Joule2Wear

js

2024-02-07

Relate forces to wear

Trying machine learning (random forest) to test the relation between forces on a car during a length of track and the amount of wear on the tyres, as measured by IDIADA. First set constants and prepare to calculate the forces given the track description. Also define a helper function. Roll coefficients of the tyres are mostly mission, the average velocity per section of the track is used as a proxy for the roll resistance. The end results are the aggragations of all sections for each track. Also the total distance is needed per section.

```
#ThisData
m_vehicle = 1644
heavy_veh = 1868
#Vehicle surface area in m^2
A_vehicle = 2.629
#Vehicle aerodynamic drag coefficient
c_drag = 0.347
### Gravitational constant in m.s^-2
grav_constant = 9.81
## Landscape data ##
###Density of air in kg.m^-3
rho_air = 1.205

#'@param v_start Velocity at the start of the section of the track (m/s)
#'@param v_end Acceleration time (s)
#'@param dv Acceleration/Descelaration constant of the vehicle (m/s^2)
dv_distance <- function(v_start, v_end, dv) {
  dv_time <- abs((v_start-v_end)/dv)
  v_start*dv_time+1/2*dv*dv_time^2
}

AirResist <- function (c_drag,
          A_vehicle,
          rho_air,
          velocity_kmh
          # v_wind #no data; circuit goes 360.. neglected
        ) {
  pmax(0, c_drag * A_vehicle * rho_air * velocity_kmh^2)
}

TrackFilename <- "data/IDIADA track data/IDIDAsTables.xlsx" #/rivm/r/E121554 LEON-T/03 - uitvoering WP3/
Tracks <- openxlsx::getSheetNames(TrackFilename)
#First separate General and read them all
general <- openxlsx::read.xlsx(xlsxFile = TrackFilename, sheet = "general")
TracksData <- list()
```

```
TrackSumData <- list()
for (Track in Tracks[Tracks != "general"]) {#Track = "rural5"
  TracksData[[Track]] <- openxlsx::read.xlsx(TrackFilename, sheet = Track)
  #km/h to m/s conversion
  TracksData[[Track]]$velocity <- TracksData[[Track]]$velocity_kmh * 1000 / 3600
  TracksData[[Track]]$start_velocity <- TracksData[[Track]]$start_velocity_kmh * 1000 / 3600
}
#TracksData
finalNames <- c("distance", "velocity", "start_velocity", "corner_radius" )
for (TrackName in names(TracksData)) {#TrackName = "urban2"
  Track <- TracksData[[TrackName]]
  #remove testTot, if needed
  if ("testTot" %in% names(Track)) {
    Track <- Track[,names(Track)[names(Track)!="testTot"]]
  }
  #1 expand sectionRepeat, if needed
  if ("sectionRepeat" %in% names(Track)) {
    Track$sectionRepeat[is.na(Track$sectionRepeat)] <- 1
    SepRows <- lapply(1:nrow(Track), function(numline){ #numline = 1
     cbind(as.data.frame(lapply(Track[numline,names(Track)[names(Track)!="sectionRepeat"]], rep, Track[
    })
    Track <- do.call(rbind,SepRows)
  }
  #2 repeat df, re-bind
  #AddOs <- T # add section to start and end at v = 0
  TotTrack <- cbind(as.data.frame(lapply(Track, rep, general$repeats[general$TrackName == TrackName])))
  # A exception 5*6 = 27 corrected in the last four rows for "rural6"
  if (TrackName == "rural6"){
    Aggr4 <- aggregate(distance ~ corner_radius + velocity , data = tail(TotTrack, 3), FUN = sum)
    Aggr4$start_velocity = Aggr4$velocity
    TotTrack <- rbind(head(TotTrack[, finalNames], nrow(TotTrack) - 3),
                      Aggr4[, finalNames])
  } else {
    TotTrack <- TotTrack[,finalNames]
  }
  #3 acceleration decel distances; begin and end at 0
  accellDist <- dv_distance(c(0,TotTrack$start_velocity),
                            c(TotTrack$start_velocity[1], TotTrack$velocity),
                            general$accel_ms2[general$TrackName == TrackName])
  StartNext <- c(TotTrack$start_velocity[-1], 0)
  descelDist <-  dv_distance(c(TotTrack$velocity),
                             StartNext,
                             - general$decel_ms2[general$TrackName == TrackName])
  #correct and split for ascel distances
  nwAscelRows <- which(accellDist[-1] > 0)
  if (length(nwAscelRows) > 0) {
    AscelDf <- data.frame(
      distance = accellDist[-1][nwAscelRows],
      velocity = (TotTrack$velocity[nwAscelRows] + TotTrack$start_velocity[nwAscelRows]) / 2, #mean
      start_velocity = TotTrack$start_velocity[nwAscelRows],
      corner_radius = TotTrack$corner_radius[nwAscelRows],
      centrfac = 0, # no ascel in corners
      accelleration = general$accel_ms2[general$TrackName == TrackName]
```

```
  )
  TotTrack$distance[nwAscelRows] <- TotTrack$distance[nwAscelRows] - AscelDf$distance
} else AscelDf <- NULL
nwDecelRows <-  which(descelDist > 0)
#the last is not in TotTrack, so
nwDecelRows <- nwDecelRows[nwDecelRows != nrow(TotTrack)]
if (length(nwDecelRows) > 0) {
  DecelDf <- data.frame(
    distance = descelDist[nwDecelRows],
    velocity = (TotTrack$velocity[nwDecelRows] + TotTrack$start_velocity[nwDecelRows + 1]) / 2, #mean
    start_velocity = TotTrack$start_velocity[nwDecelRows],
    corner_radius = TotTrack$corner_radius[nwDecelRows],
    centrfac = 0, # no descel in corners
    accelleration = -general$decel_ms2[general$TrackName == TrackName]
  )
  TotTrack$distance[nwDecelRows] <- TotTrack$distance[nwDecelRows] - DecelDf$distance
} else DecelDf <- NULL
TotTrack$centrfac <- ifelse(TotTrack$corner_radius == 0, 0, TotTrack$velocity^2 / TotTrack$corner_radi
TotTrack$accelleration <- 0
SectTrack <- rbind(
  TotTrack[,c(finalNames, "accelleration", "centrfac")],
  AscelDf[,c(finalNames, "accelleration", "centrfac")],
  DecelDf[,c(finalNames, "accelleration", "centrfac")]
)
#check!
# :) sum(SectTrack$distance)

row1 <- data.frame (
  distance = accellDist[1],
  velocity = TotTrack$velocity[1] / 2, #mean
  start_velocity = 0,
  centrfac = 0,
  corner_radius = 0,
  accelleration = general$accel_ms2[general$TrackName == TrackName]
)
lastrow <- data.frame (
  distance = tail(descelDist,1),
  velocity = tail(TotTrack$velocity, 1) / 2, #mean
  start_velocity = tail(TotTrack$velocity, 1),
  corner_radius = 0,
  centrfac = 0,
  accelleration = -general$decel_ms2[general$TrackName == TrackName]
)
SectTrack <- rbind(
  row1[,names(SectTrack)],
  SectTrack,
  lastrow[,names(SectTrack)]
)
SumTrack <- aggregate(distance ~ velocity + centrfac + accelleration,
                      data = SectTrack,
                      FUN = sum)
SumTrack$Track <- TrackName
TrackSumData[[TrackName]] <- SumTrack
```

```
}
TrackSum <- do.call(rbind, TrackSumData)
DistSum <- aggregate(distance~Track, data = TrackSum, FUN = sum)
TrackSum
```

```
##            velocity    centrfac accelleration     distance   Track
## urban1.1   2.777778   0.0000000         -1.11     13.90279  urban1
## urban1.2   5.555556  -5.2759312          0.00    210.00000  urban1
## urban1.3   5.555556  -1.6159266          0.00   1560.00000  urban1
## urban1.4   5.555556   0.0000000          0.00  11460.00000  urban1
## urban1.5   5.555556   1.6159266          0.00   1560.00000  urban1
## urban1.6   5.555556   5.2759312          0.00    210.00000  urban1
## urban1.7   2.777778   0.0000000          1.11     13.90279  urban1
## urban2.1   2.777778   0.0000000         -1.11    152.93071  urban2
## urban2.2   5.555556  -5.2759312          0.00     70.00000  urban2
## urban2.3   5.555556  -1.6159266          0.00    520.00000  urban2
## urban2.4   5.555556   0.0000000          0.00   3541.94417  urban2
## urban2.5   5.555556   1.6159266          0.00    520.00000  urban2
## urban2.6   5.555556   5.2759312          0.00     70.00000  urban2
## urban2.7   2.777778   0.0000000          1.11    152.93071  urban2
## urban3.1   4.166667   0.0000000         -2.94    602.32426  urban3
## urban3.2   6.944444   0.0000000         -2.94    334.62459  urban3
## urban3.3   8.333333 -11.8708452          0.00    357.00000  urban3
## urban3.4   5.555556  -1.6159266          0.00   2652.00000  urban3
## urban3.5   8.333333   0.0000000          0.00  34111.23180  urban3
## urban3.6   4.166667   0.0000000          1.00   1770.83333  urban3
## urban3.7   6.944444   0.0000000          1.00    983.79630  urban3
## urban4.1   5.555556   0.0000000         -2.94   1196.77501  urban4
## urban4.2   8.333333   0.0000000         -2.94    897.58125  urban4
## urban4.3  11.111111 -21.1037248          0.00    399.00000  urban4
## urban4.4   5.555556  -1.6159266          0.00   2964.00000  urban4
## urban4.5  11.111111   0.0000000          0.00  34006.23238  urban4
## urban4.6   5.555556   0.0000000          1.00   3518.51852  urban4
## urban4.7   8.333333   0.0000000          1.00   2638.88889  urban4
## rural5.1   8.333333   0.0000000         -1.00    138.88889  rural5
## rural5.2  15.277778   0.0000000         -1.00    679.01235  rural5
## rural5.3  16.666667   0.0000000          0.00   7641.97531  rural5
## rural5.4  16.666667   0.5910165          0.00   6000.00000  rural5
## rural5.5   8.333333   0.0000000          1.00    138.88889  rural5
## rural5.6  15.277778   0.0000000          1.00    679.01235  rural5
## rural6.1   9.722222   0.0000000         -1.40    135.03086  rural6
## rural6.2  16.666667   0.0000000         -1.40   1785.71429  rural6
## rural6.3  19.444444   0.0000000          0.00  18528.57143  rural6
## rural6.4  19.444444   0.8044392          0.00  15000.00000  rural6
## rural6.5   9.722222   0.0000000          1.40    135.03086  rural6
## rural6.6  16.666667   0.0000000          1.40   1785.71429  rural6
## rural7.1  11.111111   0.0000000         -2.94     83.98421  rural7
## rural7.2  18.055556   0.0000000         -2.94   1535.33636  rural7
## rural7.3  22.222222   0.0000000          0.00  17828.97341  rural7
## rural7.4  22.222222   1.0288066          0.00  15000.00000  rural7
## rural7.5  11.111111   0.0000000          1.65    149.64459  rural7
## rural7.6  18.055556   0.0000000          1.65   2735.69024  rural7
## motway8.1 18.055556   0.0000000         -2.94    221.77081 motway8
## motway8.2 25.000000   0.0000000         -2.94   2834.46712 motway8
```

```
## motway8.3 36.111111   0.0000000          0.00  54708.97732 motway8
## motway8.4 36.111111   2.7166924          0.00  45000.00000 motway8
## motway8.5 18.055556   0.0000000          1.50    434.67078 motway8
## motway8.6 25.000000   0.0000000          1.50   5555.55556 motway8
## RunIn.1   18.055556   0.0000000         -1.50    434.67078   RunIn
## RunIn.2   29.166667   0.0000000         -1.50  33757.71605   RunIn
## RunIn.3   36.111111   0.0000000          0.00 203114.50617   RunIn
## RunIn.4   22.222222   1.0288066          0.00 189000.00000   RunIn
## RunIn.5   11.111111   0.0000000          1.50    164.60905   RunIn
## RunIn.6   29.166667   0.0000000          1.50  34027.77778   RunIn
```

Next step is to apply physics where we can. We postpone the multiplication by mass, this comes later when we deal with the tyre data and apply the right mass.

```
#from f / mass + distance to J / mass.km
perkmTrack <- list()
for (TrackName in names(TrackSumData)){#TrackName = "RunIn" names(TrackSumData)[2]
  TRfr <- TrackSumData[[TrackName]]
  TRfr$duration <- TRfr$distance / TRfr$velocity
  TotDistKm <- DistSum$distance[DistSum$Track == TrackName]
  TRfr$centrW_g_1 <- abs(TRfr$centrfac) * TRfr$duration / TotDistKm
  TRfr$decelW_g_1 <- -min(0, TRfr$accelleration) * TRfr$duration / TotDistKm
  TRfr$accelW_g_1 <- max(0, TRfr$accelleration) * TRfr$duration / TotDistKm
  TRfr$airRes_Ac_1 <- AirResist(c_drag, A_vehicle, rho_air, velocity_kmh = TRfr$velocity) / TotDistKm
  perkmTrack[[TrackName]] <- c(
                  centrW_g_1 = sum(TRfr$centrW_g_1),
                  decelW_g_1 = sum(TRfr$decelW_g_1),
                  accelW_g_1 = sum(TRfr$accelW_g_1),
                  airRes_Ac_1 = sum(TRfr$airRes_Ac_1)
                  )
}
perkmTrack <- as.data.frame(do.call(rbind, perkmTrack))
perkmTrack
```

```
##         centrW_g_1 decelW_g_1 accelW_g_1 airRes_Ac_1
## urban1  0.08692984 0.20016969 0.20016969 0.012417358
## urban2  0.08660934 0.21195463 0.21195463 0.037114730
## urban3  0.03136165 0.38705701 0.13165204 0.008105519
## urban4  0.03550917 0.31597673 0.10747508 0.011527338
## rural5  0.01392650 0.06157576 0.06157576 0.083556149
## rural6  0.01660600 0.07366715 0.07366715 0.044146665
## rural7  0.01860104 0.13662068 0.07667487 0.055549578
## motway8 0.03112871 0.08469829 0.04321341 0.045586435
## RunIn   0.01900112 0.05372214 0.05372214 0.009426077
```

Read the wear data and cleaning

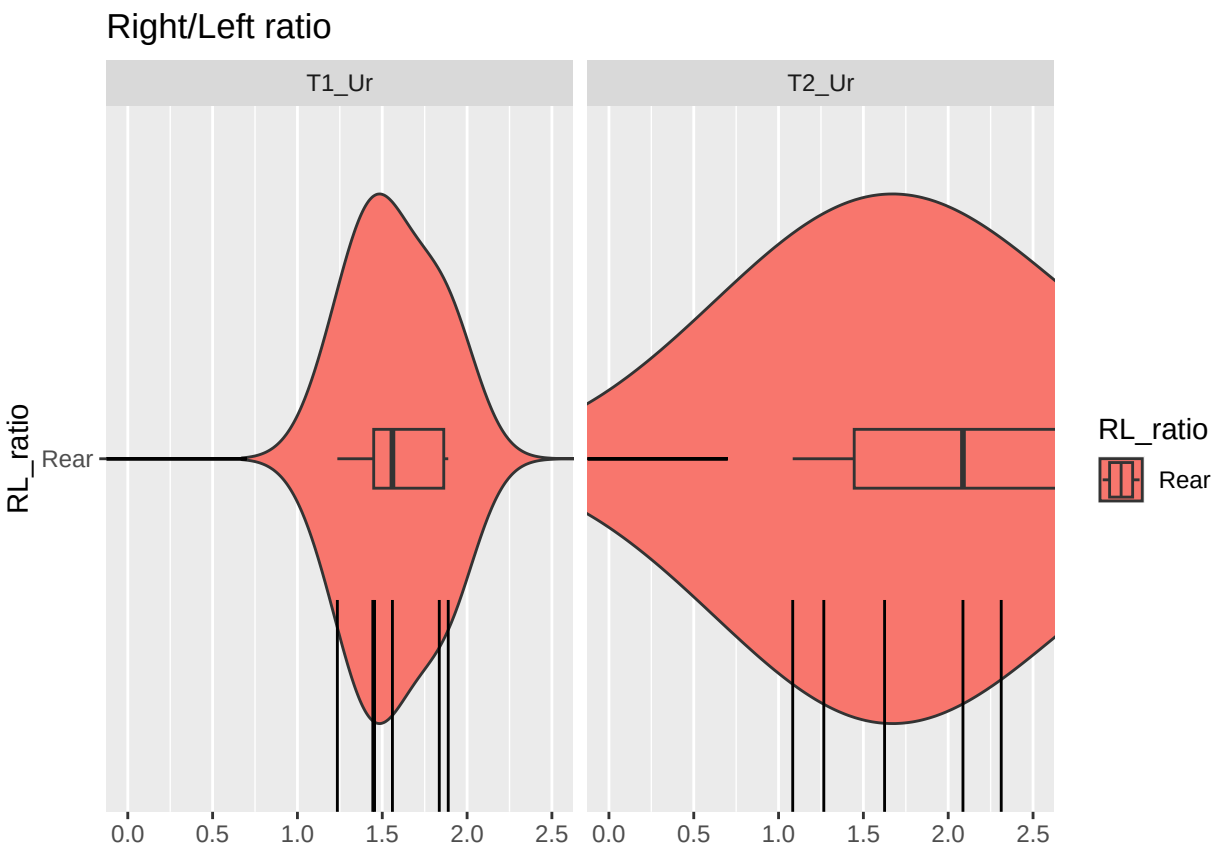
```
library(tidyr)
library(openxlsx)
IDIADAwear <- read.xlsx("data/IDIADA track data/Abrasion test_WP2.3_Leon-T_IDIADA.xlsx", startRow = 10)
#provide proper column names
names(IDIADAwear)[c(1,2)] <- c("Tyre","Wheel")
names(IDIADAwear) <- sapply(names(IDIADAwear), function(x){
  gsub("-", "_", x)
})
#extend Tyre to all its rows
```

```
for(i in 1:nrow(IDIADAwear)){
  if(is.na(IDIADAwear$Tyre[i])){
    IDIADAwear$Tyre[i] <- IDIADAwear$Tyre[i-1]
  }
}
#What?
IDIADAwear$C0 <- NULL
#Track to long format
WearAsLong <- tidyr::pivot_longer(IDIADAwear,
                            cols = names(IDIADAwear)[!names(IDIADAwear) %in% c("Tyre","Wheel")], #,"Whee
                            names_to = "track",
                            values_to = "wear")
WearAsLong$Wheel <- trimws(WearAsLong$Wheel)
WearAsLong$Tyre <- gsub(" ", "", WearAsLong$Tyre)

WearWheelsWideAgain <- tidyr::pivot_wider(WearAsLong, names_from = Wheel, values_from = wear)
#Change Left/Right to Inner/Outer
WearWheelsWideAgain$FInner <- ifelse(endsWith(WearWheelsWideAgain$track, "_Ur"),
                                     WearWheelsWideAgain$FL, WearWheelsWideAgain$FR)
WearWheelsWideAgain$FOuter <- ifelse(endsWith(WearWheelsWideAgain$track, "_Ur"),
                                     WearWheelsWideAgain$FR, WearWheelsWideAgain$FL)
WearWheelsWideAgain$RInner <- ifelse(endsWith(WearWheelsWideAgain$track, "_Ur"),
                                     WearWheelsWideAgain$RL, WearWheelsWideAgain$RR)
WearWheelsWideAgain$ROuter <- ifelse(endsWith(WearWheelsWideAgain$track, "_Ur"),
                                     WearWheelsWideAgain$RR, WearWheelsWideAgain$RL)
WearWheelsWideAgain$Front <- WearWheelsWideAgain$FR / WearWheelsWideAgain$FL
WearWheelsWideAgain$Rear <- WearWheelsWideAgain$RR / WearWheelsWideAgain$RL
#backtolong #1 for plot
WearRLLong <- tidyr::pivot_longer(data = WearWheelsWideAgain,
                                  cols = c("Front", "Rear"), #,"Wheel"
                                  names_to = "RL_ratio",
                                  values_to = "wear")
WearRLLong$RL_ratio <- factor(WearRLLong$RL_ratio, levels = c("Rear", "Front"))
WearRLLong
```

```
## # A tibble: 252 x 13
##    Tyre     track     FR    FL    RR    RL Total FInner FOuter RInner ROuter
##    <chr>    <chr>  <dbl> <dbl> <dbl> <dbl> <dbl>  <dbl>  <dbl>  <dbl>  <dbl>
##  1 LingLong R1     100.   91.6 19.0   29.4  240.  100.    91.6  19.0    29.4
##  2 LingLong R1     100.   91.6 19.0   29.4  240.  100.    91.6  19.0    29.4
##  3 LingLong R2     105.  106.  29.0   40.0  279.  105.   106.   29.0    40.0
##  4 LingLong R2     105.  106.  29.0   40.0  279.  105.   106.   29.0    40.0
##  5 LingLong R3      80.5  95.2  8.65  42.4  227.   80.5   95.2   8.65   42.4
##  6 LingLong R3      80.5  95.2  8.65  42.4  227.   80.5   95.2   8.65   42.4
##  7 LingLong T1_Rur 103.  125.  40.3   40.3  309.  103.   125.   40.3    40.3
##  8 LingLong T1_Rur 103.  125.  40.3   40.3  309.  103.   125.   40.3    40.3
##  9 LingLong T1_Mot 258.  297.  71.6  182.   809.  258.   297.   71.6   182.
## 10 LingLong T1_Mot 258.  297.  71.6  182.   809.  258.   297.   71.6   182.
## # i 242 more rows
## # i 2 more variables: RL_ratio <fct>, wear <dbl>
```

There is something remarkable with the right rear wheel, even for the symmetrical urban 1 and urban 2 tracks, the ones where the car drives in an 8 shape. The LRatio = wear right wheel / wear left wheel. Values above one indicate a higher wear on the right wheel.

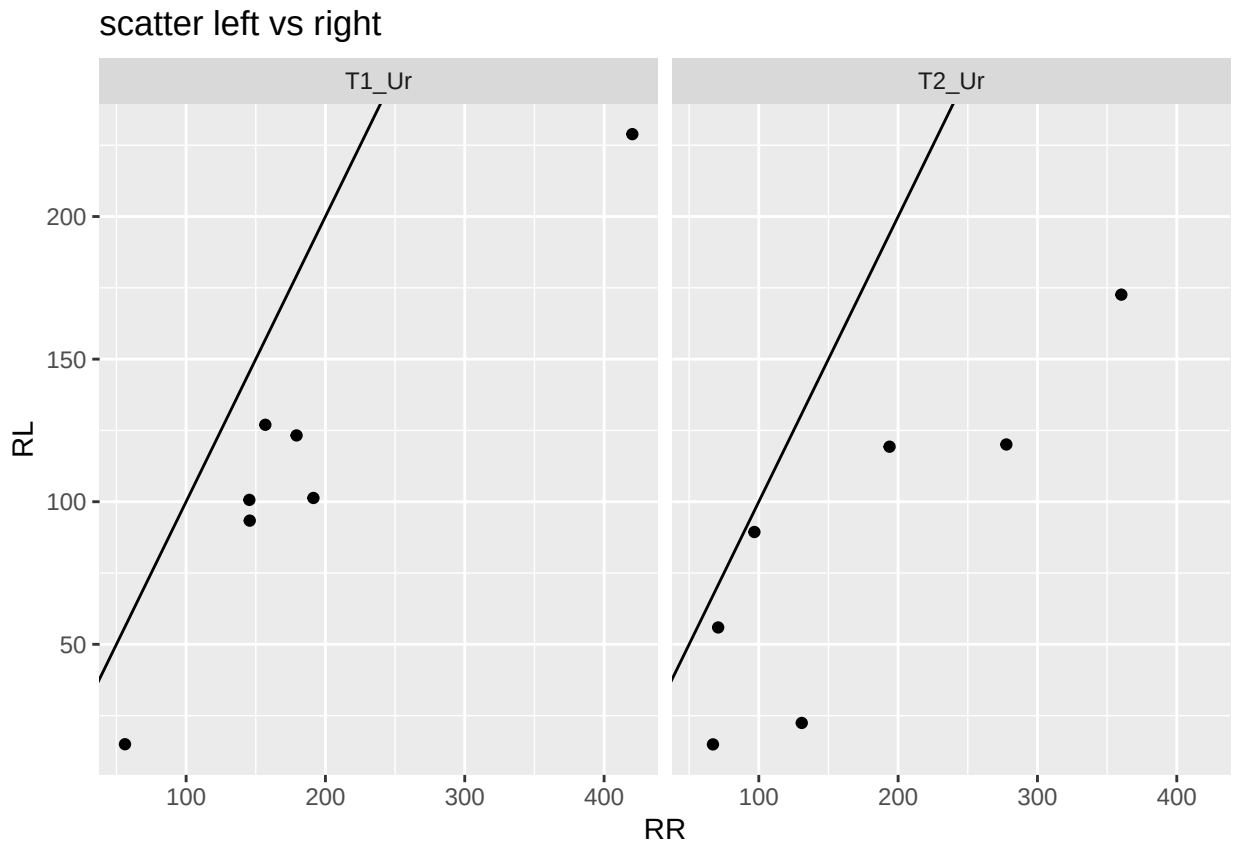
```
library(ggplot2)
ggplot(data = WearRLLong[WearRLLong$track %in% c("T1_Ur", "T2_Ur") & WearRLLong$RL_ratio == "Rear",], ae
  geom_violin(trim = F) +
  geom_boxplot(width = 0.1) +
  geom_rug(length = unit(0.3, "npc") ) +
  #geom_vline(xintercept = 1) +
  labs(title = "Right/Left ratio", x = NULL, colour = NULL) +
  facet_wrap(~track) +
  coord_cartesian(xlim = c(0,2.5))
```




```
ggsave("results/graphs/Ur8.pdf")
```

```
## Saving 6.5 x 4.5 in image
```

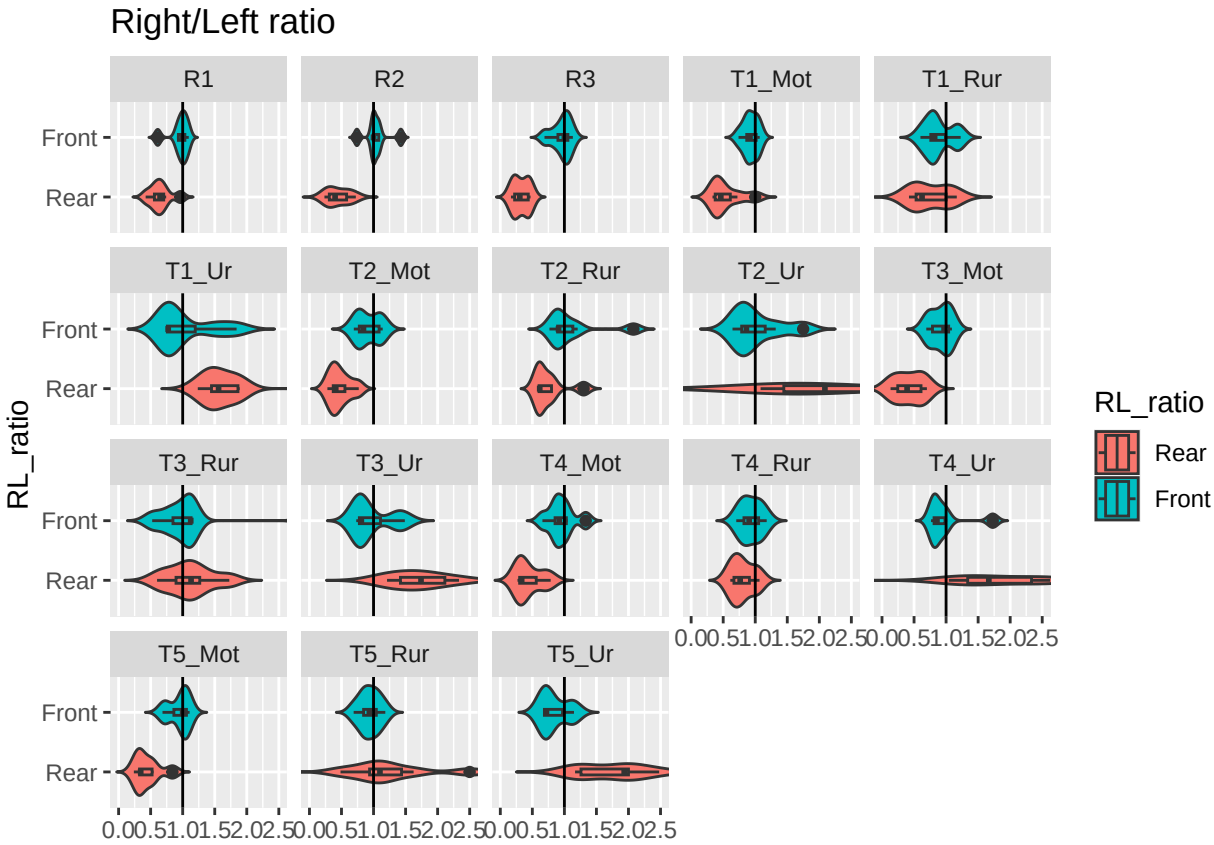
```
library(ggplot2)
ggplot(data = WearWheelsWideAgain[WearWheelsWideAgain$track %in% c("T1_Ur", "T2_Ur") ,], aes(y = RL, x =
  geom_point() + geom_abline(slope=1, intercept=0) +
  labs(title = "scatter left vs right") +
  facet_wrap(~track)
```




```
ggsave("results/graphs/Ur8.pdf")
```

```
## Saving 6.5 x 4.5 in image
```

```
library(ggplot2)
ggplot(data = WearRLLong, aes(y = RL_ratio, x = wear, fill = RL_ratio)) +
  geom_violin(trim = F) +
  geom_boxplot(width = 0.1) +
  geom_vline(xintercept = 1) +
  labs(title = "Right/Left ratio", x = NULL, colour = NULL) +
  facet_wrap(~track) +
  coord_cartesian(xlim = c(0,2.5))
```




```
ggsave("results/graphs/RLall.pdf")
```

```
## Saving 6.5 x 4.5 in image
```

Further preparations; we end up with 28 observations per track.

```
#Back to long
WearAsLong <- tidyr::pivot_longer(data = WearWheelsWideAgain,
                                  cols = c("FInner", "FOuter", "RInner", "ROuter"), #,"Wheel"
                                  names_to = "Wheel",
                                  values_to = "wear")
#correct for T1_Ur and T2_Ur which are 8 shaped
WearAsLong$Wheel[WearAsLong$track %in% c("T1_Ur", "T2_Ur") & startsWith(WearAsLong$Wheel, "F")] <- "Fro
WearAsLong$Wheel[WearAsLong$track %in% c("T1_Ur", "T2_Ur") & startsWith(WearAsLong$Wheel, "R")] <- "Rea

#Potentially simplify
WearAsLong$FrOrRear <- startsWith(WearAsLong$Wheel, "F")

#Drop now superfluous columns
WearAsLong <- WearAsLong[,c("Tyre", "track", "wear", "Wheel", "FrOrRear")]
Map2track <- unique(WearAsLong$track)
table(WearAsLong$track)
```

```
##
##     R1     R2     R3 T1_Mot T1_Rur  T1_Ur T2_Mot T2_Rur  T2_Ur T3_Mot T3_Rur
##     28     28     28     28     28     28     28     28     28     28     28
##  T3_Ur T4_Mot T4_Rur  T4_Ur T5_Mot T5_Rur  T5_Ur
##     28     28     28     28     28     28     28
```

First analyses, is there a trend for the runin wear?

```
#strings to factor
WearAsLong$Tyre <- as.factor(WearAsLong$Tyre)
WearAsLong$Wheel <- as.factor(WearAsLong$Wheel)
#WearAsLong$track <- as.factor(WearAsLong$track)

#randomForest invest R1, R2, R3 trend?
library(randomForest)
```

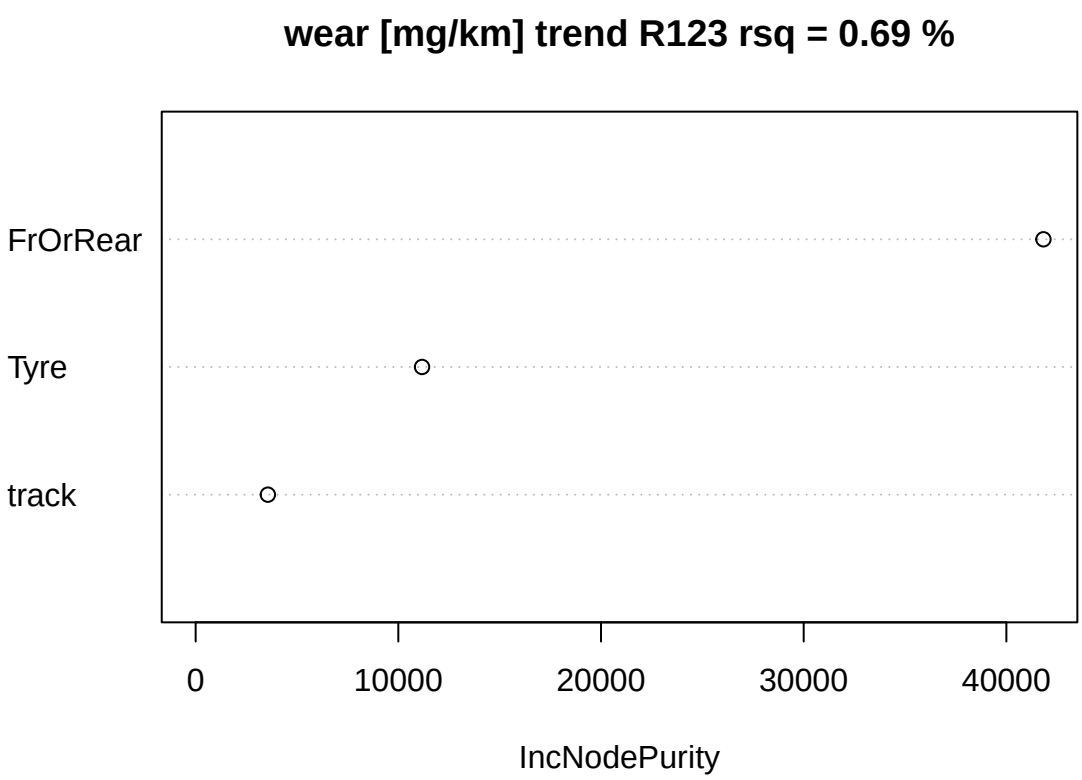
```
## randomForest 4.7-1.1
```

```
## Type rfNews() to see new features/changes/bug fixes.
```

```
##
## Attaching package: 'randomForest'
```

```
## The following object is masked from 'package:ggplot2':
##
##     margin
```

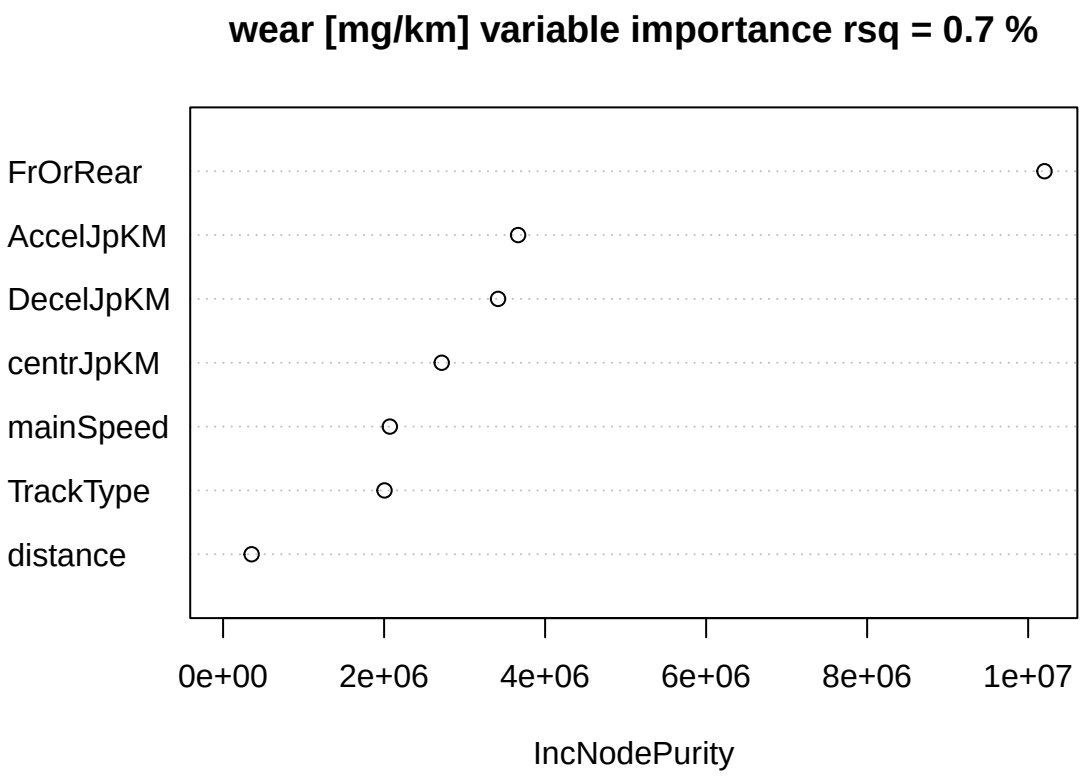
```
rf <- randomForest(wear~ Tyre + track + FrOrRear,WearAsLong[WearAsLong$track %in% c("R1", "R2", "R3"),])
varImpPlot(rf, main = paste("wear [mg/km] trend R123", "rsq =", round(mean(rf$rsq),2), "%"))
```




```
rf <- randomForest(wear~track,WearAsLong[WearAsLong$track %in% c("R1", "R2", "R3"),])
rsqList <- list("trend R123" = round(mean(rf$rsq),2))
```

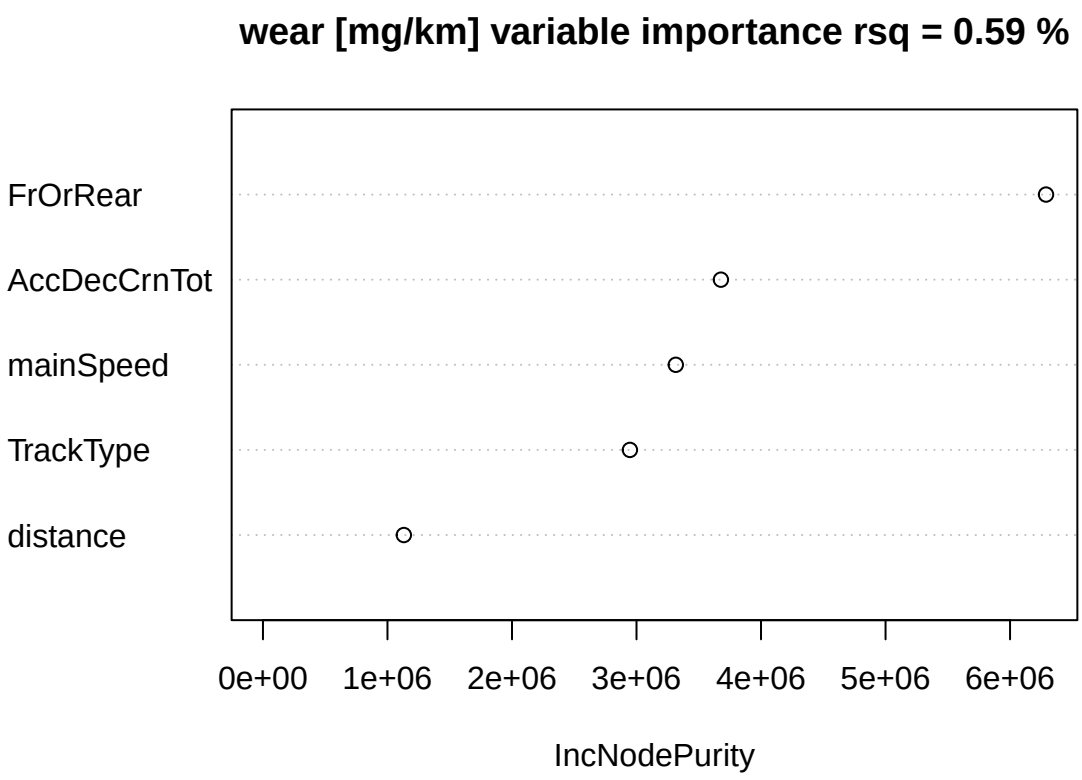
But we remove R1 and R2 and assume the Runin was sufficient after R1 and R2; we need the data. Finalising preparations; relate the waer to the track data.

```
#Remove the first 2 RunIn
WearAsLong <- WearAsLong[!WearAsLong$track %in% c("R1", "R2"),]
general$AIname <- c("T1_Ur","T2_Ur","T3_Ur","T4_Ur","T1_Rur","T2_Rur","T3_Rur","T1_Mot", "R3")

general <- cbind(general, perkmTrack)
DFin <- merge(WearAsLong, general[, c("TrackType", "decel_ms2", "accel_ms2", "accelFrac", "decelFrac",
              "mainSpeed", "mainCorner1dRadius", "maincornerSpeed", "CornerFraction", "breaks",
              "distance","rotationpkm", "AIname", "centrW_g_1",
              "decelW_g_1","accelW_g_1","airRes_Ac_1")],
              by.x = "track", by.y = "AIname")

#involve the mass
DFin$DecelJpKM <- ifelse(DFin$Tyre == "LingLongHighload", heavy_veh, m_vehicle) * DFin$decelW_g_1
DFin$AccelJpKM <- ifelse(DFin$Tyre == "LingLongHighload", heavy_veh, m_vehicle) * DFin$accelW_g_1
DFin$centrJpKM <- ifelse(DFin$Tyre == "LingLongHighload", heavy_veh, m_vehicle) * DFin$centrW_g_1
rf <- randomForest(wear~ DecelJpKM+AccelJpKM+centrJpKM+distance+TrackType+mainSpeed+FrOrRear, data = DF
rsqList[["Mass with LingLongHighload"]] <- round(mean(rf$rsq),2)
varImpPlot(rf, main = paste("wear [mg/km] variable importance", "rsq =", round(mean(rf$rsq),2), "%"))
```



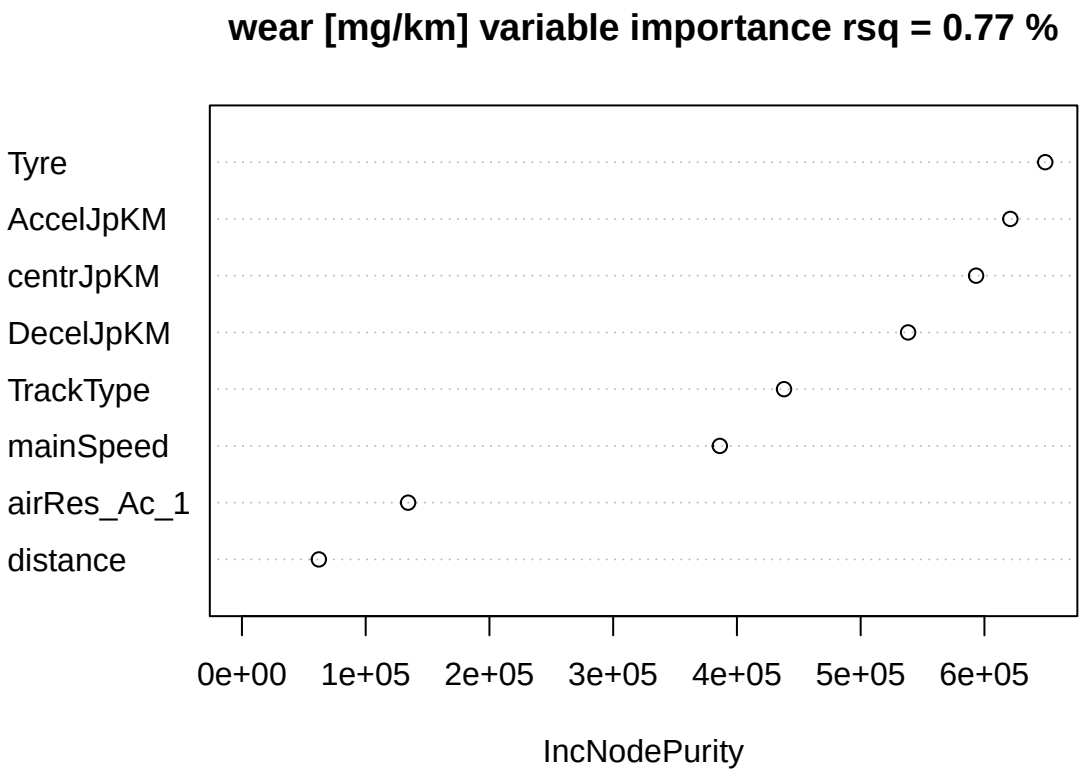
Can we do it more simple: lump the forces into a single term?

```
DFin$AccDecCrnTot <- DFin$AccelJpKM + DFin$DecelJpKM + DFin$centrJpKM
rf <- randomForest(wear~ AccDecCrnTot+distance+TrackType+mainSpeed+FrOrRear, data = DFin)
rsqList[["Mass with Highload; lumped F"]] <- round(mean(rf$rsq),2)
varImpPlot(rf, main = paste("wear [mg/km] variable importance", "rsq =", round(mean(rf$rsq),2), "%"))
```



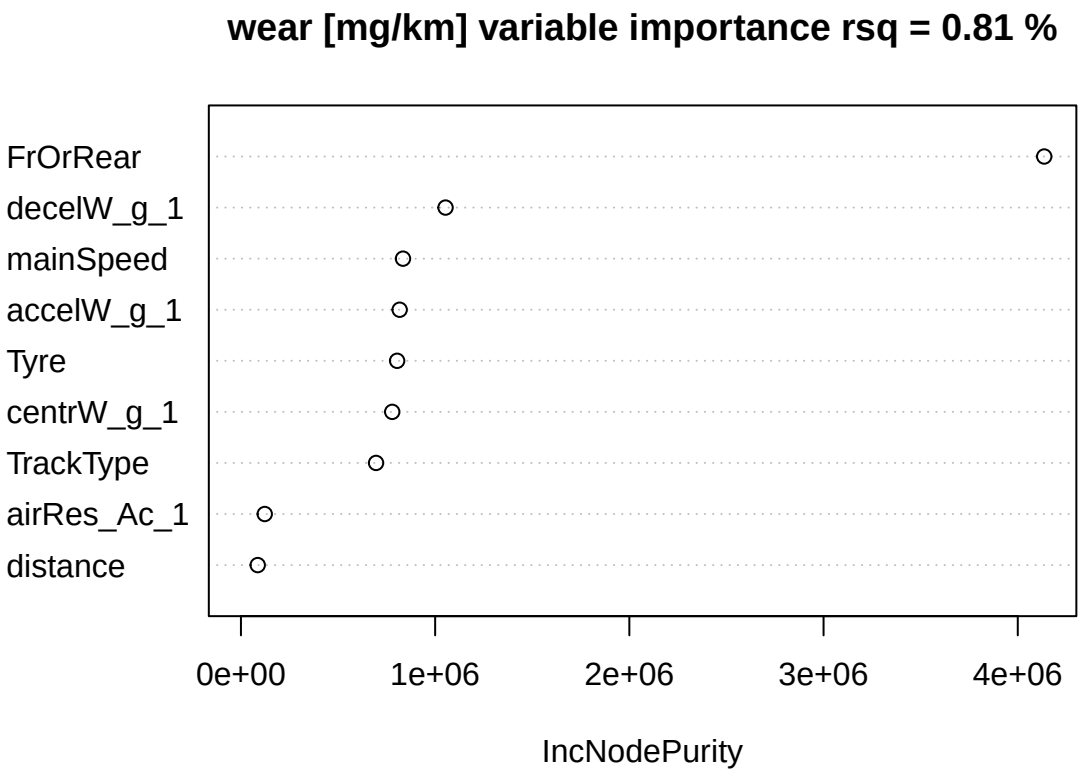
Or if we simplify by taking the average over the wheels?

```
DFinAgg <- aggregate(wear~ Tyre + track, data = WearAsLong, FUN = mean)
DFinAgg <- merge(DFinAgg, general[, c("TrackType", "decel_ms2", "accel_ms2", "accelFrac", "decelFrac",
                              "mainSpeed", "mainCorner1dRadius", "maincornerSpeed", "CornerFraction", "
                              "distance","rotationpkm", "AIname", "centrW_g_1",
              "decelW_g_1","accelW_g_1","airRes_Ac_1")],
            by.x = "track", by.y = "AIname")
#involve the mass again
DFinAgg$DecelJpKM <- ifelse(DFinAgg$Tyre == "LingLongHighload", heavy_veh, m_vehicle) * DFinAgg$decelW_
DFinAgg$AccelJpKM <- ifelse(DFinAgg$Tyre == "LingLongHighload", heavy_veh, m_vehicle) * DFinAgg$accelW_
DFinAgg$centrJpKM <- ifelse(DFinAgg$Tyre == "LingLongHighload", heavy_veh, m_vehicle) * DFinAgg$centrW_

rf <- randomForest(wear~ DecelJpKM+centrJpKM+AccelJpKM+airRes_Ac_1+distance+TrackType+mainSpeed+Tyre, da
rsqList[["Mass with Highload; avg wheels"]] <- round(mean(rf$rsq),2)
varImpPlot(rf, main = paste("wear [mg/km] variable importance", "rsq =", round(mean(rf$rsq),2), "%"))
```



And on a bombshell, what if we ignore Mass, and ignore the longling variations?

```
notin <- which(levels(DFin$Tyre) %in% c("LingLongHightemperature", "LingLongHighload"))
rf <- randomForest(wear~ Tyre + centrW_g_1+decelW_g_1+accelW_g_1+airRes_Ac_1+distance+TrackType+mainSpe
                   data = DFin[!(as.numeric(DFin$Tyre) %in% notin),])
#rf <- randomForest(wear~Tyre+centrW_g_1+decelW_g_1+accelW_g_1+airRes_Ac_1+distance+TrackType+mainSpeed
#                    data = DFin)
rsqList[["no Mass, no Highload, no HighTempeature"]] <- round(mean(rf$rsq),2)
varImpPlot(rf, main = paste("wear [mg/km] variable importance", "rsq =", round(mean(rf$rsq),2), "%"))
```




```
rf <- randomForest(wear~ Tyre+DecelJpKM+AccelJpKM+centrJpKM+accelW_g_1+distance+TrackType+mainSpeed+FrO
                   data = DFin[!(as.numeric(DFin$Tyre) %in% notin),])
rsqList[["Mass, no Highload, no HighTempeature"]] <- round(mean(rf$rsq),2)
```

An overview of the r-squares:

```
do.call(rbind, rsqList)
```

```
##                                        [,1]
## trend R123                            -0.05
## Mass with LingLongHighload             0.70
## Mass with Highload; lumped F           0.59
## Mass with Highload; avg wheels         0.77
## no Mass, no Highload, no HighTempeature  0.81
## Mass, no Highload, no HighTempeature     0.82
```