The number of cycles

For OICA and Jan, 2021 TF1meeting,

Japan Automobile Manufacturers Association

Japan Automobile Research Institute

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1. Back ground

Definition of HDV
58 agreement : over 3.5ton at GVM
US・CA : 10000lb(4.5ton) at GVM

- The number of cycle of GTR no.13 was based on estimation.
  - ✓The estimation was 2 full feelings per day for an entire service life of 15 years of taxi usage.
  - ✓But it is known that taxi has limited service life(ex. 5-7years).

Table1. Rational of the number of pressure cycles of GTR no.13 phase1

Region	Source	Max svc. life	Estimated extreme lifetime range	Corresponding Number of Cycles
CA/US	Scraped vehicles*1	N.A.	560,000 km	1,200 - 1,800
BC/Canada	Emission testing*1	N.A.	800,000 - 1,000,000 km	1,650 - 3,100
NYC/US	Taxis	5 years	(72,000 km/week)	2,750 - 3,600
Toronto, Ottawa/Canada	Taxis	7 years	1,400,000 – 1,900,000 km	2,900 - 6,000

*1 incl. Taxis

It was agreed that 25yeas of service life is needed for HDV

2. Research result of Number of cycles

➢Research vehicle ODD data of public agency in Germany, Japan and US.

- ✓Calculate annual vehicle mileage from public ODD data.
- ✓Estimate extreme life time range by annual vehicle mileage.
- ✓Estimate corresponding number of cycles by using “320km” per fill.

Table2. Result for HDV

Region	Source	Annual vehicle mileage	Service life	Estimated extreme lifetime range	Corresponding Number of Cycles*1
Japan	MLIT	TBD	20 yrs	3,800,000 km	12,000
		TBD	25 yrs	4,400,000 km	14,000
Germany	VDA	TBD	20 yrs	2,300,000 km	7,200
		TBD	25 yrs	2,900,000 km	9,000
US	NHTSA	TBD	20 yrs	4,200,000 km	10,400
		TBD	25 yrs	5,200,000 km	16,250

Table3. Result for LDV

Region	Source	Annual vehicle mileage	Service life	Estimated extreme lifetime range	Corresponding Number of Cycles*1
Japan	MLIT	TBD	25 yrs	1,900,000 km	5,900

*1 fill/320km, *2cate gory 1-1, include taxis

3. Proposal

- “the number of cycles” at service life of 25 year is following.
  - ✓The result was differ from each region so it should be set by each Contracting Party as previous GTR.
  - ✓The result was completely differ from vehicle type so it shall be changed by vehicle type.
  - ✓Japanese data shows below 6,000cycles for 25 years for LDV. So we set the number of cycles to 5,500/7,500/11,000 by considering with GTR phase1 value.
  - ✓Data shows 9,000/14,000/17,000 cycles for Germany, Japanese and US for 25 years of HDV. So we set the number of cycles with corresponding to it.

Table4. Vehicle type and proposal of “the number of cycles”

Vehicle type	The number of cycles
LDV	5,500/7,500/11,000
HDV	9,000/14,000/17,000

3. Proposal (Continued)

- Example of draft is following.

5.1. Compressed hydrogen storage system

(omit)

All new compressed hydrogen storage systems produced for on-road vehicle service shall have a NWP of 70 MPa or less and a service life of ~~15~~ **25** years or less, and be capable of satisfying the requirements of paragraph 5.1.

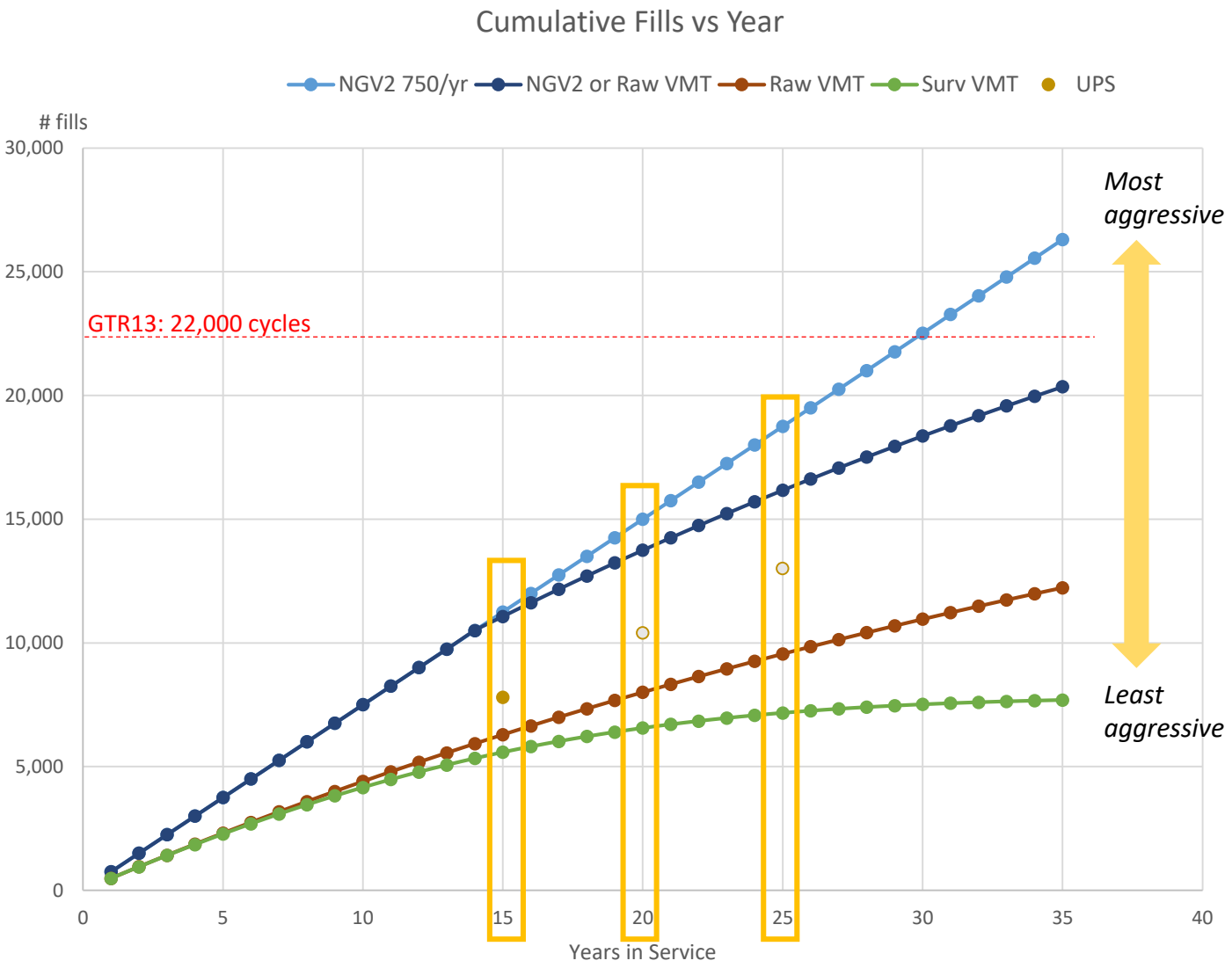
5.1.1.2. Baseline initial pressure cycle life
Three (3) new containers randomly selected from the design qualification batch are hydraulically pressure cycled at 20(±5)° C to 125 per cent NWP without rupture for specified number of test cycles or until a leak occurs (para. 6.2.2.2. test procedure). Leakage shall not occur within a number of Cycles, where the number of Cycles is set individually by each Contracting Party ~~**at 5,500, 7,500 or 11,000 cycles for a 15-year service life.**~~ **Table xxx shows the number of cycles and test cycles for corresponding vehicle type.**

Table xxx The number of cycles and Test cycles

Vehicle type	The number of cycles	Test cycles
LDV	5,500/7,500/11,000	22,000
HDV	9,000/14,000/17,000	34,000

APPENDIX

Cumulative Fills with Varying VMT Assumptions



Source: UPS via NHTSA, Surv VMT (NHTSA)

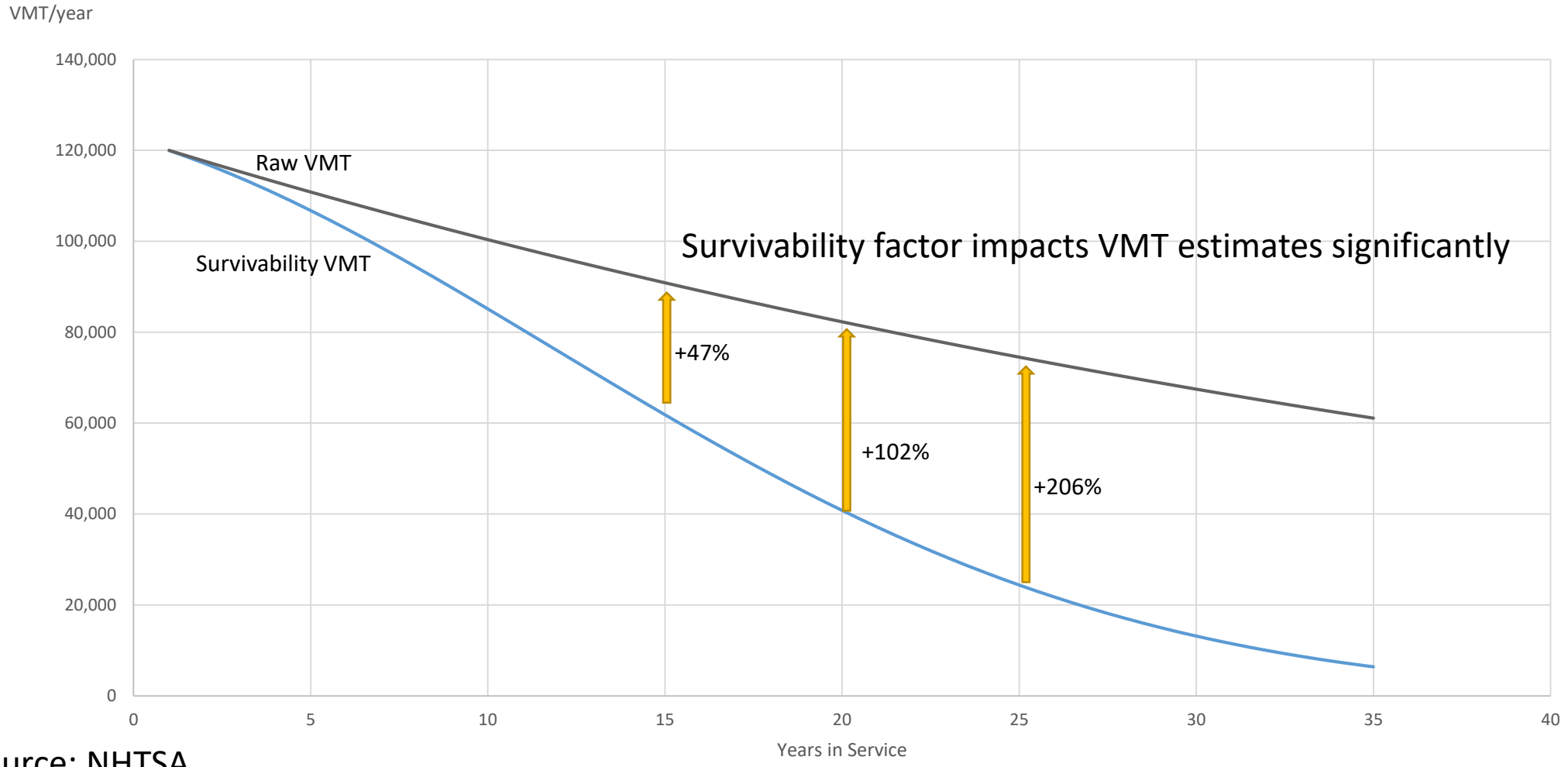
Comparison of Cumulative Refueling Instances Using Different VMT Assumptions

VMT assumptions	15 yr	20 yr	25 yr
NGV2 (750 fills/yr)	11,250	15,000	18,750
NGV2 or Raw VMT	11,068	13,744	16,168
UPS	7,800	10,400	13,000
Raw VMT (unadj. for surv.)	6,288	8,001	9,552
Survivability VMT	5,578	6,556	7,167

Note:

- *Assumes range of 250 miles/fill*
- *VMT data from Class 8 trucks*
- *"NGV2 750/yr" – Assumes constant 750 fill/year*
- *"NGV2 or Raw VMT" – Uses 750 fill/yr (more aggressive) when > 250 mi/day (1 refuel/day). Adjusted down to Raw VMT when < 1 refuel/day (250 miles/day)*
- *"Raw VMT" – VMT decrease by year but not adjusted for survivability*
- *"Surv VMT" – VMT adjusted for survivability factor*
- *"UPS" – In-use experience for CNG HDV. 130K mi/year, 250 mi range. 15 yr data actual. 20 & 25 yr extrapolated.*

Impact of Survivability Factor on VMT



Source: NHTSA

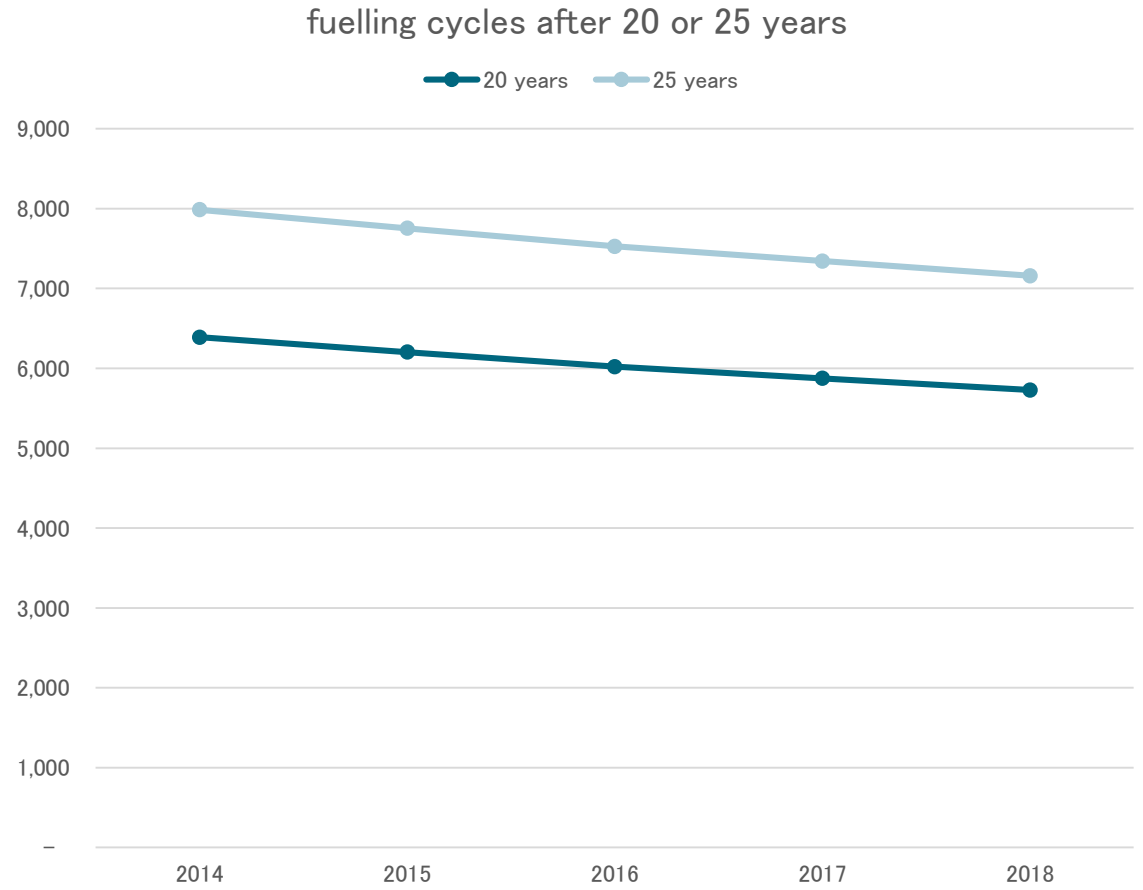
For Class 8 vehicles (33K+ lbs). Assumes NHTSA survivability factor and FCV VMT of 120,000 for 1st year

There is no increase in pressure cycles based on average mileage of heavy-duty vehicles over their service life expectancy of 20–25 years.

	Average km / year[1]	total mileage after		# cycles after	
		20 years	25 years	20 years	25 years
2014	115,017	2,300,340	2,875,425	6,390	7,987
2015	111,656	2,233,120	2,791,400	6,203	7,754
2016	108,387	2,167,740	2,709,675	6,022	7,527
2017	105,758	2,115,160	2,643,950	5,875	7,344
2018	103,101	2,062,020	2,577,525	5,728	7,160

Assuming a steady average mileage for hdv (based on semi-trailer truck numbers of the most recent 5 years). The average working hours of a European truck driver per day is 9[2]. The maximum speed on German highways for trucks is 80 km/h. Considering a conservative range of 500 km for a fully fuelled hydrogen truck this would result in approx. 1.5 fuelling cycles a day with a total range of 720 km. GTR 13 Phase 1 did not consider partial fuelling. Therefore the number was rounded to 2. Based on this the number of fuelling cycles over the service life of 20 and 25 years would be calculated as follows:

20 years * average annual mileage / 720 km * 2
25 years * average annual mileage / 720 km * 2

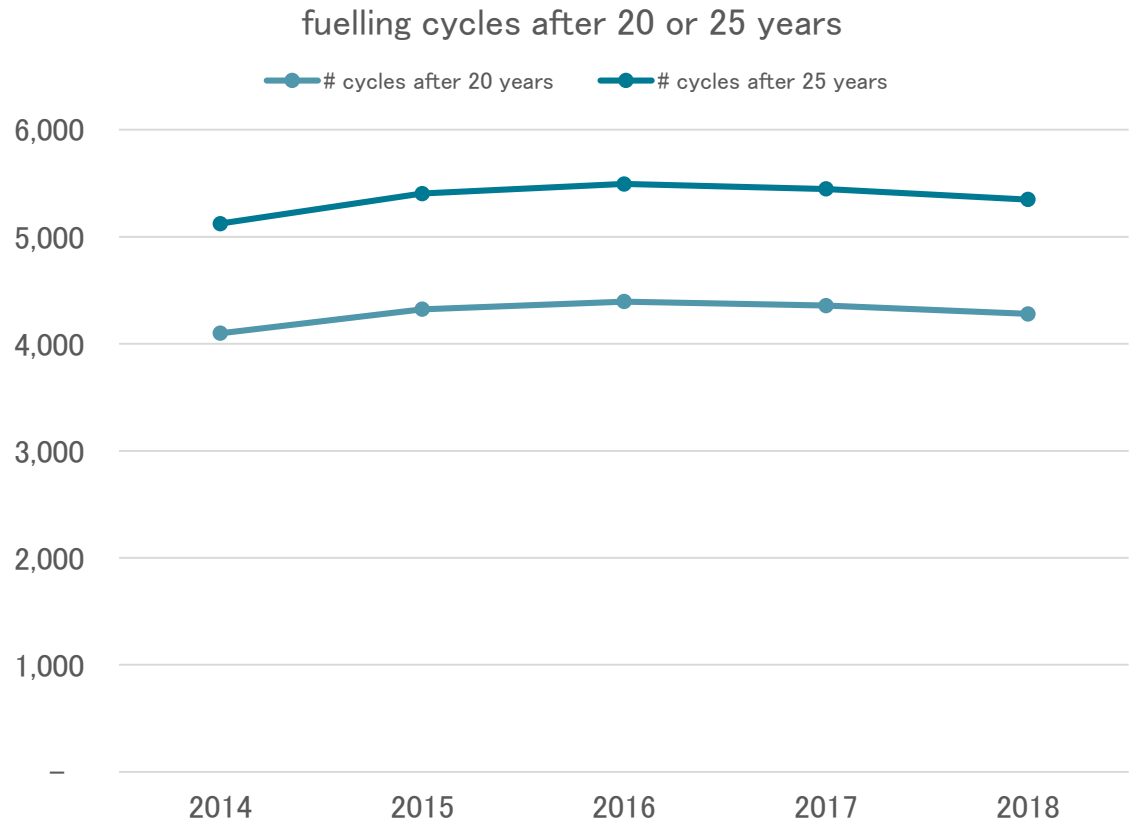


[1] For simplification purposes the number for vehicles up to 3 years old were used and multiplied with the expected lifetime. See also https://www.kba.de/DE/Statistik/Kraftverkehr/VerkehrKilometer/verkehr_in_kilometern_node.html

[2] https://ec.europa.eu/transport/modes/road/social_provisions/driving_time_en

There is no increase in pressure cycles based on average mileage of heavy-duty vehicles over their service life expectancy of 20-25 years.

	Average of annual km over life-time[1]	total mileage after		# cycles after	
		20 years	25 years	20 years	25 years
2014	73,775	1,475,500	1,844,375	4,099	5,123
2015	77,817	1,556,340	1,945,425	4,323	5,404
2016	79,112	1,582,240	1,977,800	4,395	5,494
2017	78,438	1,568,760	1,960,950	4,358	5,447
2018	77,019	1,540,380	1,925,475	4,279	5,349



Using the average mileage over the life-time of hdv (based on semi-trailer truck numbers over 20 years). The average working hours of a European truck driver per day is 9[2]. The maximum speed on German highways for trucks is 80 km/h. Considering a conservative range of 500 km for a fully fuelled hydrogen truck this would result in approx. 1.5 fuelling cycles a day with a total range of 720 km. GTR 13 Phase 1 did not consider partial fuelling. Therefore the number was rounded to 2. Based on this the number of fuelling cycles over the service life of 20 and 25 years would be calculated as follows:

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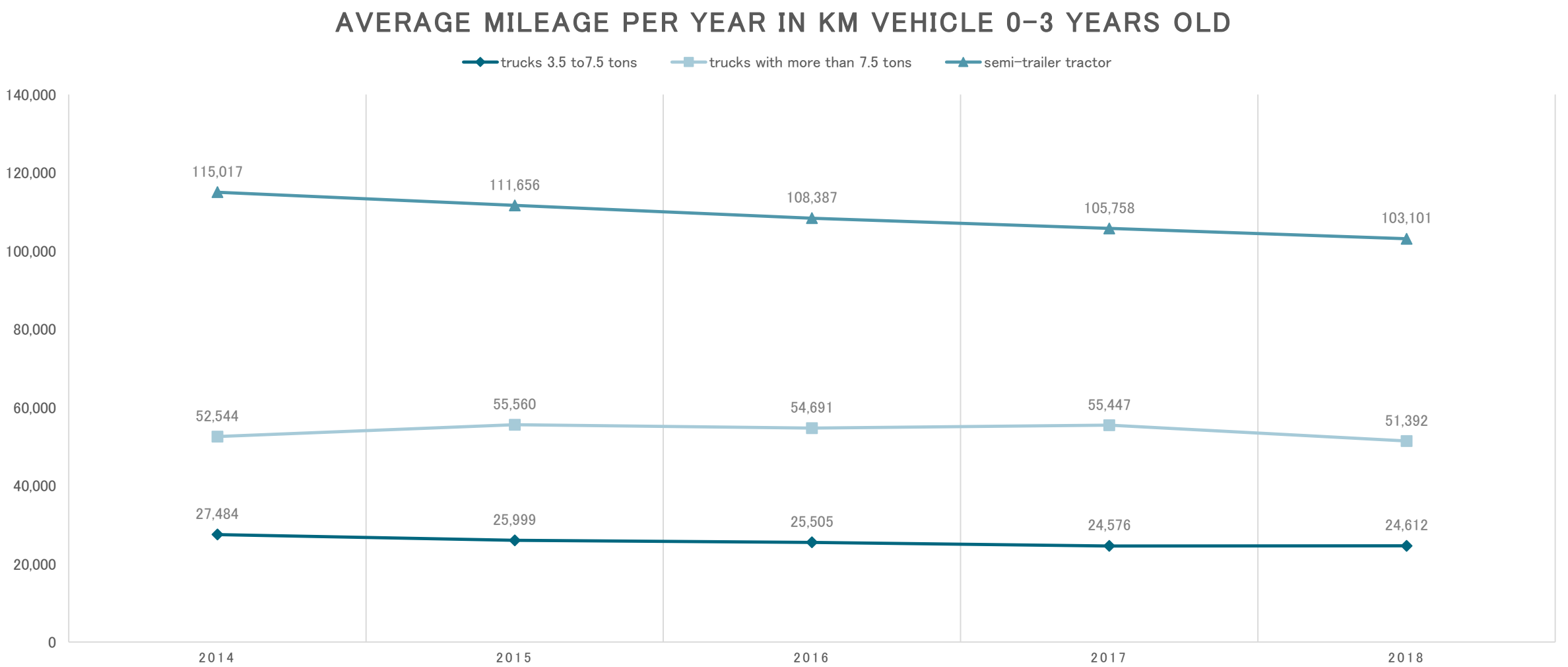
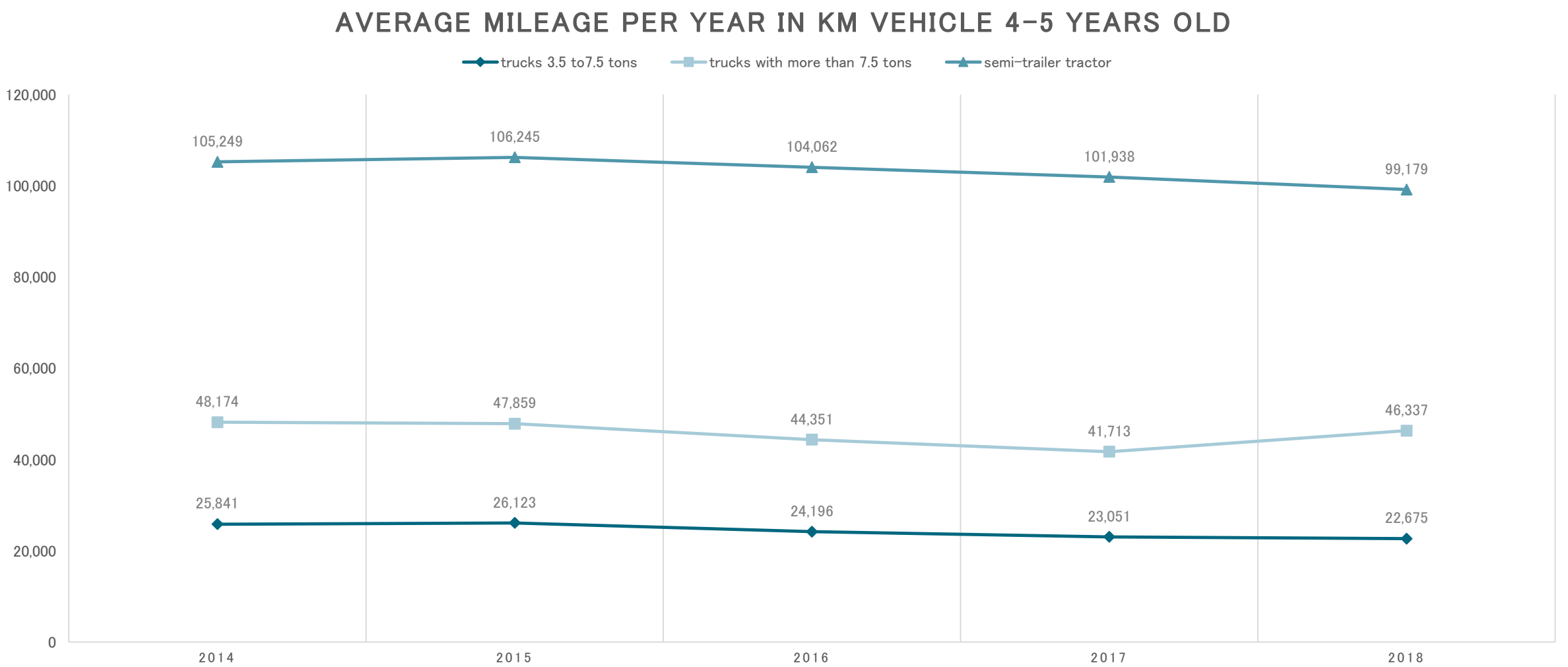
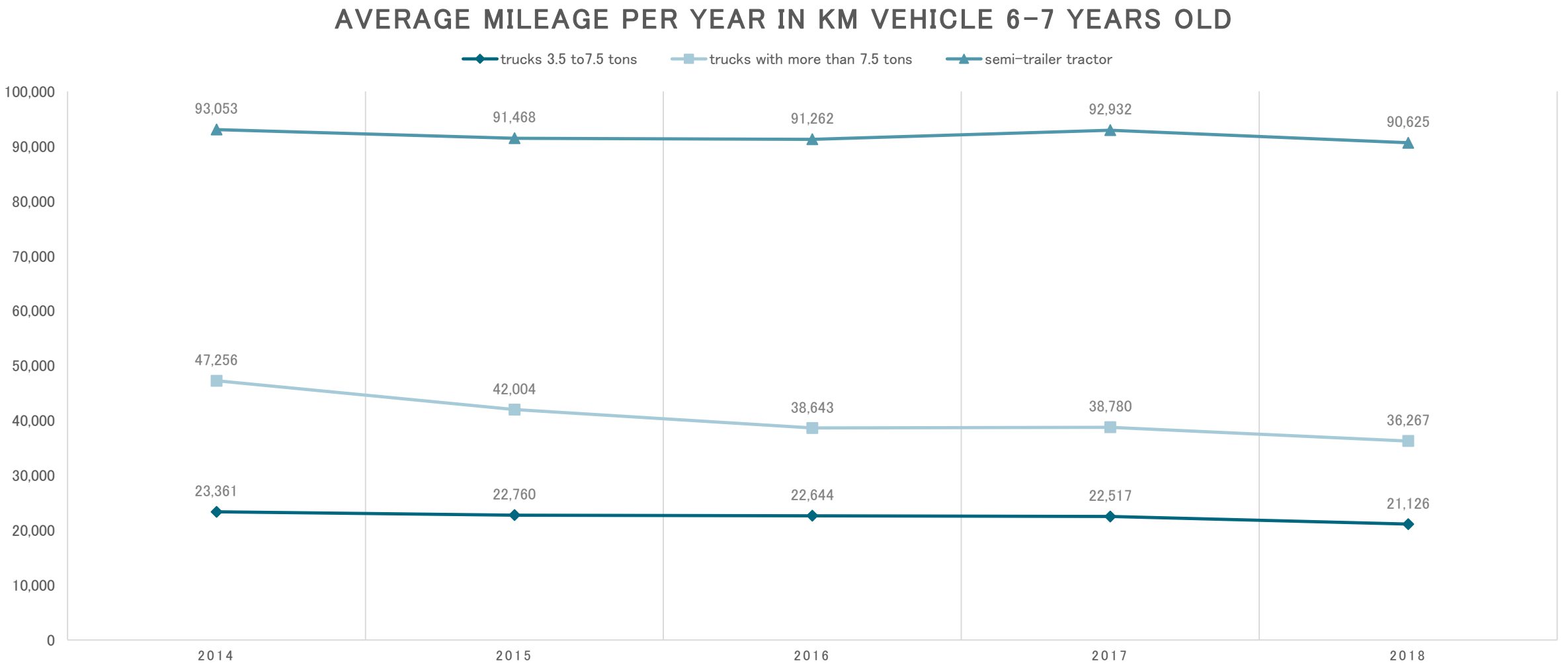
Overall


AVERAGE MILEAGE PER YEAR IN KM VEHICLE 0-3 YEARS OLD
trucks 3.5 to7.5 tons
trucks with more than 7.5 tons
semi-trailer tractor
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
115,017
111,656
108,387
105,758
103,101
52,544
55,560
54,691
55,447
51,392
27,484
25,999
25,505
24,576
24,612
2014
2015
2016
2017
2018

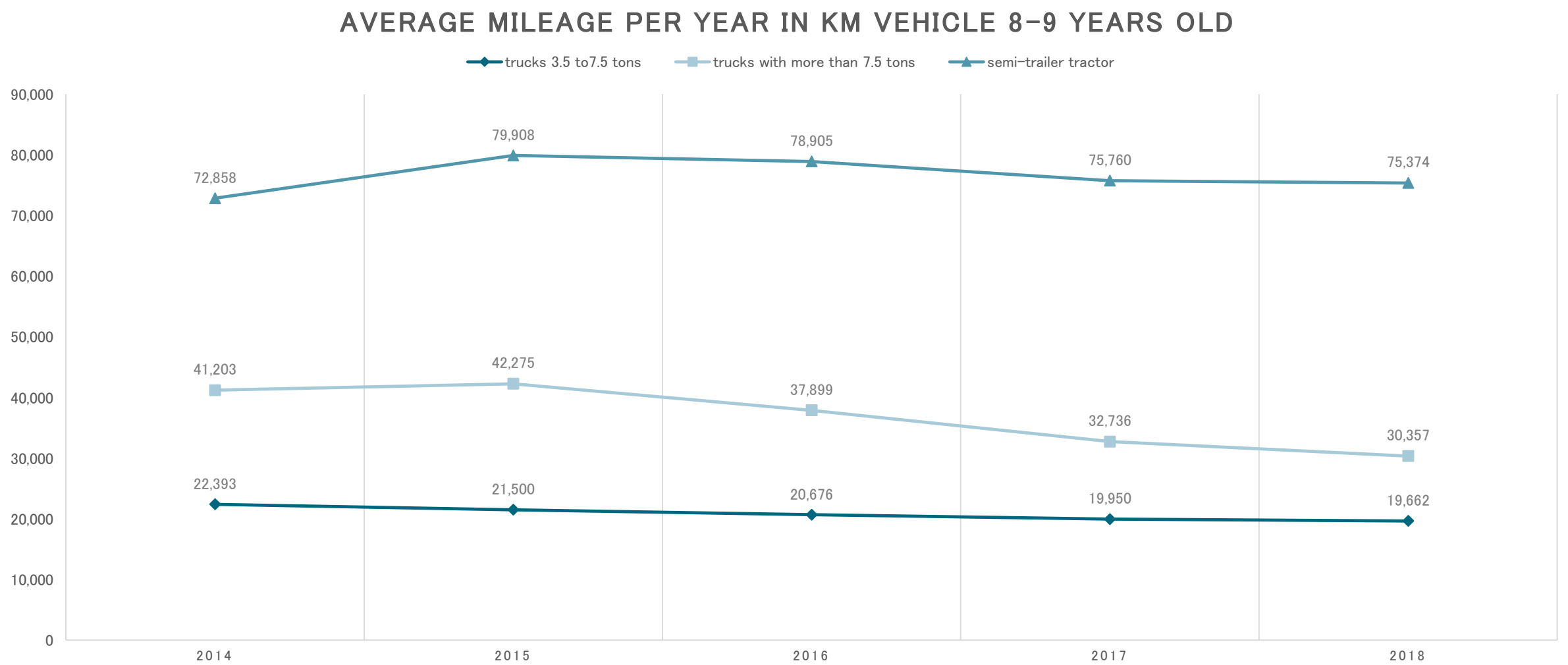
Overall


AVERAGE MILEAGE PER YEAR IN KM VEHICLE 4-5 YEARS OLD
trucks 3.5 to7.5 tons
trucks with more than 7.5 tons
semi-trailer tractor
120,000
100,000
80,000
60,000
40,000
20,000
0
105,249
106,245
104,062
101,938
99,179
48,174
47,859
44,351
41,713
46,337
25,841
26,123
24,196
23,051
22,675
2014
2015
2016
2017
2018

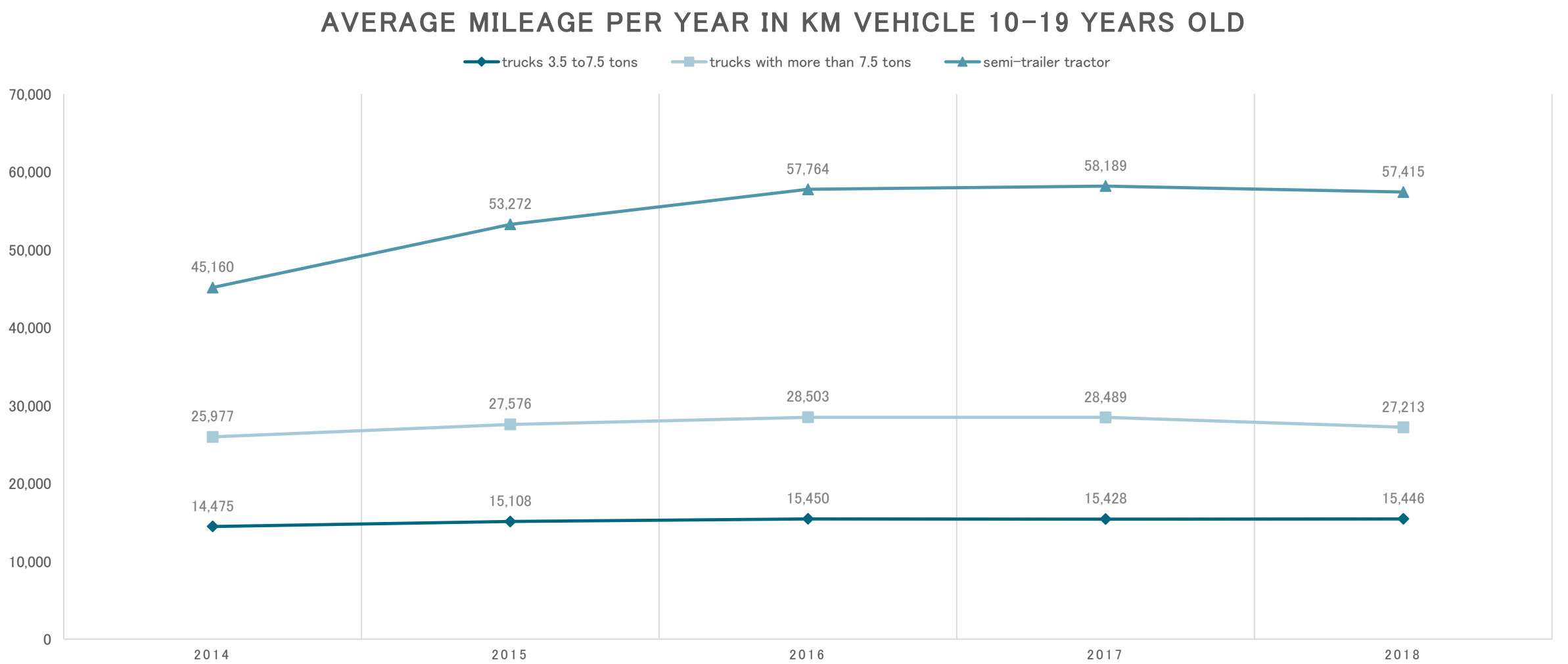
Overall


AVERAGE MILEAGE PER YEAR IN KM VEHICLE 6-7 YEARS OLD
trucks 3.5 to7.5 tons
trucks with more than 7.5 tons
semi-trailer tractor
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
93,053
91,468
91,262
92,932
90,625
47,256
42,004
38,643
38,780
36,267
23,361
22,760
22,644
22,517
21,126
2014
2015
2016
2017
2018

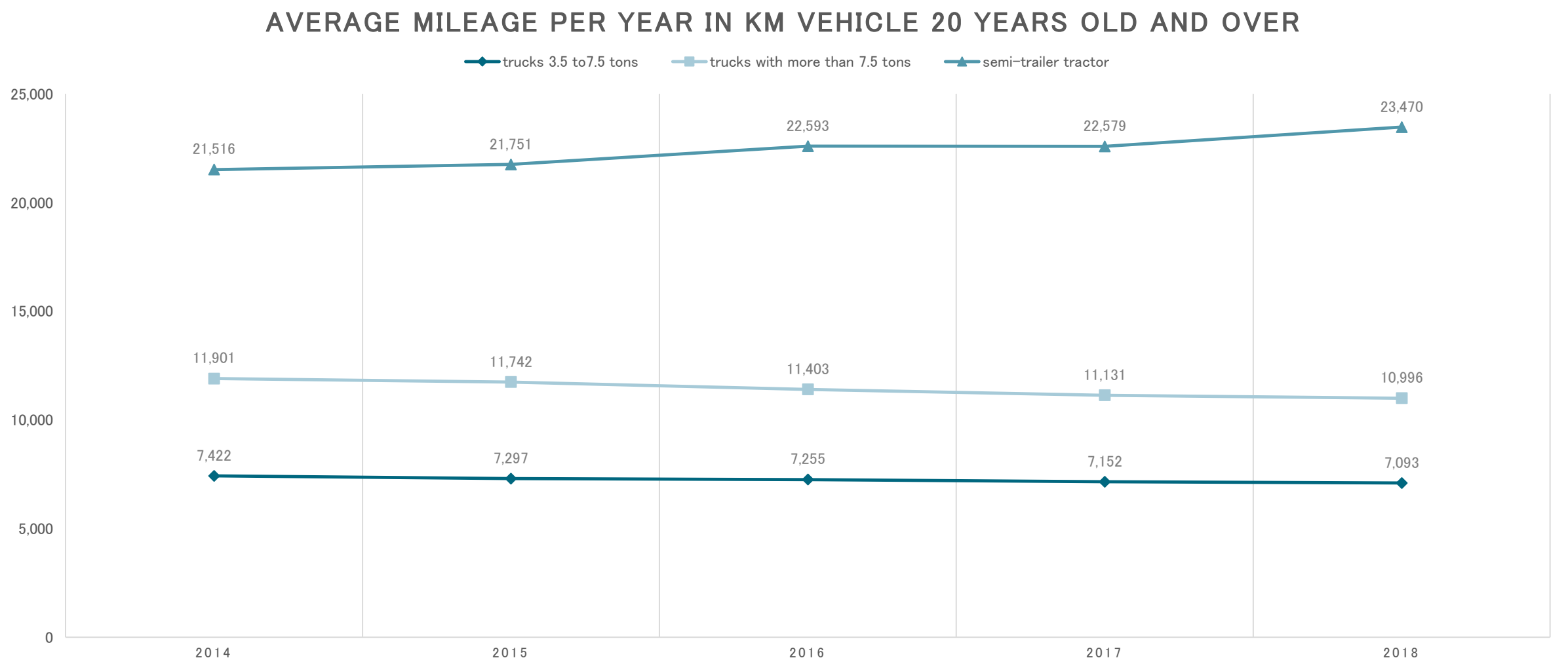
Overall


AVERAGE MILEAGE PER YEAR IN KM VEHICLE 8-9 YEARS OLD
trucks 3.5 to7.5 tons
trucks with more than 7.5 tons
semi-trailer tractor
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
72,858
79,908
78,905
75,760
75,374
41,203
42,275
37,899
32,736
30,357
22,393
21,500
20,676
19,950
19,662
2014
2015
2016
2017
2018

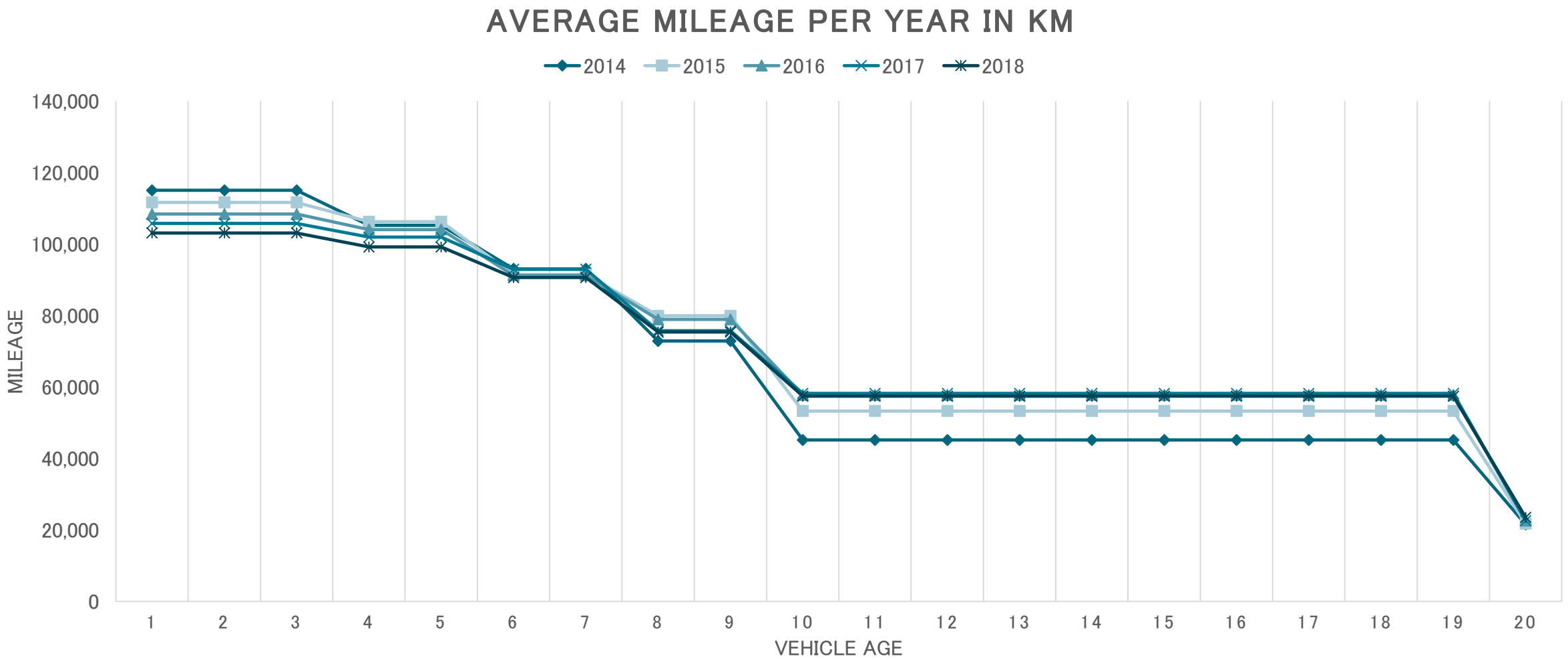
Overall


AVERAGE MILEAGE PER YEAR IN KM VEHICLE 10-19 YEARS OLD
trucks 3.5 to7.5 tons
trucks with more than 7.5 tons
semi-trailer tractor
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
2014
2015
2016
2017
2018
45,160
53,272
57,764
58,189
57,415
25,977
27,576
28,503
28,489
27,213
14,475
15,108
15,450
15,428
15,446

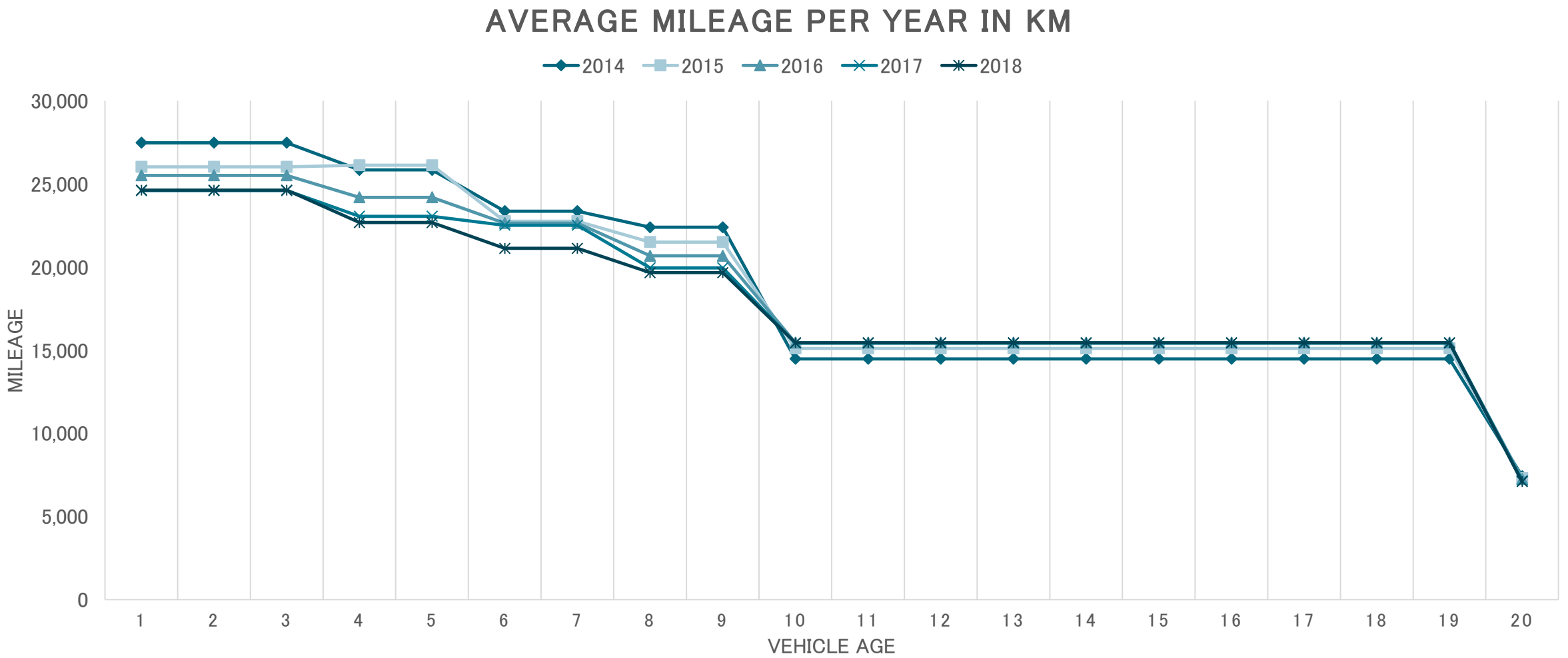
Overall


AVERAGE MILEAGE PER YEAR IN KM VEHICLE 20 YEARS OLD AND OVER
trucks 3.5 to7.5 tons
trucks with more than 7.5 tons
semi-trailer tractor
25,000
20,000
15,000
10,000
5,000
0
21,516
21,751
22,593
22,579
23,470
11,901
11,742
11,403
11,131
10,996
7,422
7,297
7,255
7,152
7,093
2014
2015
2016
2017
2018

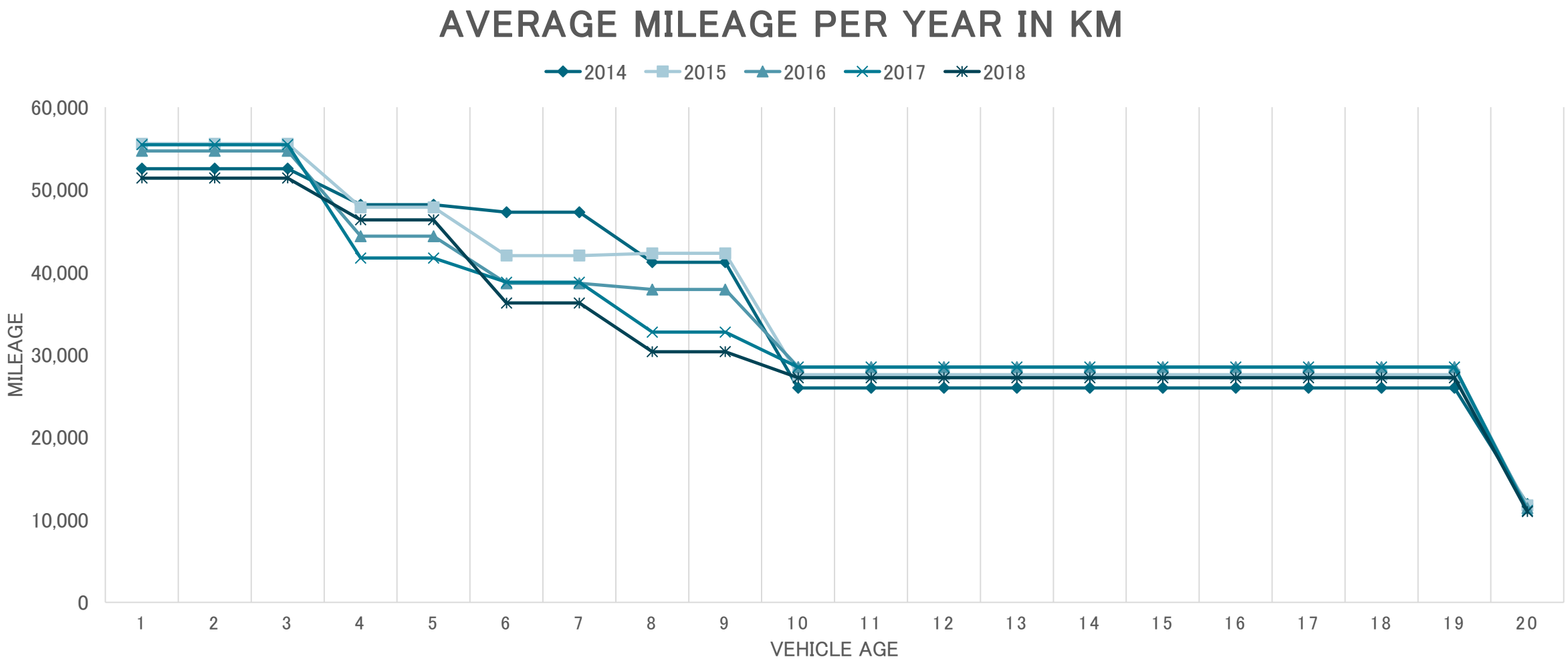
Semi-trailer tractors



Trucks 3.5 to 7.5 tons



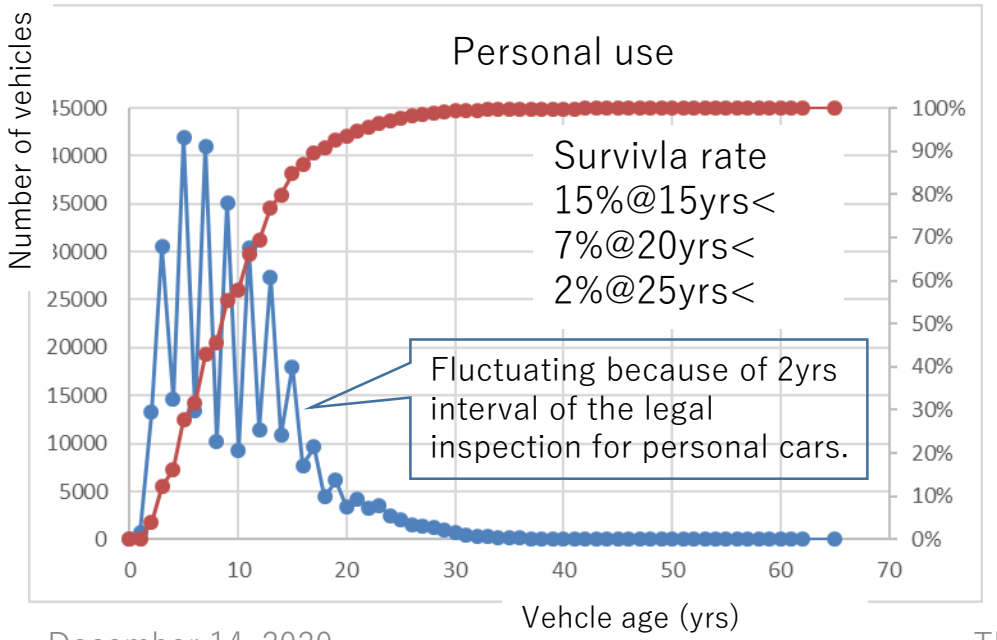
Trucks over 7 tons

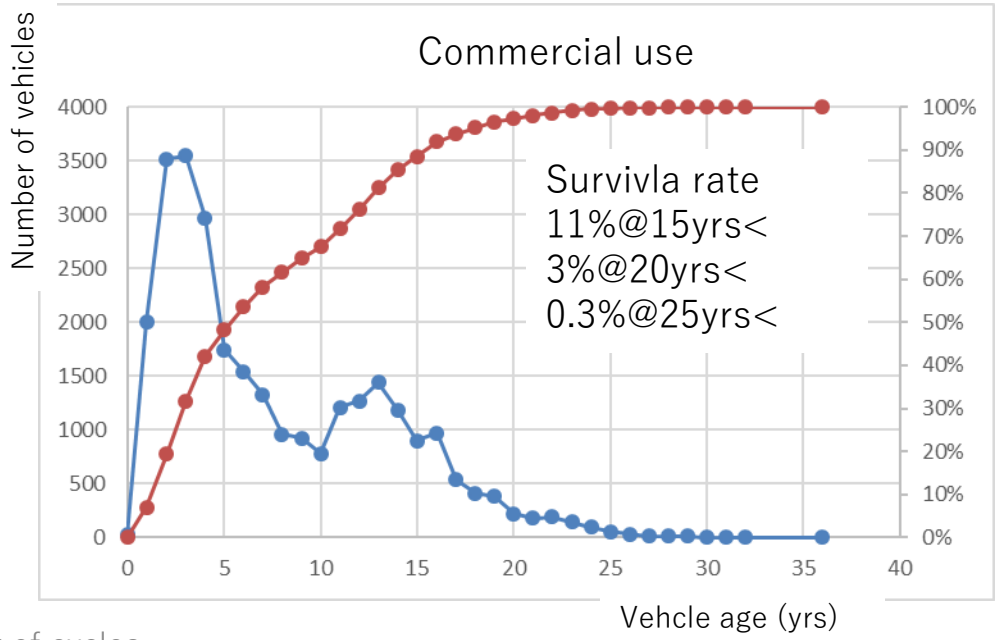


Japan Data : Commercial vehicles

Source: Legal inspection of July 2019 / 392x10^3 data (except motor cycles)

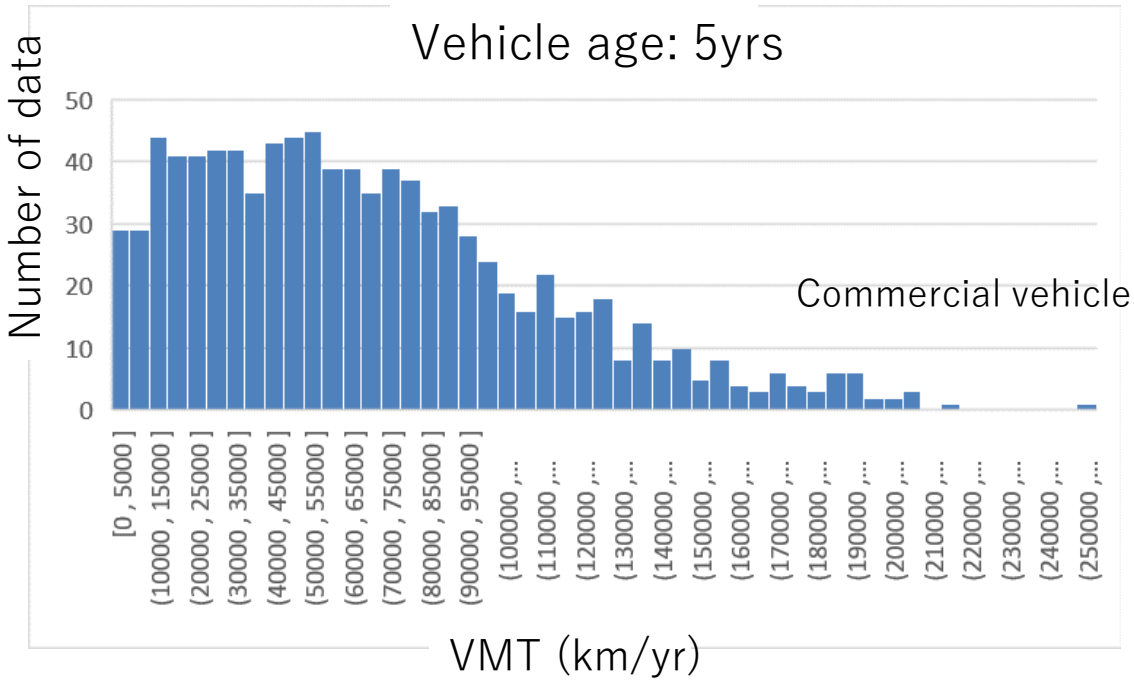
- Personal use / 363x10^3 data
- Commercial use / 28x10^3 data

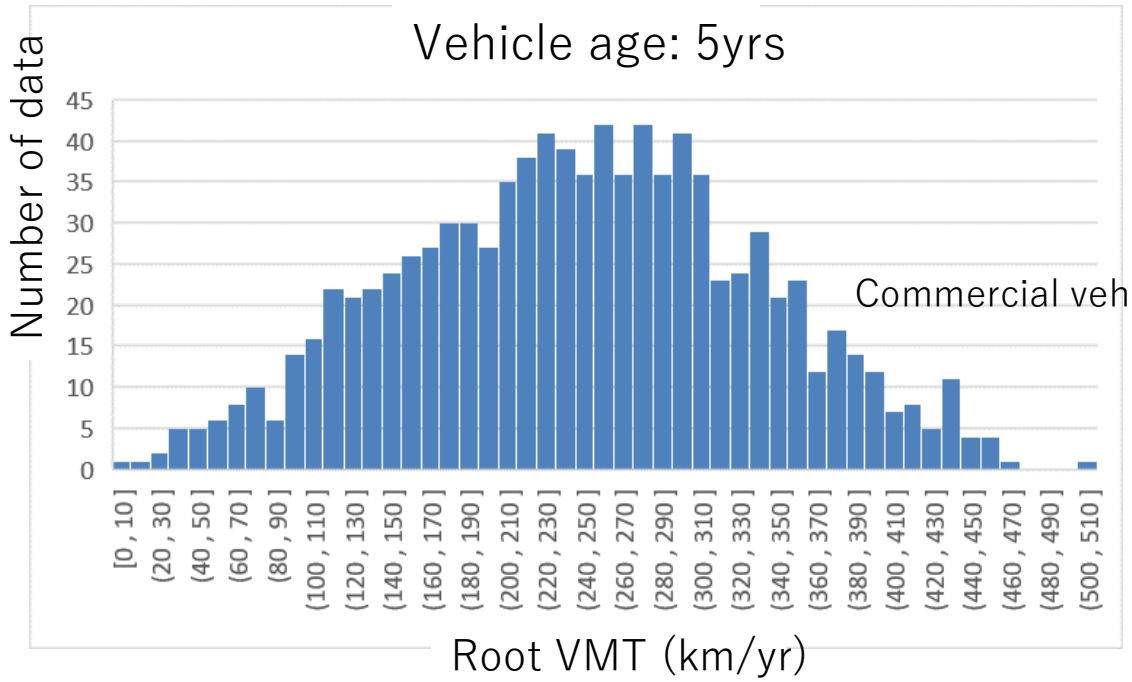




Histograms of VMT (km/yr)

The figure of “Root VMT” looks normal distribution.





Preliminary

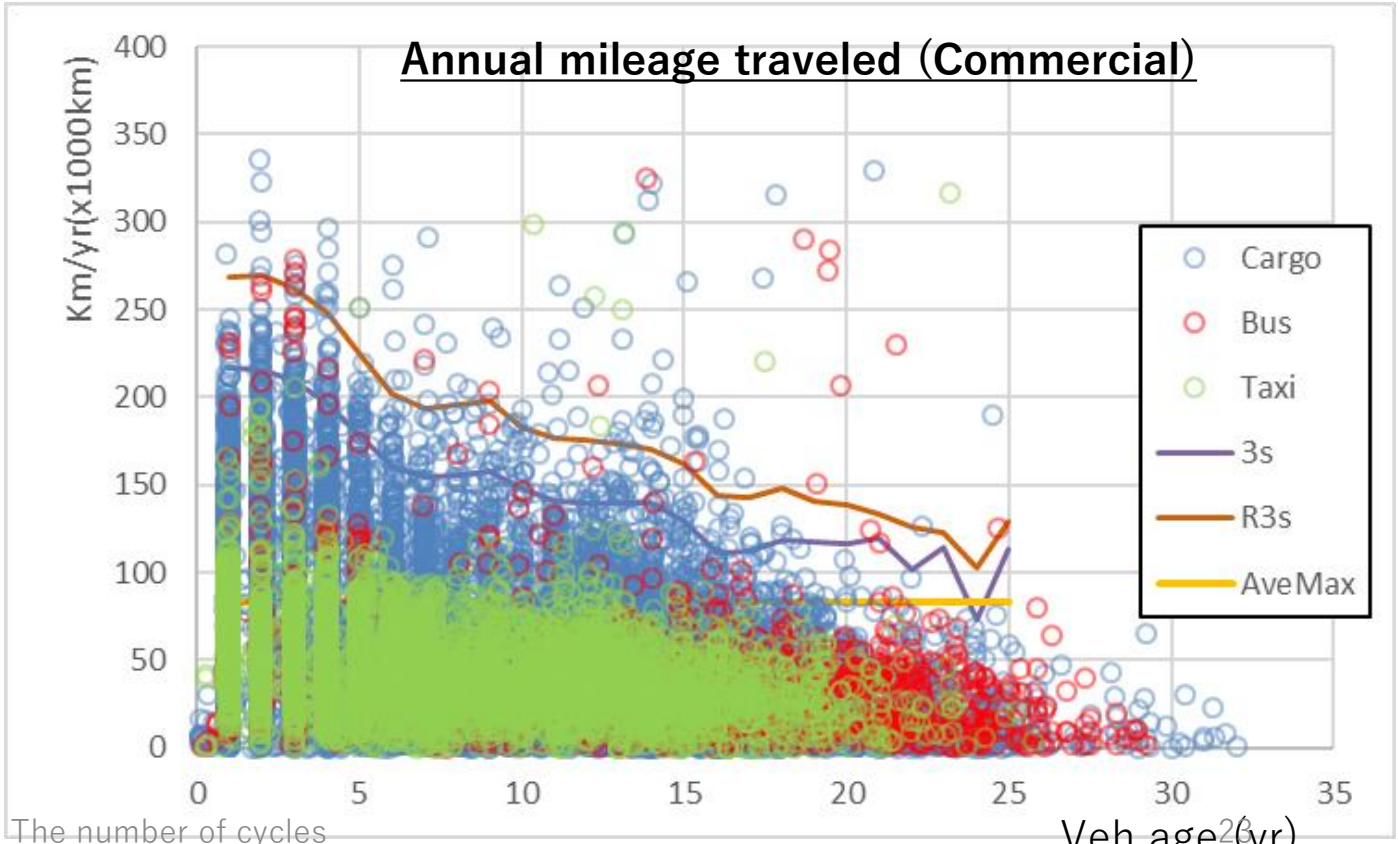
Summary

In view of statistical analysis, using “Root VMT” to calculate averages and standard deviations is reasonable. However estimated accumulated mileage for 25 years is much higher than reasonably assumed mileages for vehicle life.

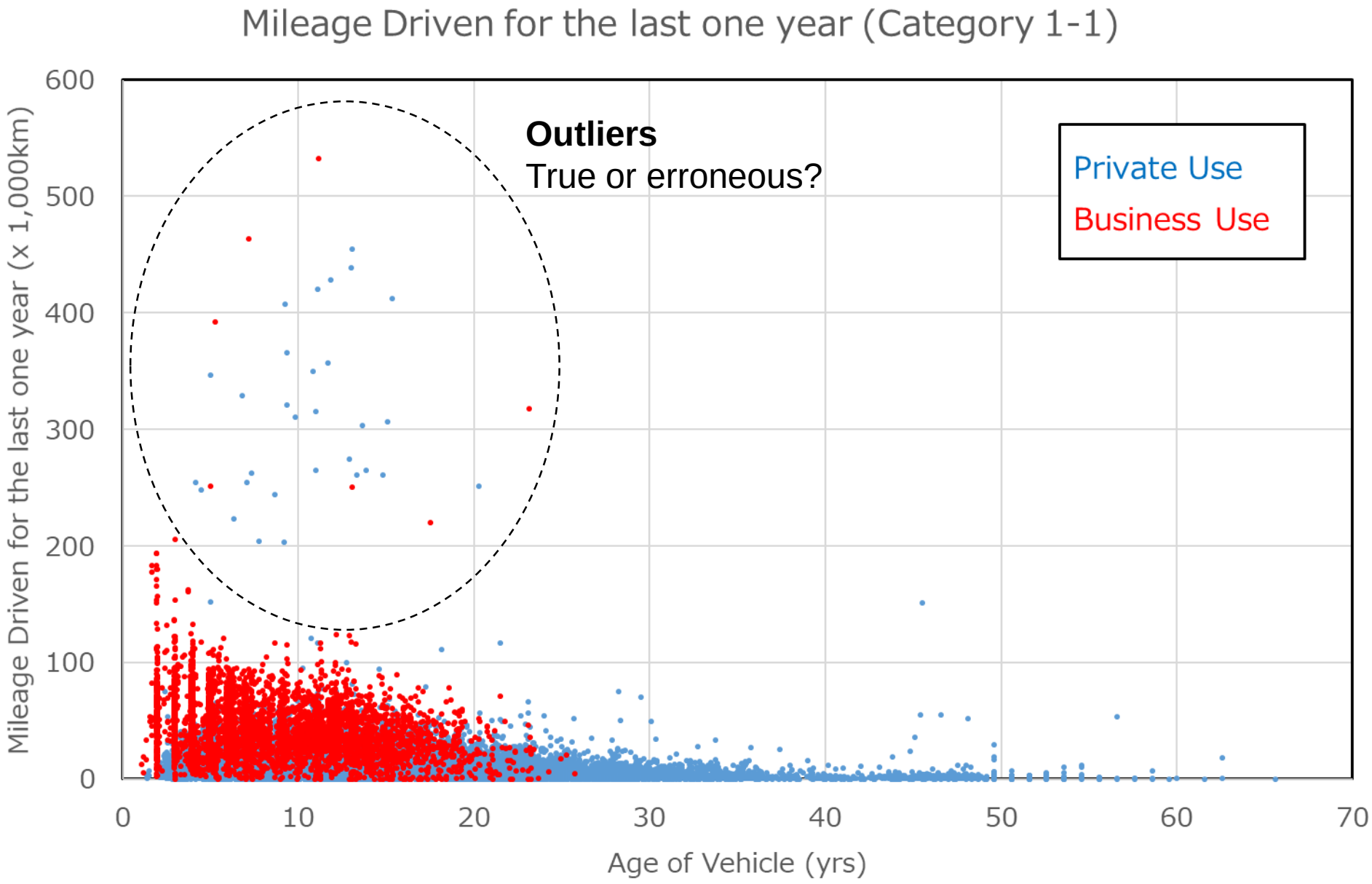
Estimation of worst case VMT for vehicle life

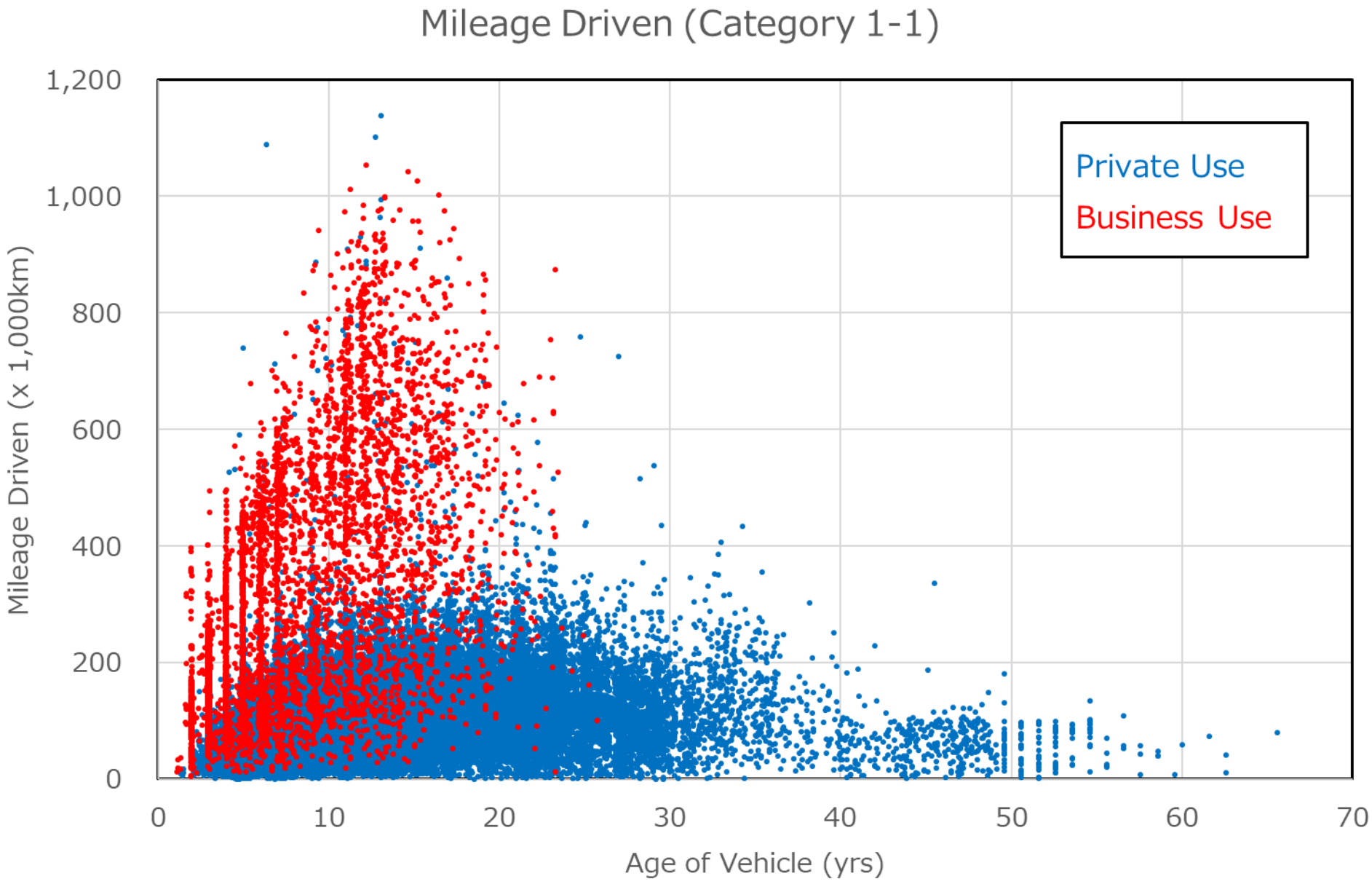
(1) Sum of (average of annual VMT+3s) (3s)
(2) Apply (1) using square root values of the annual mileages. (R3s)
(3) Longest annual VMT x Yrs (AveMax)

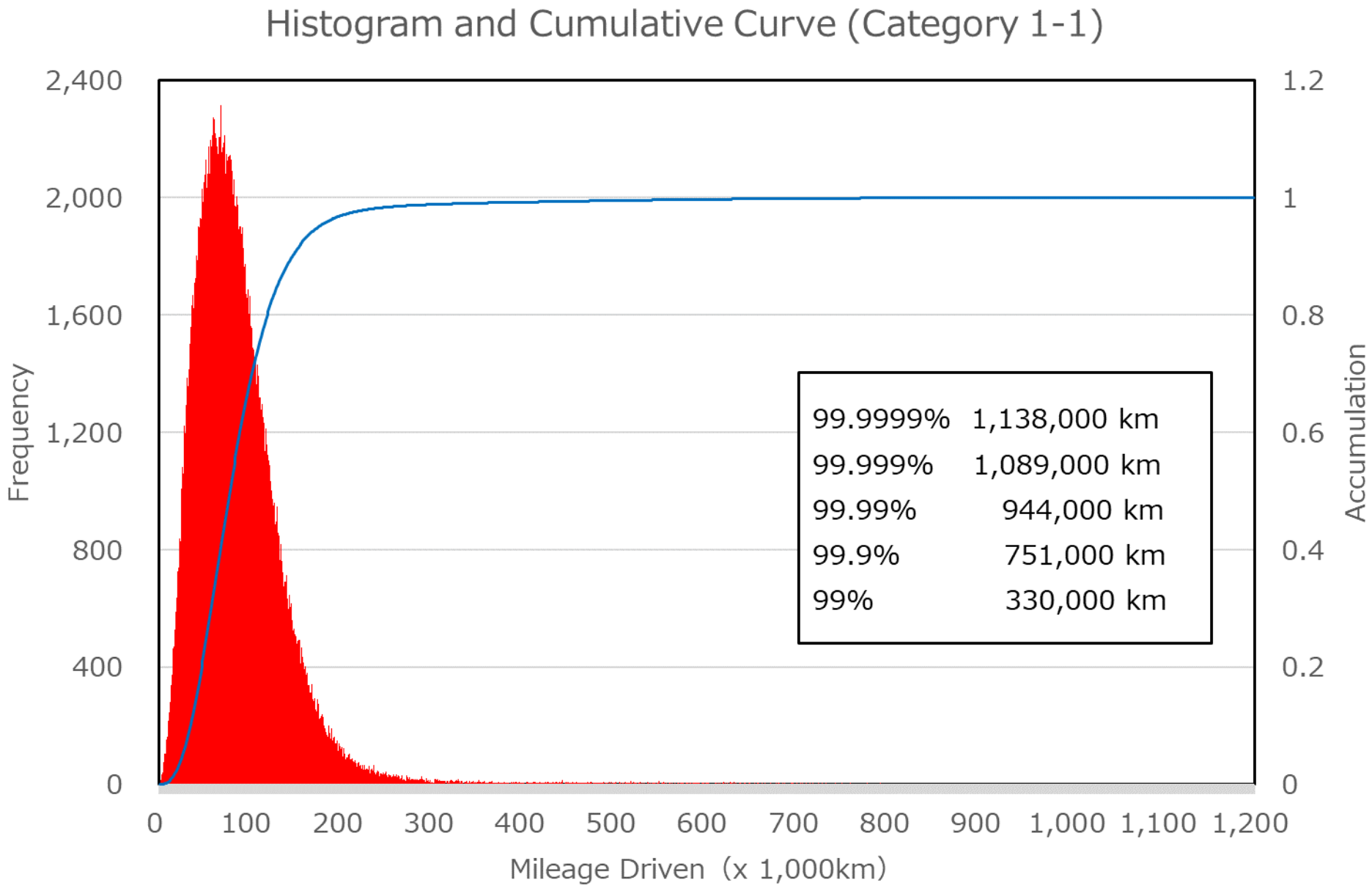
x1000km	Ave+3s (3s)	R(Ave+3s) (R3s)	AveMax x Yr (AveMax)
15years	2,481	3,104	1,254
20years	3,058	3,819	1,672
25years	**3,581**	**4,433**	**2,090**
Fills / 320km	11,191	13,853	6,531

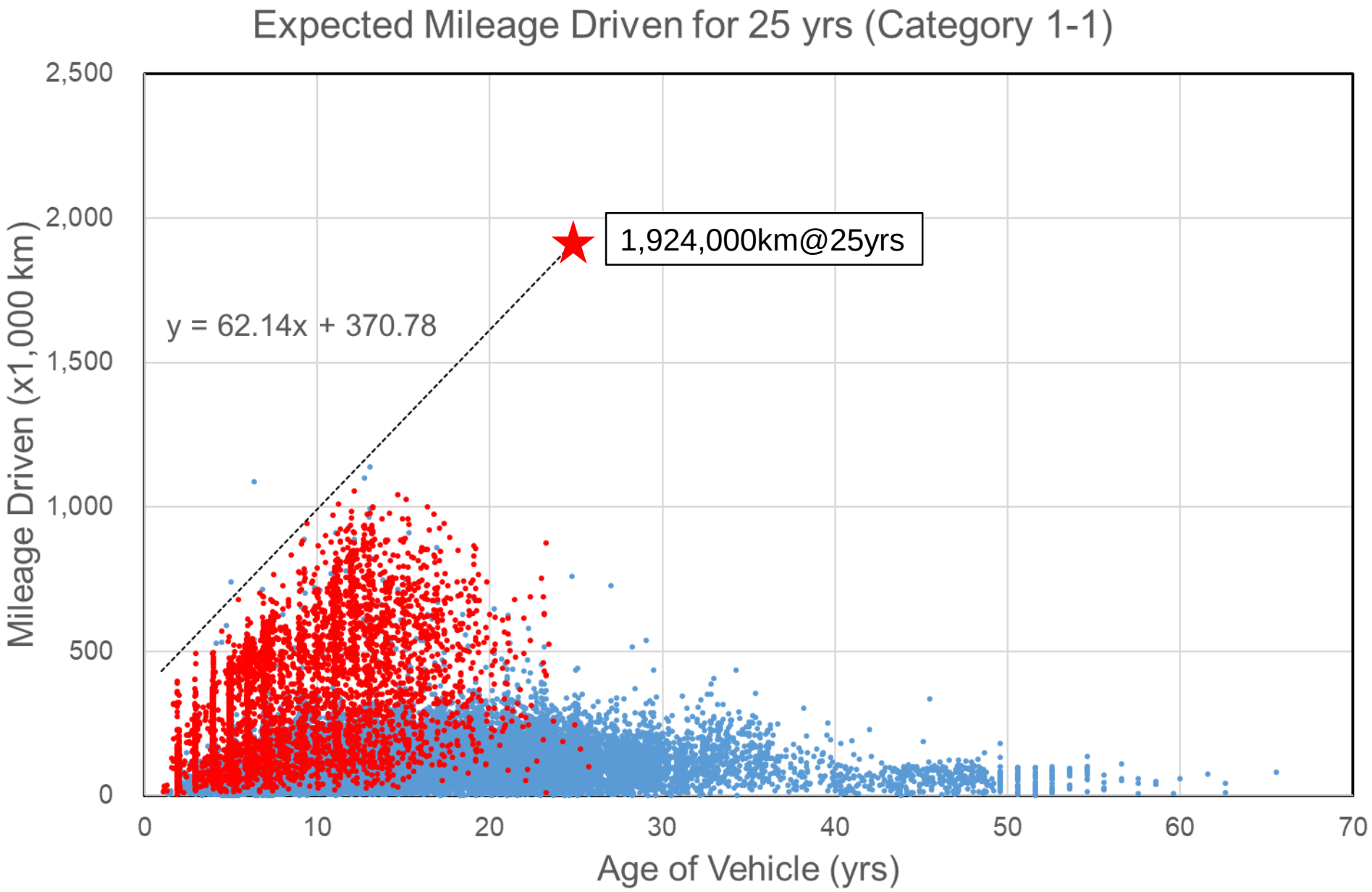


Japan Data for LDV


Mileage Driven for the last one year (Category 1-1)
Outliers
True or erroneous?
Private Use
Business Use
Mileage Driven for the last one year (x 1,000km)
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
Age of Vehicle (yrs)


Mileage Driven (Category 1-1)
Mileage Driven (x 1,000km)
1,200
1,000
800
600
400
200
0
0
10
20
30
40
50
60
70
Age of Vehicle (yrs)
Private Use
Business Use


Histogram and Cumulative Curve (Category 1-1)
Frequency
Accumulation
Mileage Driven（x 1,000km）
2,400
2,000
1,600
1,200
800
400
0
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
99.9999% 1,138,000 km
99.999% 1,089,000 km
99.99% 944,000 km
99.9% 751,000 km
99% 330,000 km


Expected Mileage Driven for 25 yrs (Category 1-1)
1,924,000km@25yrs
y = 62.14x + 370.78
Mileage Driven (x1,000 km)
2,500
2,000
1,500
1,000
500
0
0
10
20
30
40
50
60
70
Age of Vehicle (yrs)