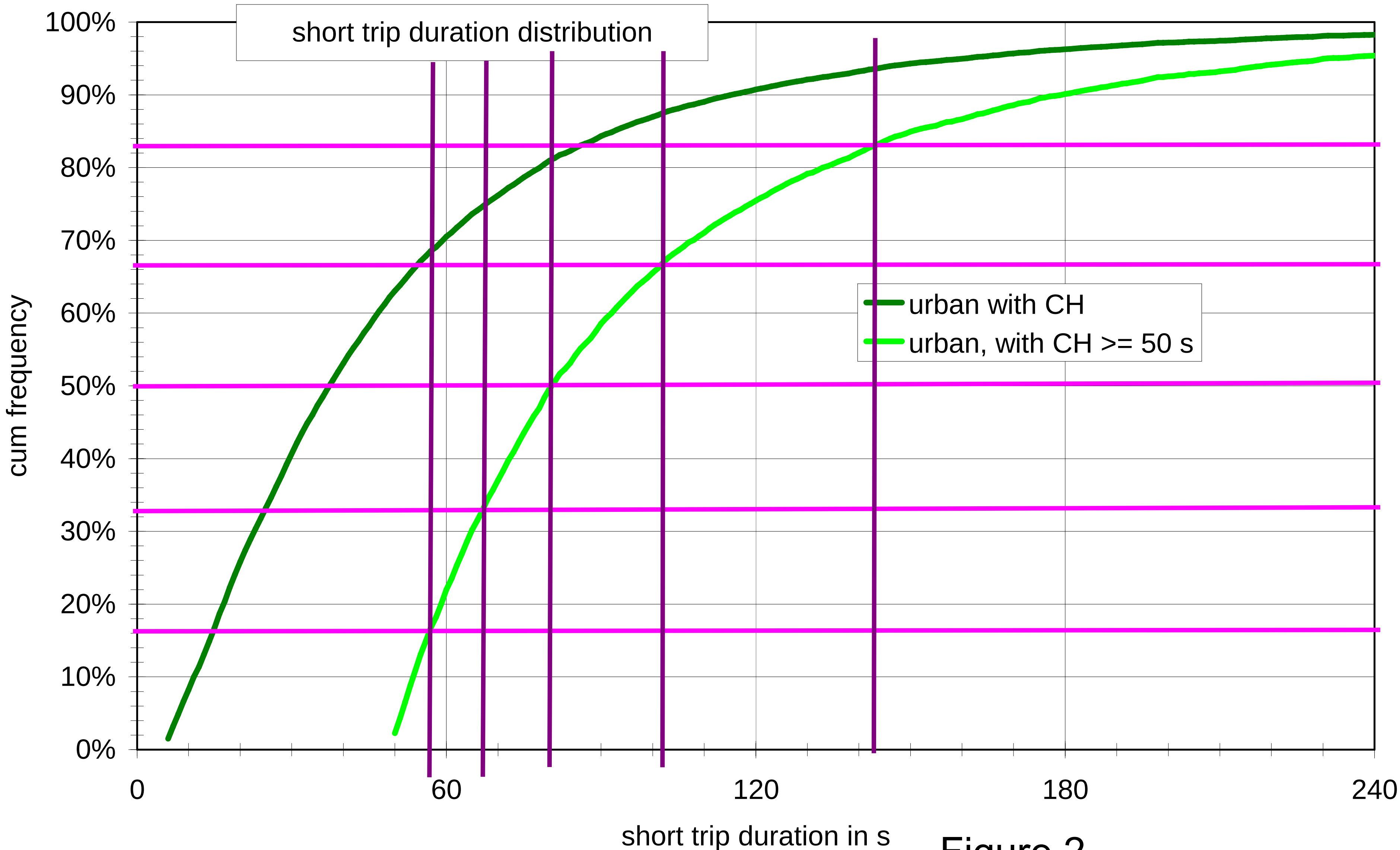

Figure 2

Application on ACEA database, 1. step

- The alternative approach to bring the total duration in line with the requirements (5 short trips, total driving time 447 s) requires that the duration of each trip was multiplied by 447/210.
- This results in the following short trip length for the urban part:
  - 181 s, 113 s, 76 s, 49 s, 28 s.

Application on ACEA database, 2. step

deletion of very short trips				correction by time ratio		
road category	**duration in s**	**number of short trips**	**v_ave in km/h**	**duration in s**	**number of short trips**	**v_ave in km/h**
urban	57	94	29.4	28	195	23.2
urban	67	71	34.1	49	140	28.4
urban	79	88	33.9	76	80	33.6
urban	101	36	33.7	113	19	32.4
urban	143	9	30.6	181	4	36.4
	447	**190,289,088**	**32.3**	**447**	**165,984,000**	**33.2**

Table 3

Application on ACEA database, 2. step

- **In a further step joint frequency distributions of v and v*a, and v and a were calculated for all short trips of the urban part of the database and for each combination of the reduced numbers of short trips in table 3.**
- **The optimal combination was then derived by calculating the sums of the squared differences between the distributions of the database and the candidate short trips for both distributions.**
- **Additionally this method was also applied to the vehicle speed distribution alone.**

Application on ACEA database, 2. step

- **For the rural part only 3 short trips were found in the database with the required duration of around 566 s. Another 15 short trips were borrowed from a US database.**
- **In order to get a broader number of options for the cycle choice combinations of 2 shorter short trips were used whose durations summed up to 566 s.**
- **27 of such combinations were included in the calculations so that the total sample number sums up to 45.**
- **The best fit with the database was found for one of the combination of 2 shorter short trips.**

Application on ACEA database, 2. step

- **As one would expect no motorway short trip was found in the database whose duration is limited to the required 593 s. Therefore longer short trips were chosen and shortened to the required duration.**
- **5 of such combinations were included in the calculations.**

Application on ACEA database, 2. step

- **Figure 3 shows a comparison of the vehicle speed distributions for the different road categories.**
- **Figures 4 to 13 show the joint frequency distributions of vehicle speed (v) and vehicle speed multiplied by the acceleration (v*a) for the database with and without CH data and the candidate cycle separated for the three road types.**

v distributions, database and CC

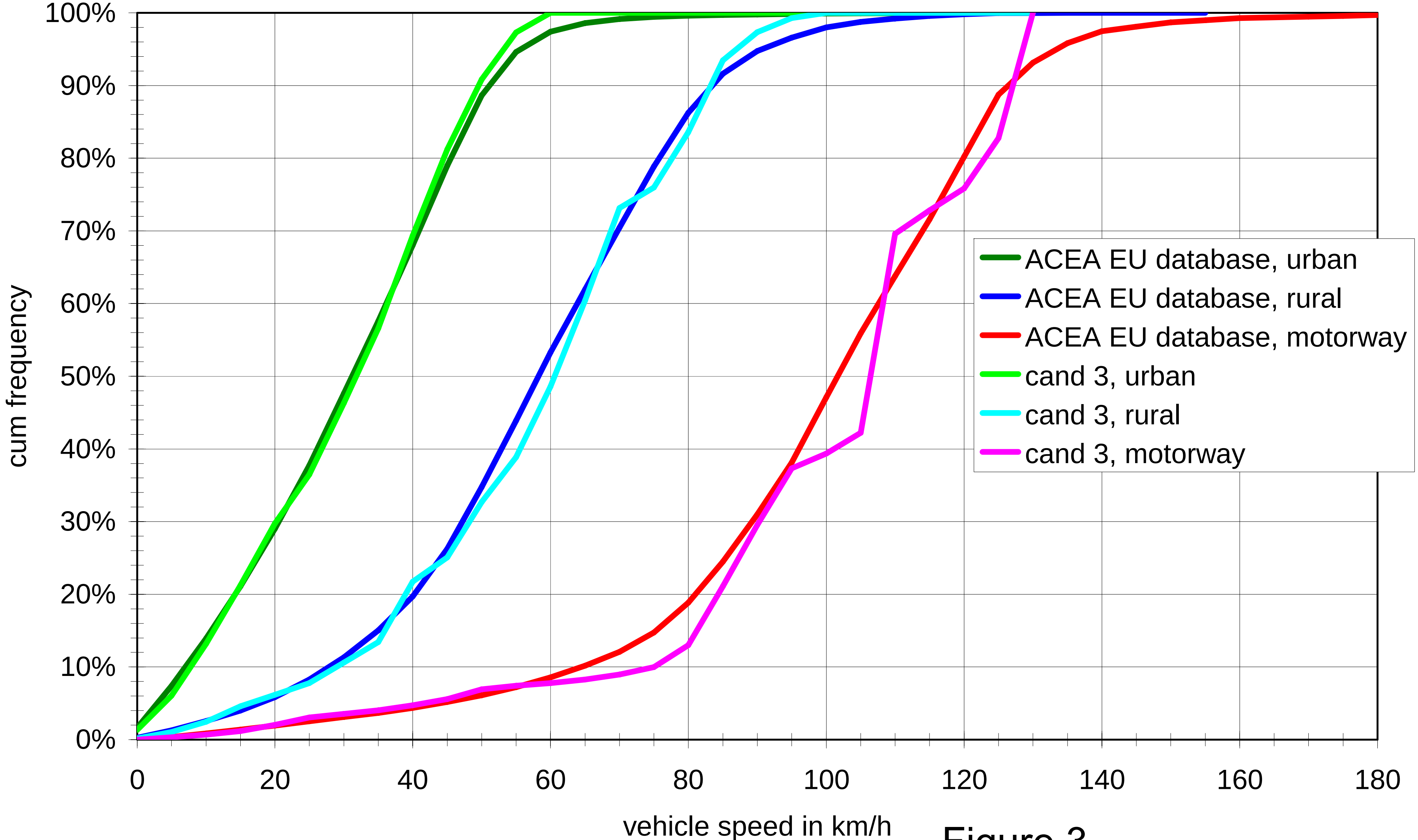

Figure 3

v, v*a, urban database wo CH

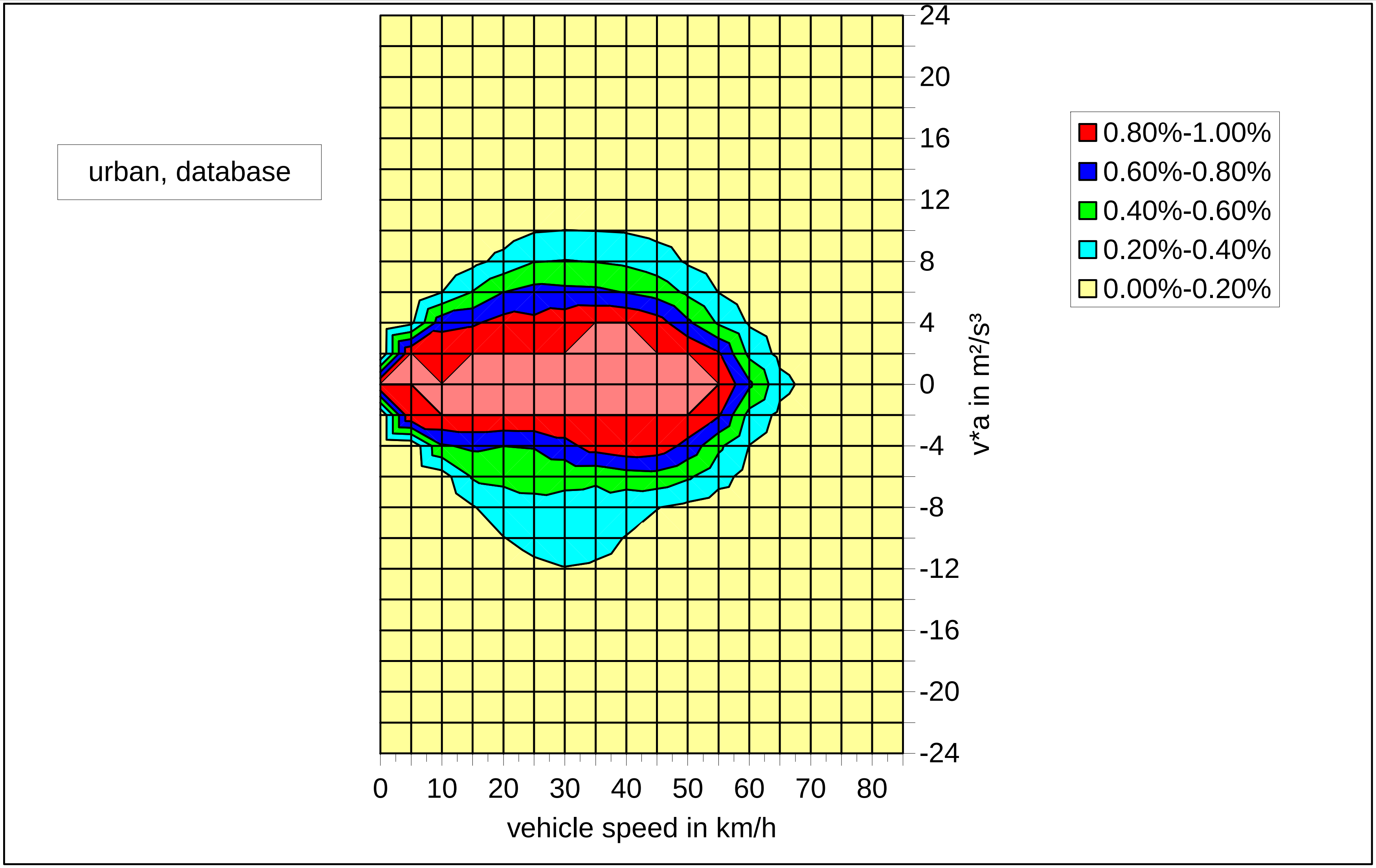

Figure 4

v, v*a, urban database with CH

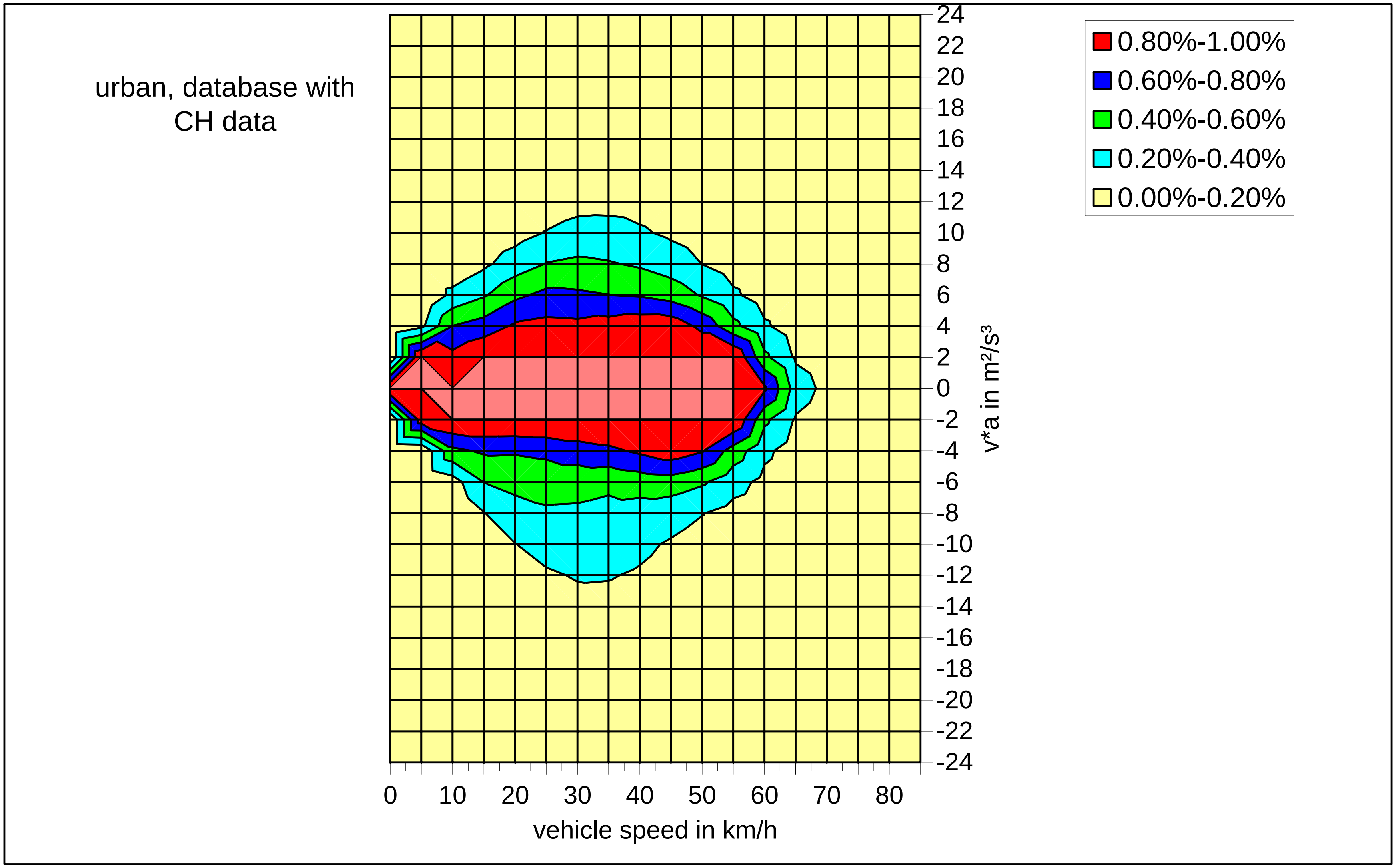

Figure 5

v, v*a, urban CC with CH

WLTP candidate cycle, urban

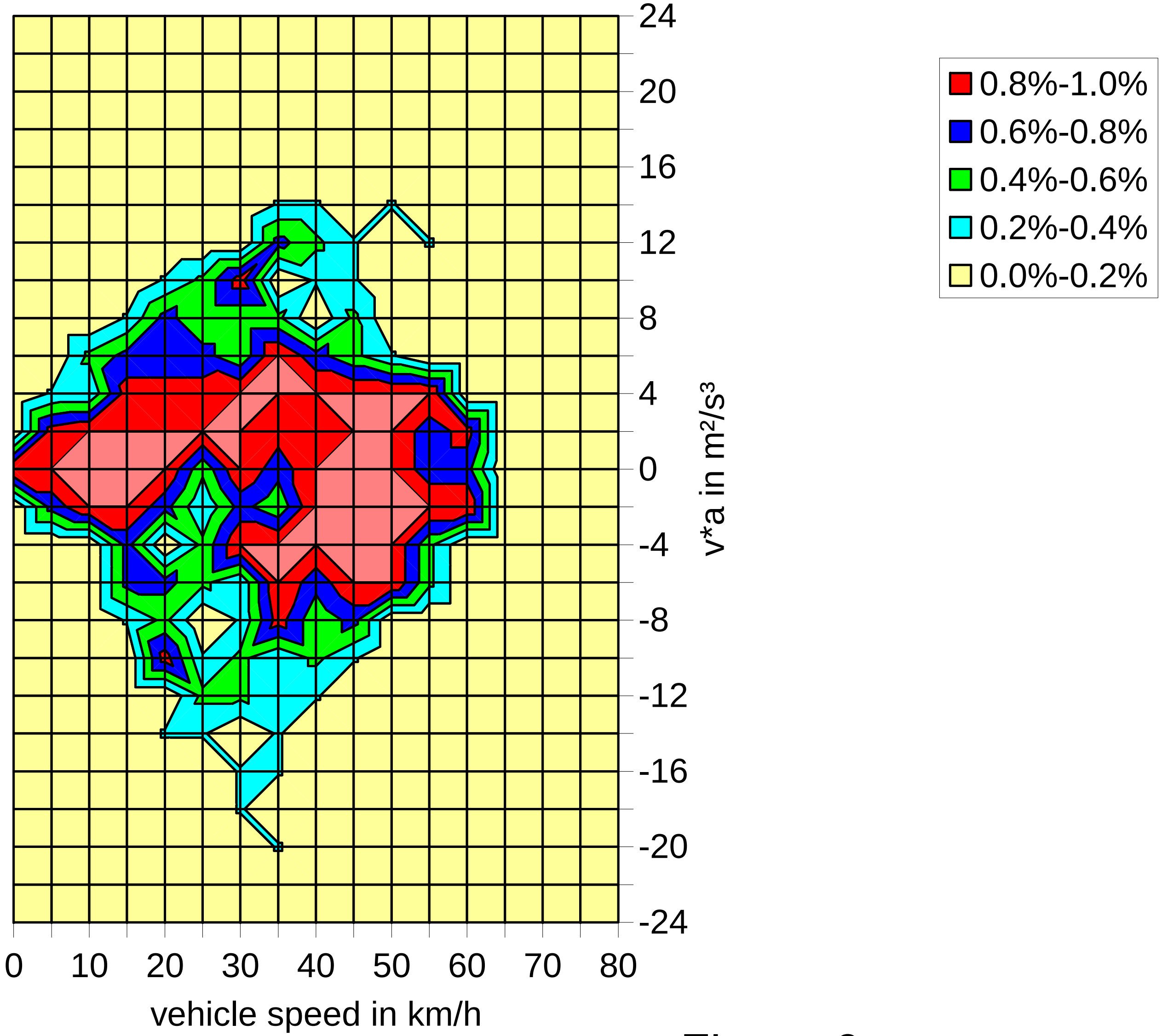

Figure 6

v, v*a, rural database wo CH

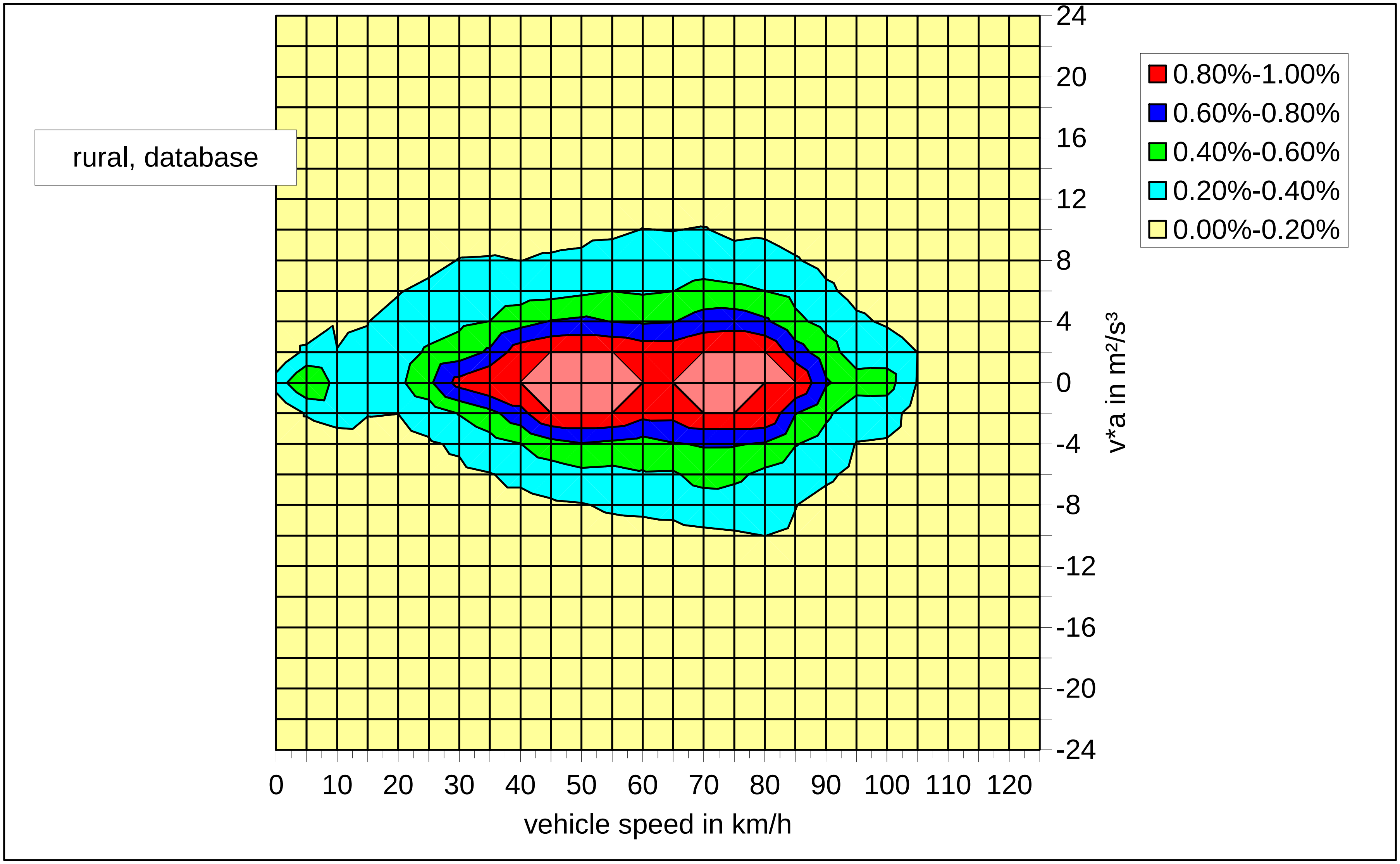

Figure 7

v, v*a, rural database with CH

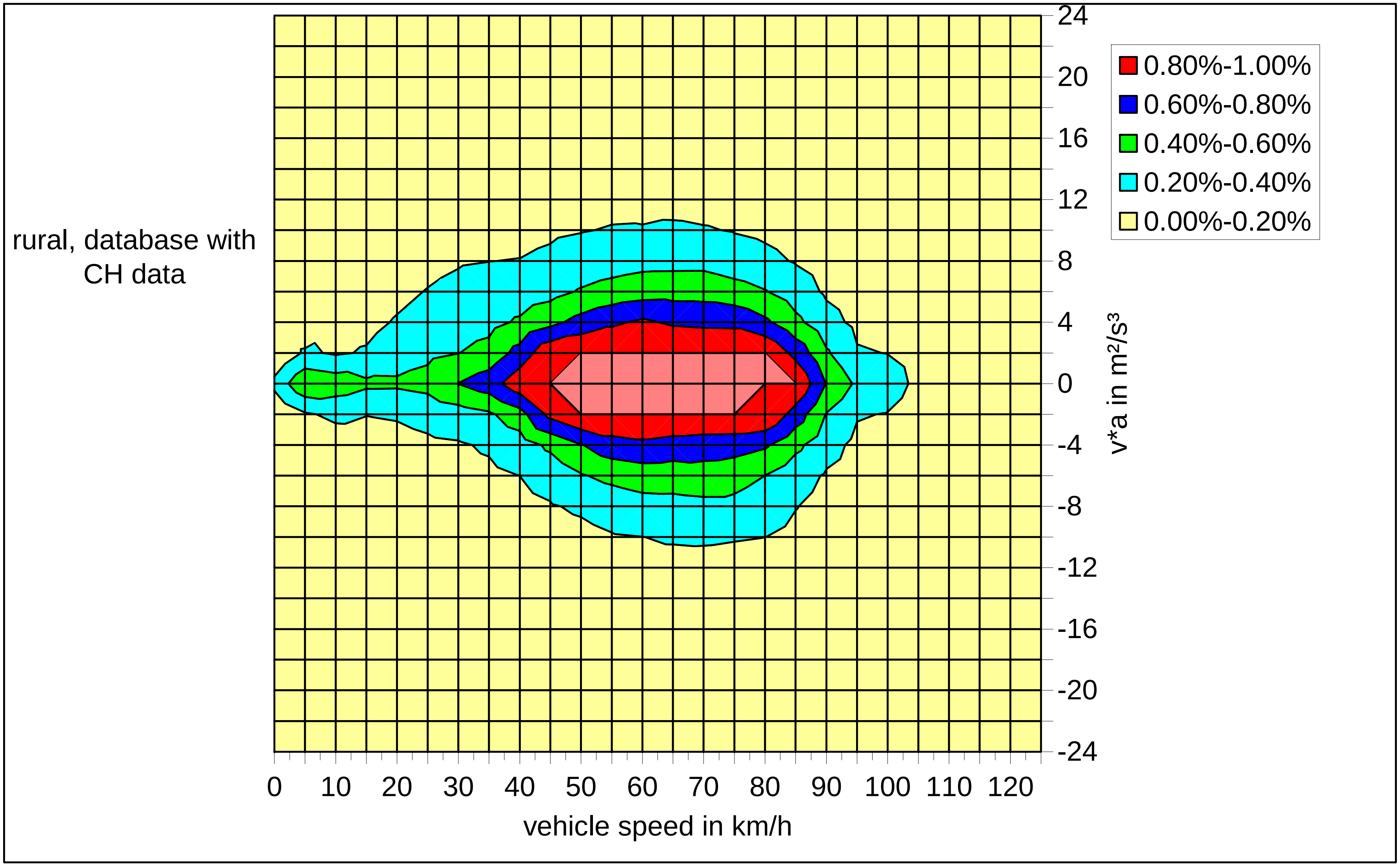

Figure 8

v, v*a, rural CC

WLTP candidate cycle, rural

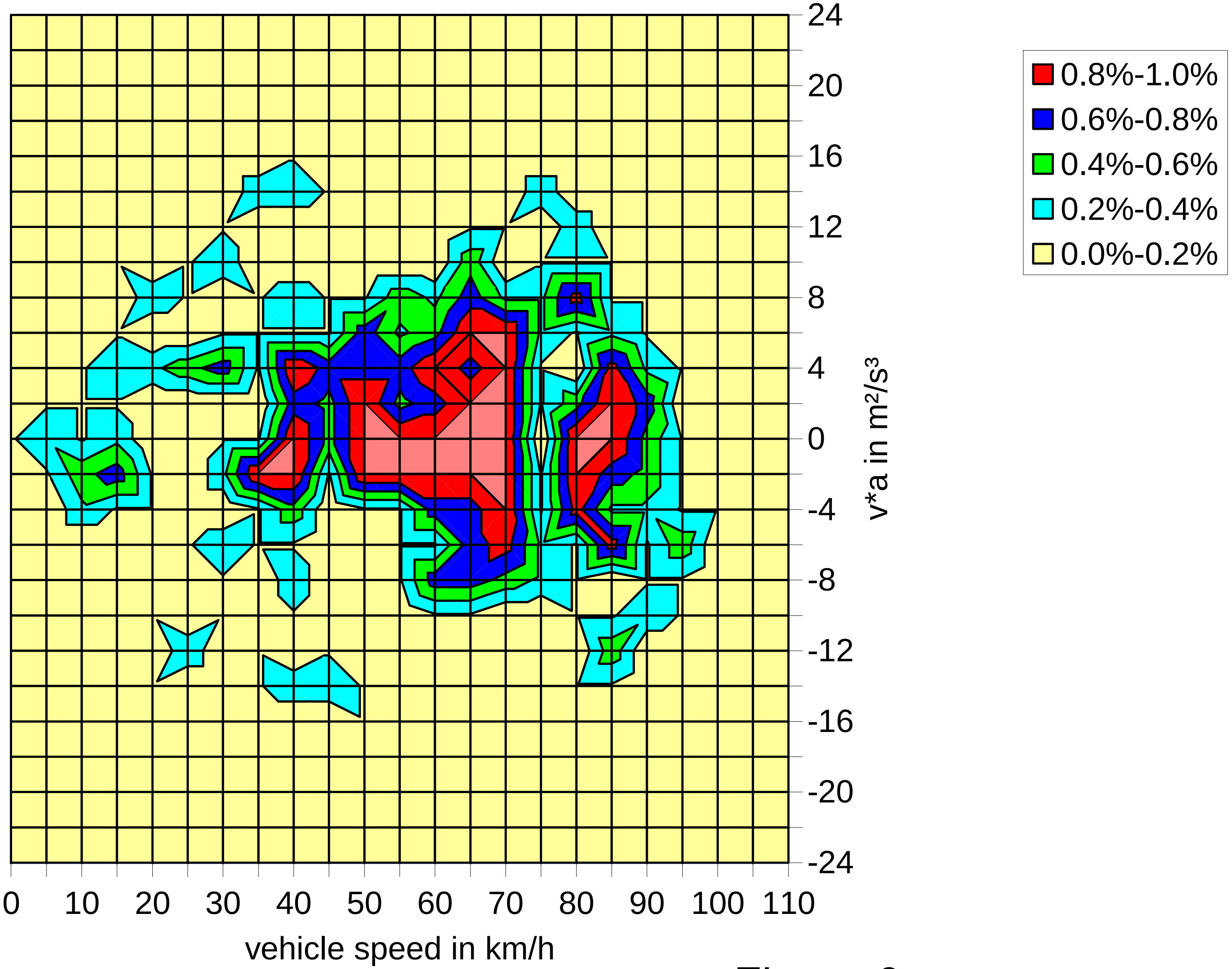

Figure 9

v, v*a, mot database wo CH

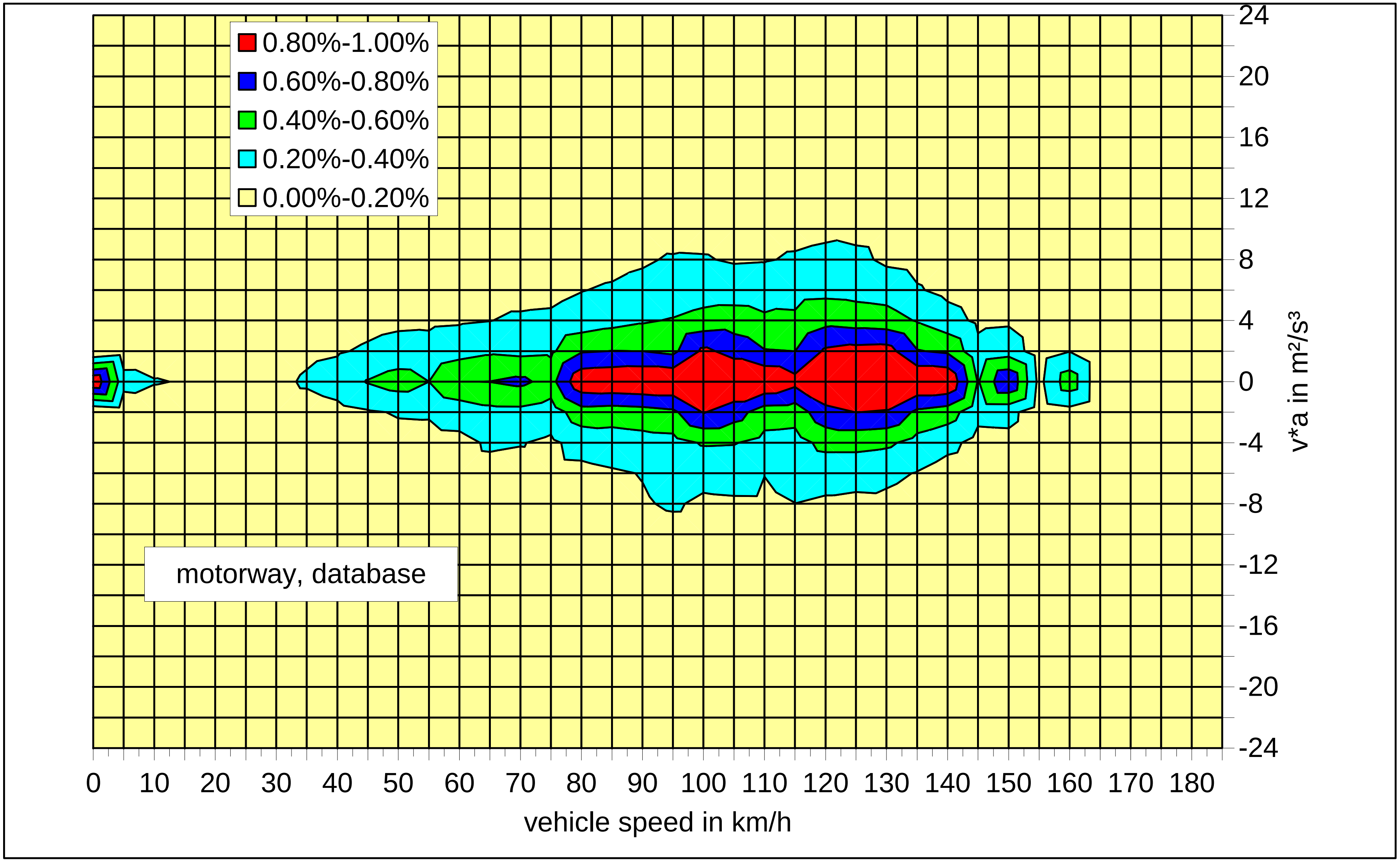

Figure 10

v, v*a, mot database with CH

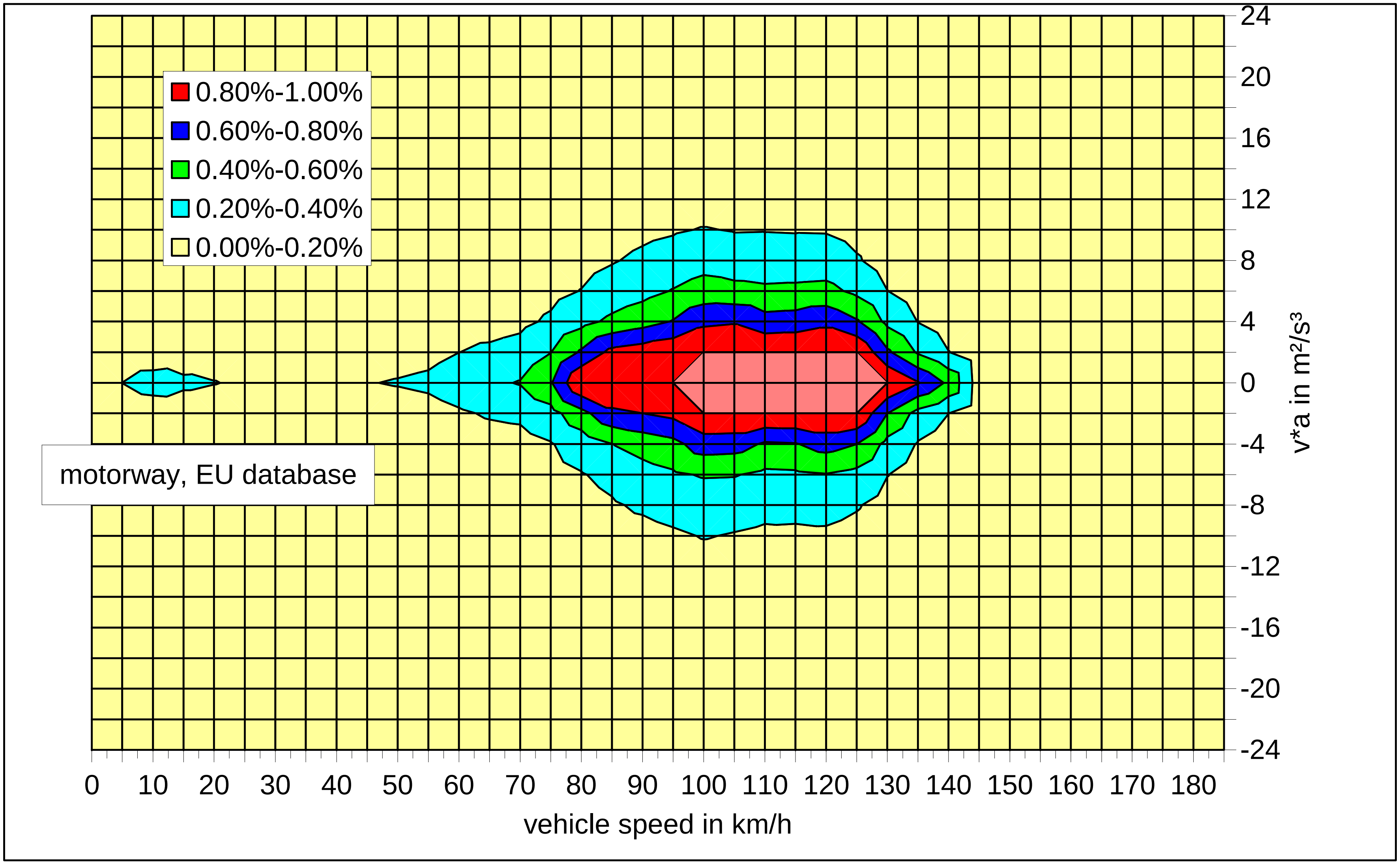

Figure 11

v, v*a distributions, mot CC

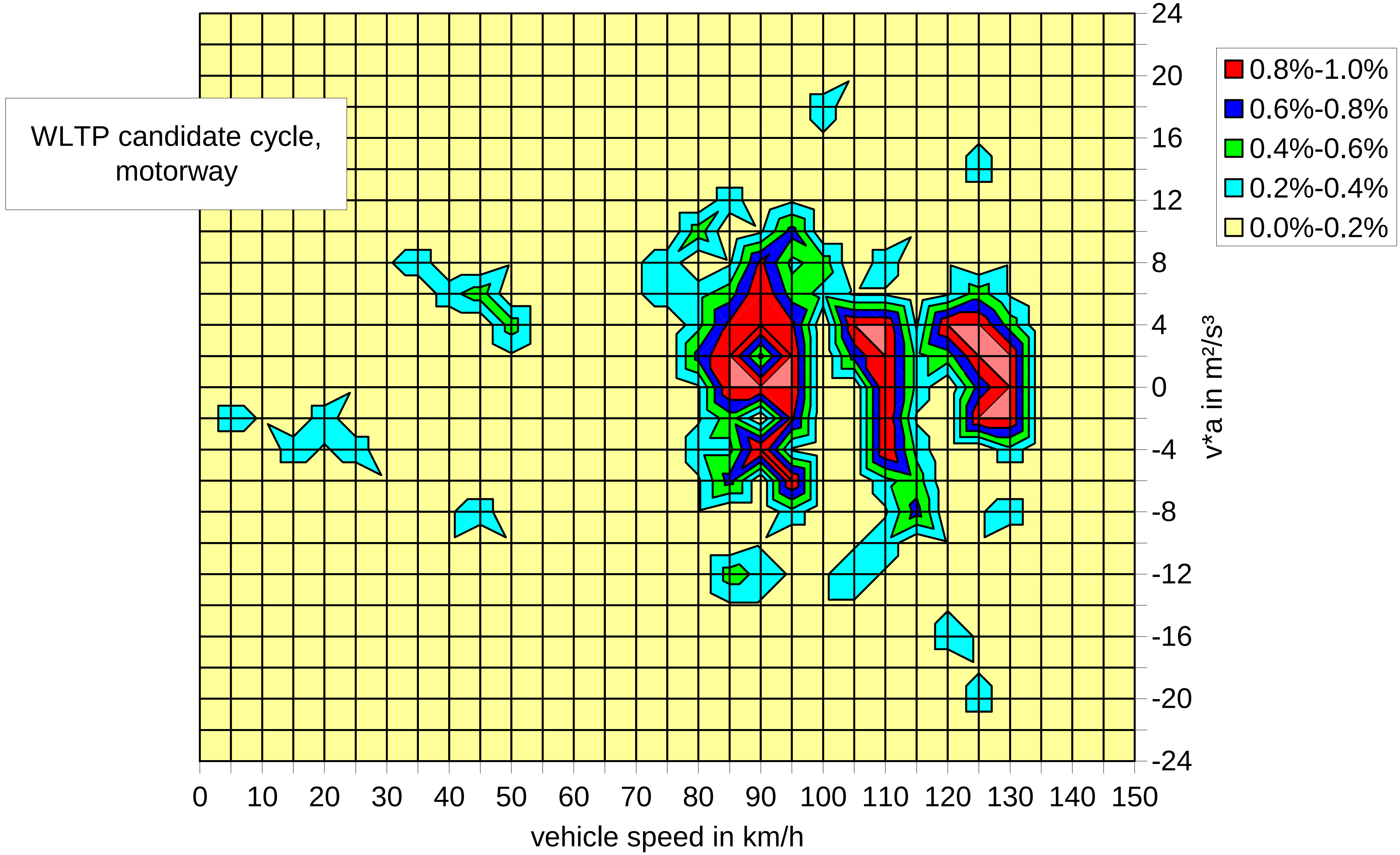

Figure 12

Conclusions

- The comparison of the database without and with the Swiss (CH) in-use data shows that the version without the Swiss data did not contain enough data for a representative database.
- With the Swiss data the database is much better balanced with respect to vehicle speed and acceleration distribution.
- Furthermore the motorway part is now more representative for Europe.
- The new database results for the urban part in a higher stop percentage and a higher percentage of long stops.

Conclusions

- **As a consequence the number of stops and short trips for the urban part of a candidate cycle would be reduced by 1 compared to the old database.**
- **The short trip duration distributions for the urban part are almost the same but significant differences were found for rural and motorway between the old and new database.**
- **A preliminary calculation for the derivation of a new urban candidate cycle was performed. The differences to the former version are low.**

Conclusions

- A corresponding calculation for the rural part would most probably lead to a reduction of the top speed of the candidate cycle.
- No differences are expected for the motorway part.
- The cycle development approach as described in WLTP-DHC-02-05 (30.10.2009) needs to be modified regarding the determination of stop and short trip duration periods.
- Very short stops and short trips should be excluded from the distributions in order to get reliable and consistent results.

Conclusions

- **The 2. step of the development process (choice of short trips from the database) leads to reasonable good results for the urban and rural parts.**
- **The differences between database and candidate cycle are significantly higher for the motorway part.**
- **The reason is the limited time of 600 s and the requirement that the cycle part starts from stop and goes back to stop at its end.**
- **These side conditions limits the fit between database and candidate cycle.**