**Extension of the service life of the container to 25 years**
**– Determination of the number of the pressure test cycles**

JAMA

The maximum lifetime miles traveled within the category of LDV/T and HDV/T were estimated to determine the number of the pressure test cycles. The study is based on the vehicles in Japan.

## 1. Japanese (JAMA) study

### (1) Summary

The estimated maximum lifetime miles traveled and lifetime number of pressure cycles are shown in Table 1. It is considered that the 1,1000 cycles in the pressure cycle test of current GTR13 can be applied to both heavy duty and light duty vehicles for 25 years.

The analyzed data were Japanese legal inspection records in July 2017. The number of record was about 6,000 for LDV/T and 21,000 for HDV/T.

The maximum lifetime miles traveled was calculated by summing the estimated maximum VMT (Vehicle Mileage Traveled) in each vehicle age. Number of pressure cycles were calculated by applying a fill per traveled mileage of 320 km for light duty and 400 km for heavy duty.

Table 1. Results of Japanese study

| Vehicle Type | Max svc. life | Max lifetime miles traveled | Lifetime N of fills (=pressure test cycles) |
|---|---|---|---|
| HD Commercial | 20 yrs<br>25 yrs | 3,500,000 km<br>4,000,000 km | 8,500<br>9,800 (fill / 400km) |
| LD Commercial | 20 yrs<br>25 yrs | 2,100,000 km<br>2,400,000 km | 6,600<br>7,400 (fill/320km) |

### (2) Points of the study

#### ① Analyzed data

The major items of the inspection records are shown in Table 2. They were obtained in the legal inspection in July 2017 from about 400 thousands on-road vehicles.

Special note is;

- HDV/T are defined as below:
  Number of seats>10 (according to Japanese categorization)
  Loading capacity>1250kg (assuming the vehicle weight more than 3,500kg)

Table 2. Major items in Japanese inspection records

| Registration | Fuel type | Type | Use | Seats | Loading (kg) | Odo (km) | Odo-last* (km) |
|---|---|---|---|---|---|---|---|
| 1954-Jan ~ | Gasoline | Passenger | Personal | 0 ~ 89 | 0 ~ | 0 ~ | 0 ~ |
| 2019-Jun | Diesel | Cargo | Commercial | | 255,260 | 999,999 | 999,999 |
| | CNG | Bus | | | | | |
| | LPG | Special | | | | | |
| | Electric | | | | | | |
| | HEV | | | | | | |
| | Dual-LPG/Gas | | | | | | |
| | Hydrogen | | | | | | |

② **Estimation of maximum lifetime miles and pressure test cycles**

The annual VMT (km/year) in each vehicle was calculated by the difference between the records at this inspection and last inspection as below.

$$VMT_{year}\ (km/yr) = \{Odometer\ display\ (This\ inspection - Last\ inspection)\} / (Inspection\ period)$$

The maximum vehicle miles traveled ($_{max}VMT_{year}$) in each vehicle age was calculated by adding 3 times standard deviation of $VMT_{year}$ to the average.

$$_{max}VMT_{year} = {}_{ave}VMT_{year} + 3_{sigma}VMT_{year}$$

Maximum lifetime miles traveled ($VMT_{life}$) was calculated by summing $_{max}VMT_{year}$ for the years.

$$VMT_{life}\ (km) = \Sigma\, {}_{max}VMT_{year}$$

The results are shown in Figure 1 (LDV) and 2 (HDV). As shown in these figures It is appropriate to use 3 times standard deviation since 6 times standard deviation shows significantly higher mileage. Furthermore as shown in Table 1 HDV/T lifetime mileage for 25 years using 3 times standard deviation is considered to be higher than actual mileage in the market. Using 6 times standard deviation gives extremely higher mileage.

③ **Analysis of the commercial vehicle data**

The commercial vehicle data were used to estimate the maximum lifetime mileage traveled since the commercial vehicles travel more mileage than the personal vehicles as shown in Figure 3 and 4.

④ **Estimation of filling interval**

The number of lifetime fillings were calculated by dividing $VMT_{life}$ by the filling interval. In the case of GTR13 the filling interval of 320km was applied to LDV/T. In this study, the same value was applied to LDV/T and 400km was applied to HDV/T. It is reasonable to consider

that HDV/Ts have longer filling interval than LDV/T since their longer mileage traveled. It is difficult to get data based filling interval of HFCV HDV/Ts but 400km can be considered to be sufficiently conservative value.

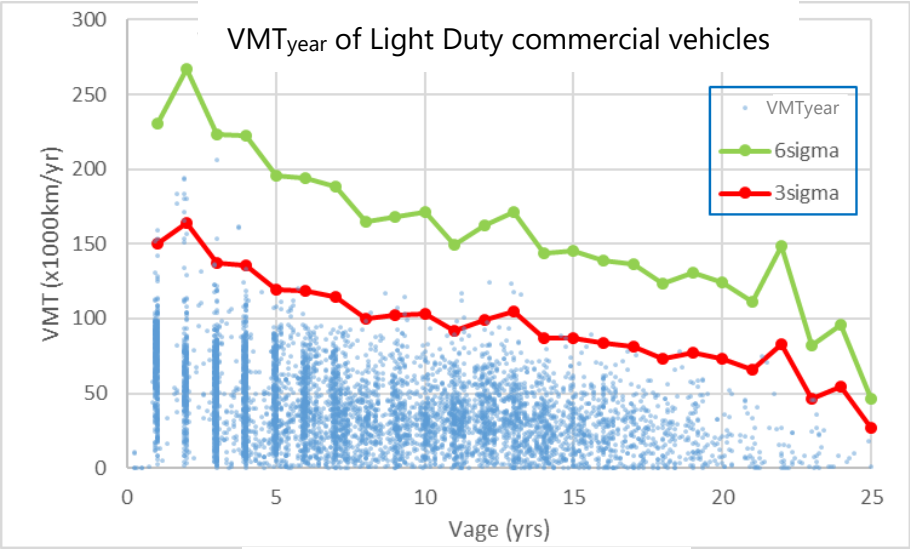


Figure 1. $VMT_{year}$ of LDV/T

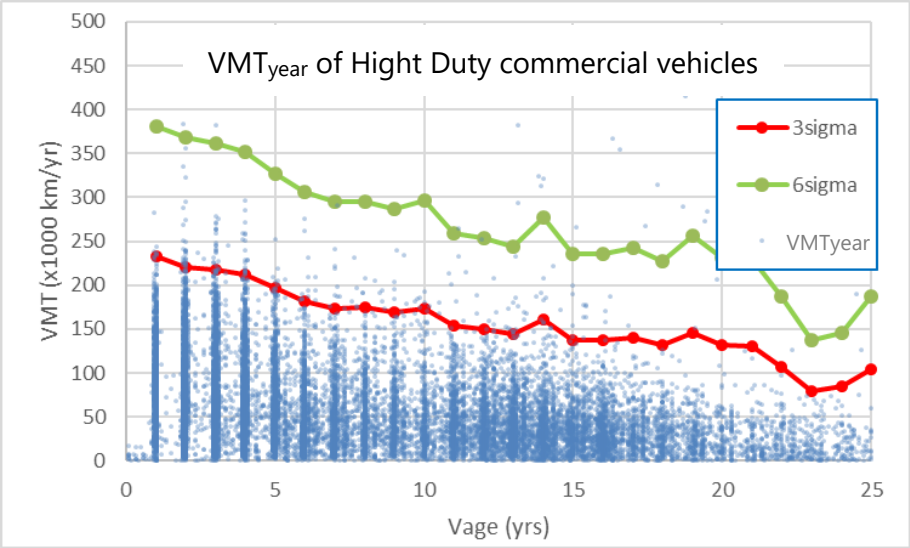


Figure 2. $VMT_{year}$ of HDV/T

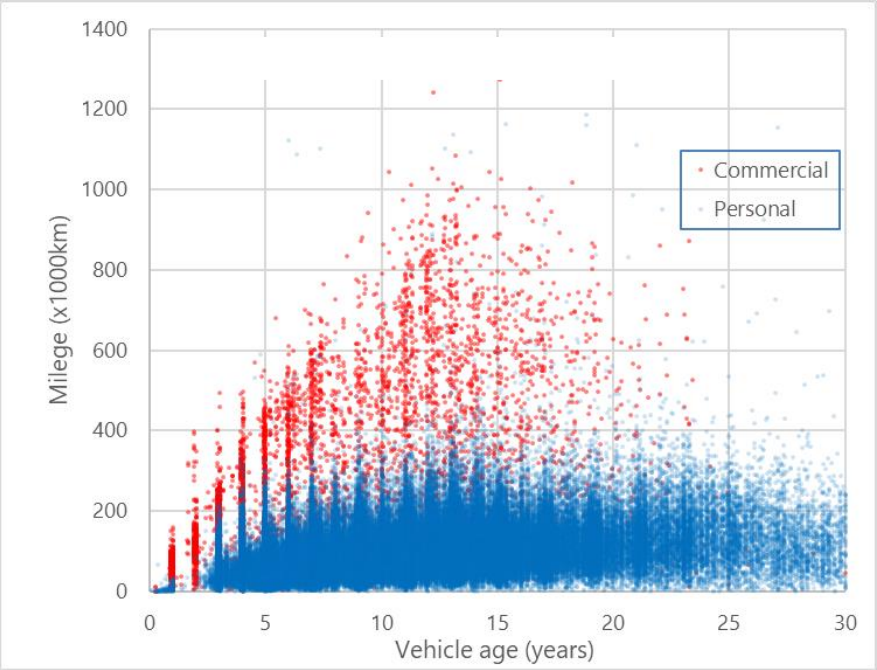


Figure 3. Lifetime VMT (LDV/T commercial)

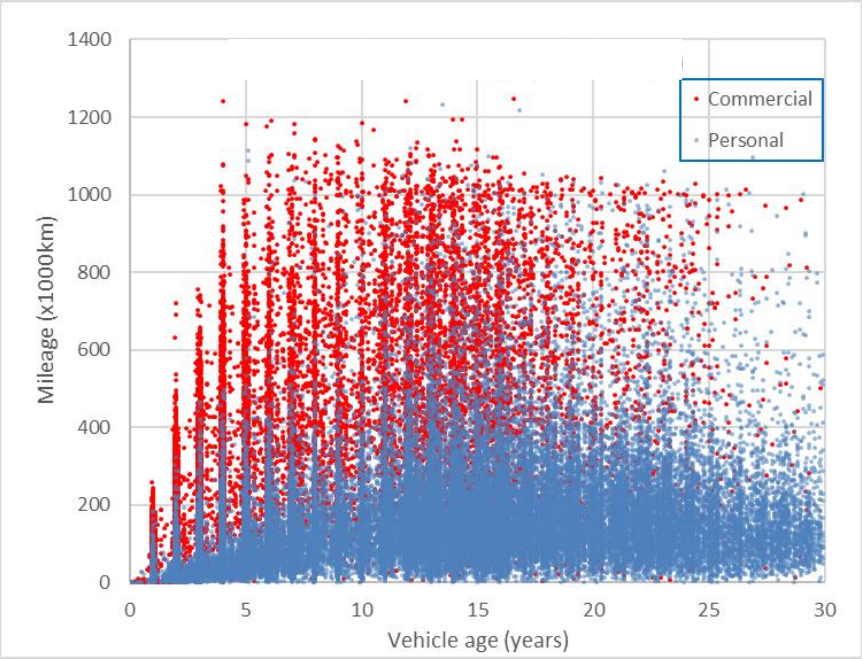


Figure 4. Lifetime VMT (HDV/T commercial)

### (3) Data filtration

#### ① Subzero values of odometer records

Odometer records have limitation because of the number of digits of the meters. Most of them were 6 digits (max. 999,999 km) and some were 5 digits. As shown in Figure 5 the raw odometer records have limitation of 1 million km.

As can be seen in Figure 6 there are hundreds of subzero records. The data of sub-zero $VMT_{year}$ was assumed that the accumulated mileage was more than maximum value of the odometer. Add 1,000,000km to these subzero records in the case of 6 digits odometer and 100,000km for the 5 digits odometers. The results are shown in Figure 7.

#### ② Remove outliers

The extremely high $VMT_{year}$ shown in Figure 7 were removed as outliers. In this study threshold of maximum effective VMTyear was defined to the maximum value of the sum of averaged VMTyear and 6 times standard deviation within the first 5 years of the vehicle ages. It is shown that the VMTyear of early vehicle ages are higher than the older ones. The result of removal of outliers is shown in Figure 8. The threshold valued calculated for LDV/T, HDV/T and all vehicles are shown Table 3.

Table 3. Thresholds of maximum effective $VMT_{year}$

| | Averaged VMT + 6 x Standard deviation | | | | |
|---|---|---|---|---|---|
| **Vehicle age (years)** | **1** | **2** | **3** | **4** | **5** |
| **LDV/T** | 230,792 | **267,266** | 223,323 | 222,726 | 195,429 |
| **HDV/T** | 380,786 | 385,961 | **473,590** | 374,449 | 341,294 |
| **All vehicles** | **351,617** | 331,483 | 297,636 | 251,214 | 231,438 |

Under Japanese traffic conditions it is reasonable to consider to be very rare or none such vehicle that would travel 1000km in everyday through the year ($VMT_{year}$=356k km/yr). Although the threshold of HDV/T in Table 3 is much higher than this value the threshold in the table was used. It is because the effects of the change of the threshold in such extent are negligible since the number of influenced outliers are few.

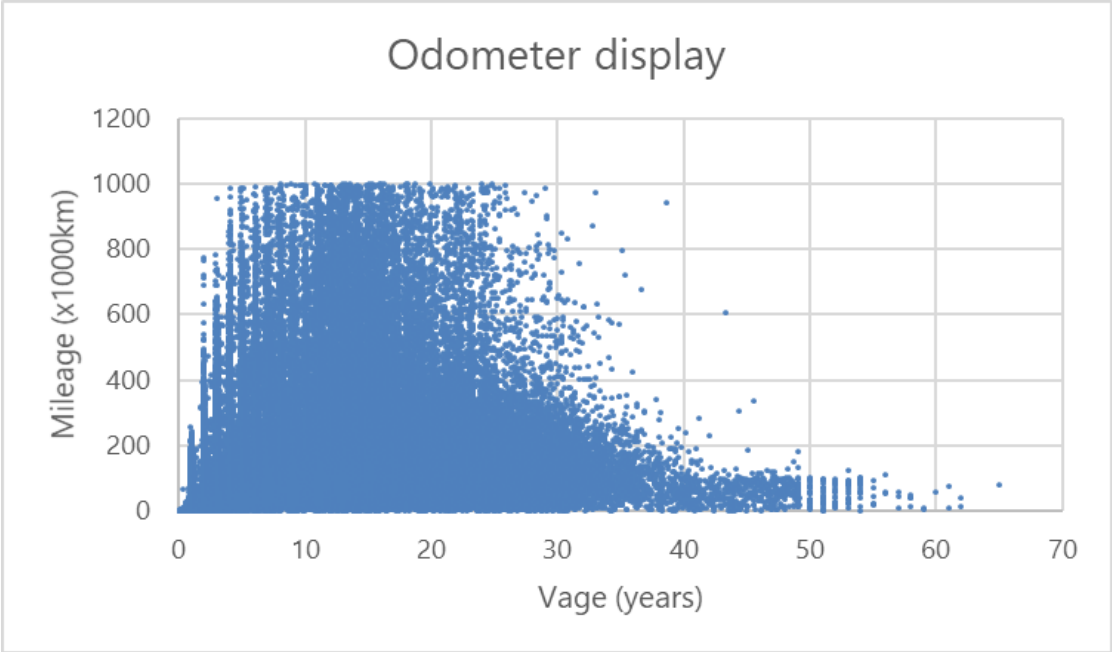


Figure 5. Odometer display (all vehicles)

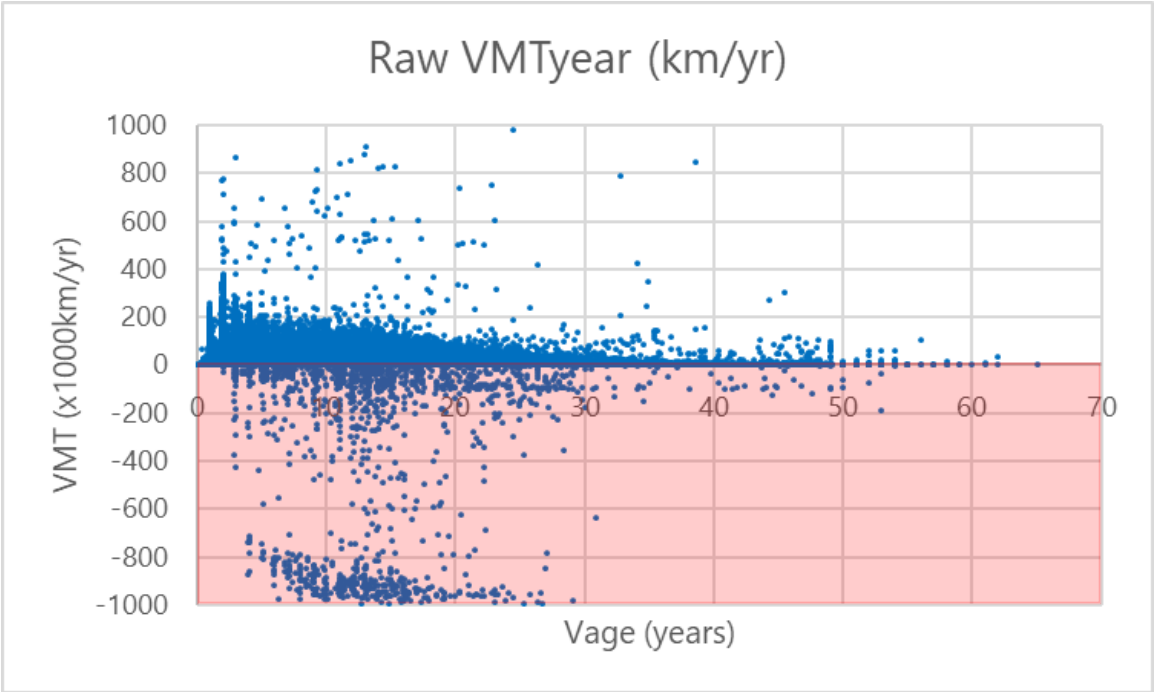


Figure 6. Annual VMT (km/year) – Raw data

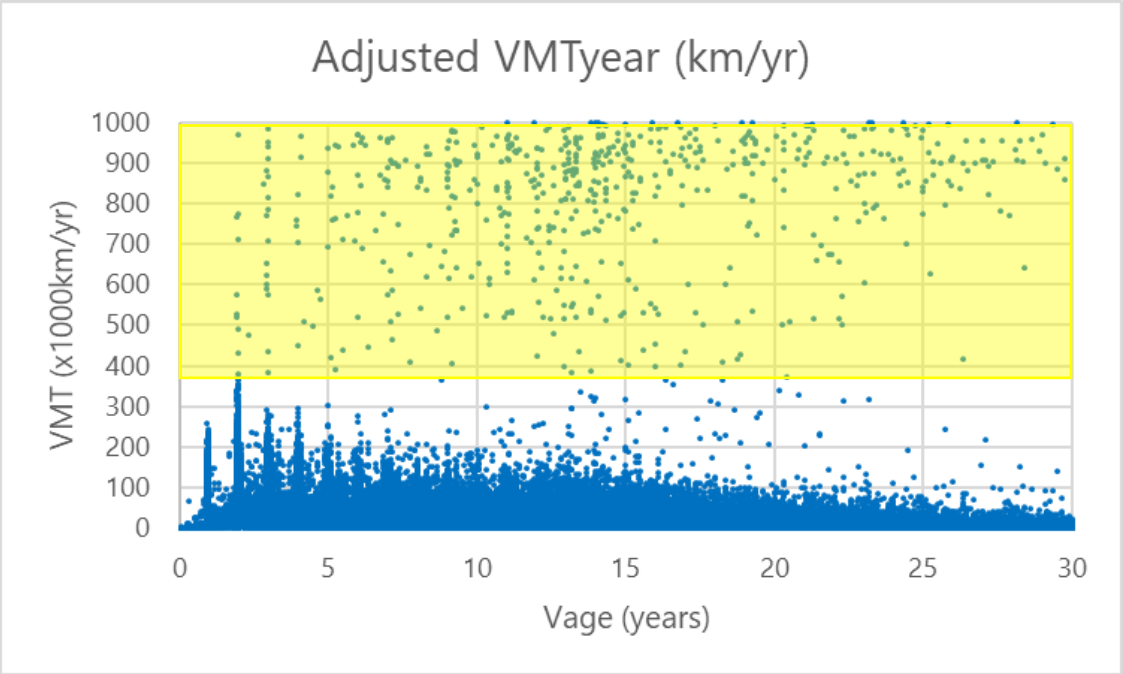


Figure 7. Annual VMT (km/year) – Adjusted the sub-zero data

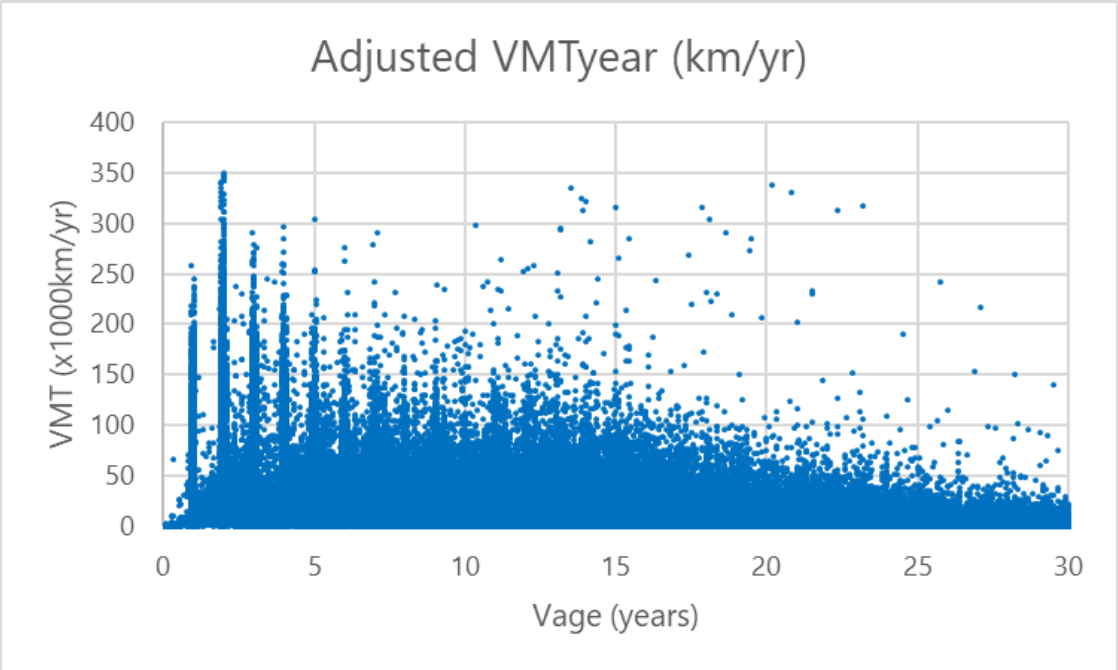


Figure 8. Annual VMT (km/year) – Adjusted the outliers