Usage Lab: Red Cells (Ketju)

```r
library(forecast)
library(ggplot2)
library(gridExtra)
library(knitr)
library(readxl)
library(plyr)
library(lubridate)
library(numbers)
source("src/evalhelp.R")
```

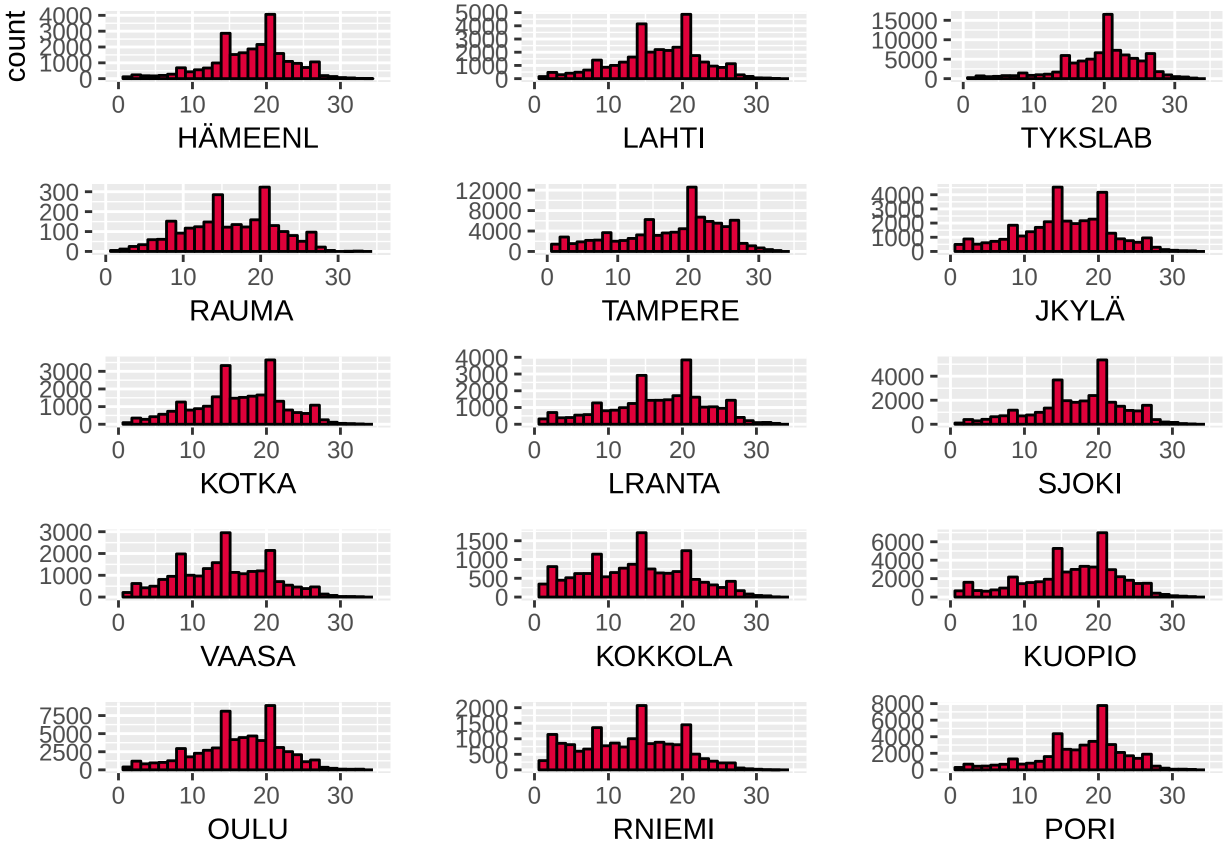
Intro

Currently under development. In this notebook we study how to use hospital blood product usage data to create demand predictions.

Create original datasets that should remain immutable throughout labbing

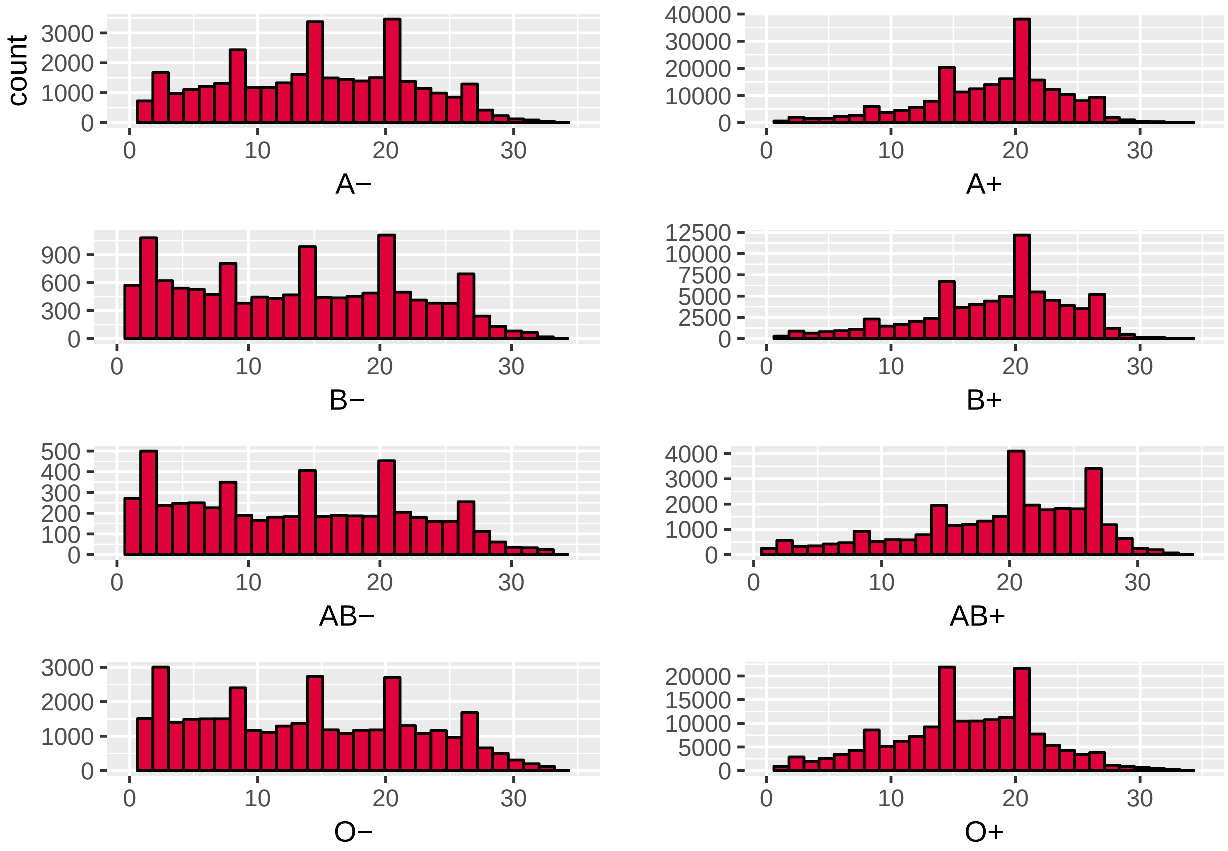
```r
# Load data
# All deliveries
deliv <- read_excel("./data/ketju_data.xlsx", sheet = "Ketju-punasolutoimitukset 2014-")[, c('Päivämäär
colnames(deliv) <- c("time", "deliveries")  # Change column names
deliv$time <- as.Date(deliv$time)

# Ketju usage 2014 -->
# I'm using read.csv() instead of read_excel() here, because this sheet contains some fields that kills
ketju <- read.csv("./data/ketju_data.csv", header = TRUE, sep = ",", colClasses=c("NULL", NA, "NULL", "
colnames(ketju) <- c("hospital", "type", "time", "exp", "pcs")  # Change column names

# Ensure compliant time format with lubridate
ketju$time <- mdy(ketju$time)
ketju$exp <- mdy(ketju$exp)  # This will produce an error "failed to parse" for fields that aren't date

# Arrange by time
ketju <- arrange(ketju, time)

# Find usage
usage <- aggregate(ketju$pcs, by = list(ketju$time), sum); colnames(usage) <- c("time", "pcs")
```

Histograms of how fresh blood is used across hospitals



The x-axis can be read as “days until an used product would’ve expired”, so a larger number corresponds to a fresher product. We see a similar pattern across all hospitals: products are used in a manner that resembles a “weekly cycle”. Most products are used 21 days from expiration, then 14 days, then 7 days. . .

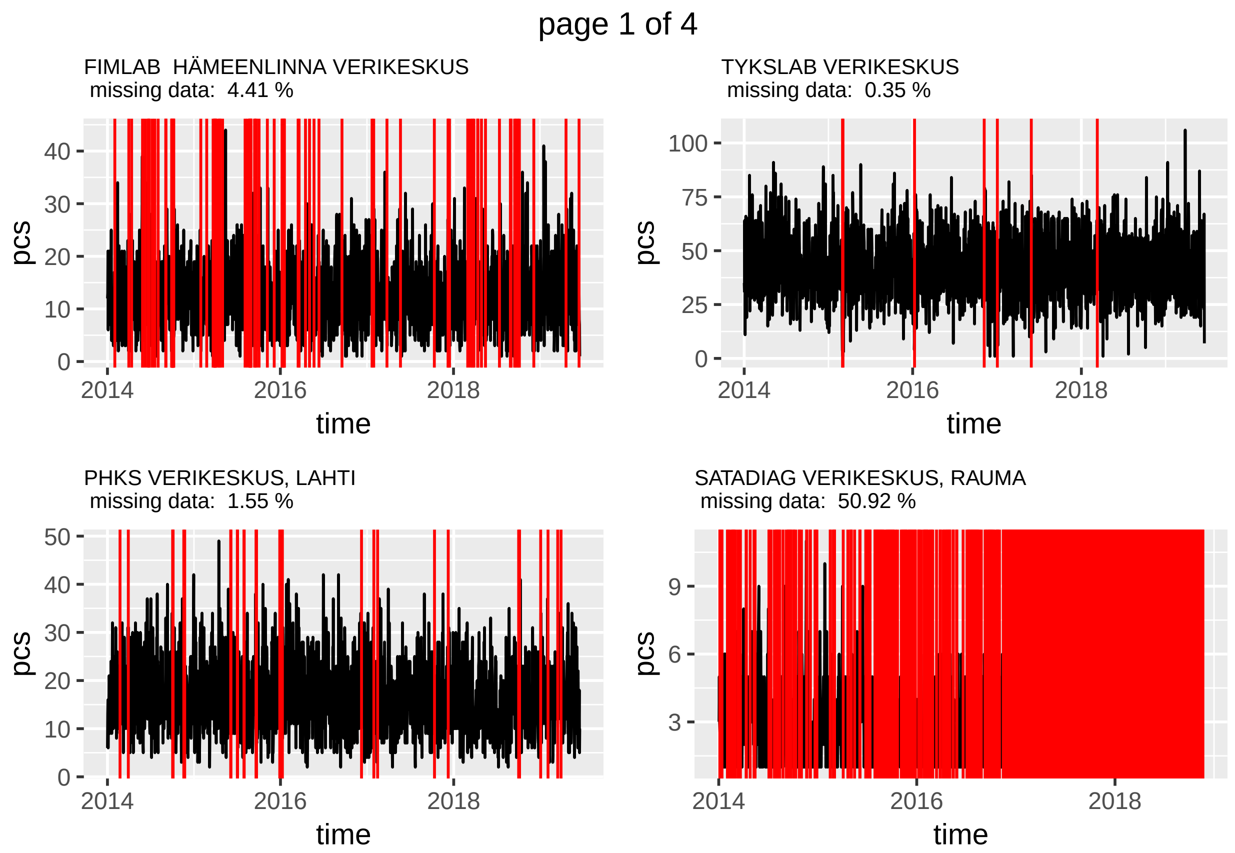
Same histogram but with blood types



Here we observe the same weekly pattern, but the shape of + products is somewhat different from - products. Older products are used more with - products.

Series of usage

```
# Create a convenience vector for hospital tags
hospitals <-c("FIMLAB  HÄMEENLINNA VERIKESKUS", "PHKS VERIKESKUS, LAHTI", "TYKSLAB VERIKESKUS", "SATADI
              "FIMLAB TAMPERE VERIKESKUS", "FIMLAB VERIKESKUS, JYVÄSKYLÄ", "KYMKS VERIKESKUS, KOTKA", "
              "SEINÄJOEN KS VERIKESKUS", "VAASAN KS VERIKESKUS", "NORDLAB KOKKOLA VERIKESKUS", "ISLAB K
              "NORDLAB OULU VERIKESKUS", "NORDLAB ROVANIEMI VERIKESKUS", "SATADIAG VERIKESKUS, PORI")
plots <- list()
i = 0
for(hospital in hospitals){
   i <- i + 1
  hospital.data <- ketju[ketju$hospital == hospital, ]
  hospital.usage <- aggregate(hospital.data$pcs, by = list(hospital.data$time), sum)
  colnames(hospital.usage) <- c("time", "pcs")
  temp <- make_whole(hospital.usage)
  hospital.whole <- temp[[1]]
  hospital.missing <- temp[[2]]

  # Plot
  hospital.plot <- ggplot() +
    geom_line(data = hospital.whole, aes(x = time, y = pcs)) +
    geom_vline(xintercept = hospital.missing, color = "red") +
    xlab("time") +
    ggtitle(paste(hospital, "\n missing data: ", round(length(hospital.missing)/length(hospital.whole$p
    theme(plot.title = element_text(size = 8))

  plots[[i]] <- hospital.plot

}

ml <- marrangeGrob(plots, nrow=2, ncol=2)
ml
```



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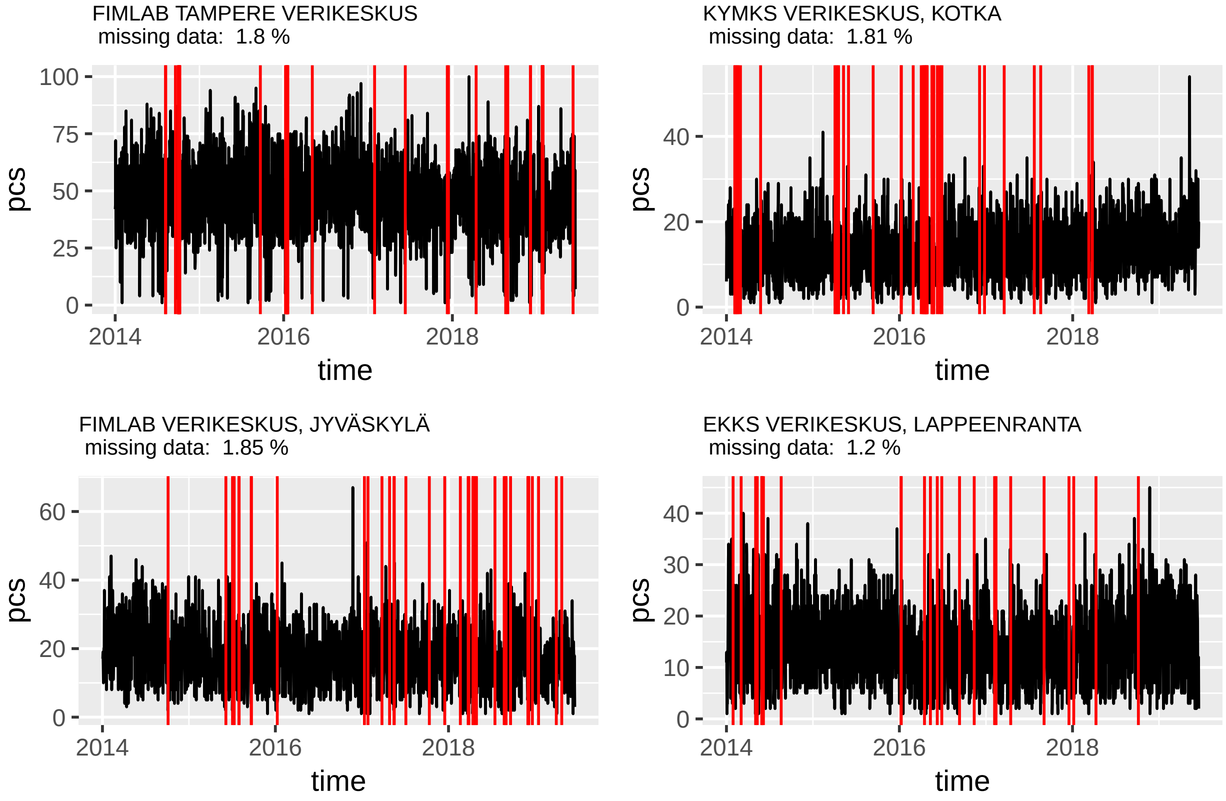

FIMLAB TAMPERE VERIKESKUS
missing data: 1.8 %

KYMKS VERIKESKUS, KOTKA
missing data: 1.81 %

FIMLAB VERIKESKUS, JYVÄSKYLÄ
missing data: 1.85 %

EKKS VERIKESKUS, LAPPEENRANTA
missing data: 1.2 %

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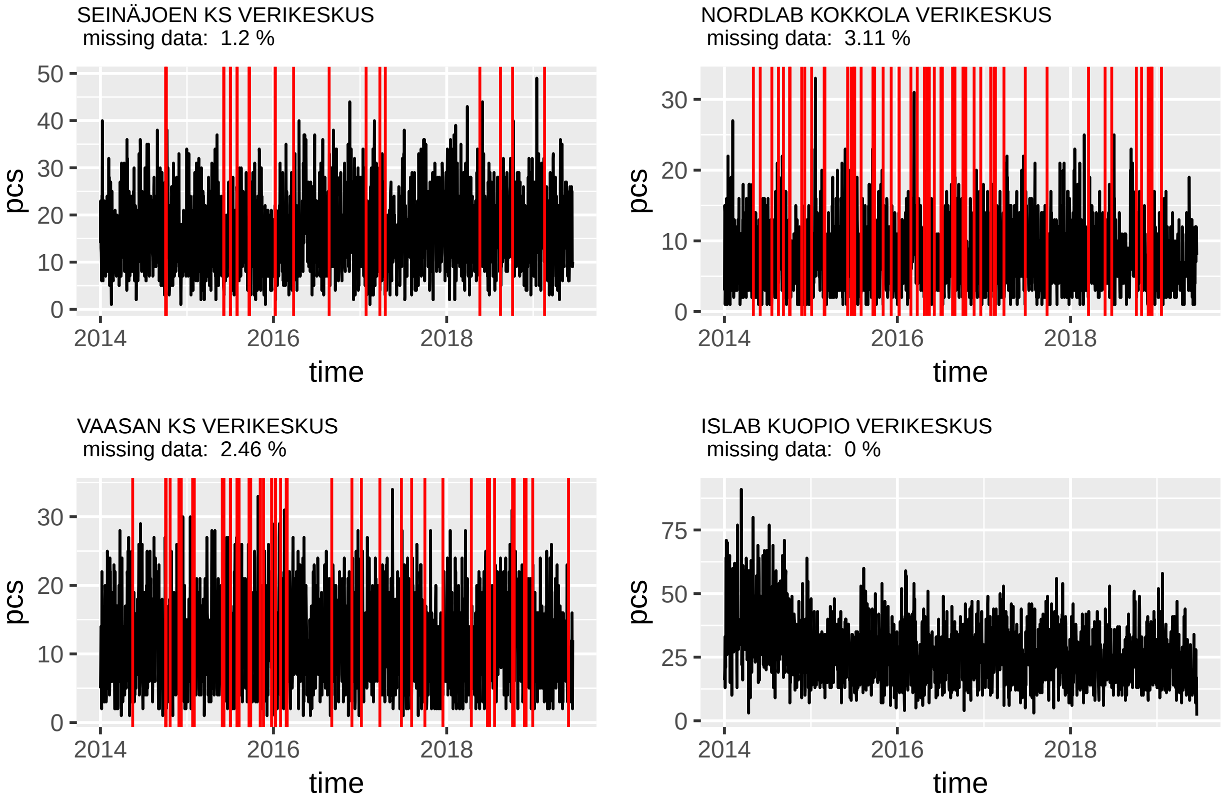
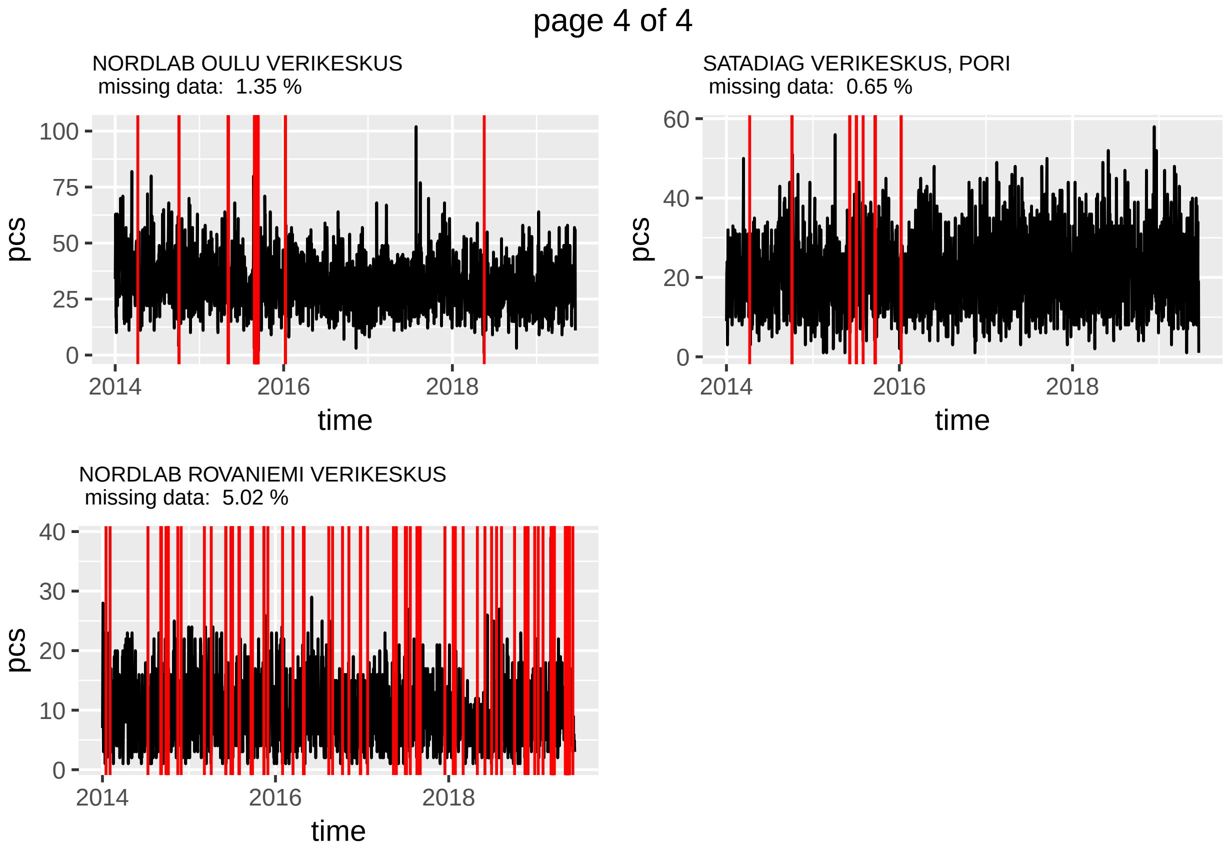


SEINÄJOEN KS VERIKESKUS
missing data: 1.2 %

NORDLAB KOKKOLA VERIKESKUS
missing data: 3.11 %

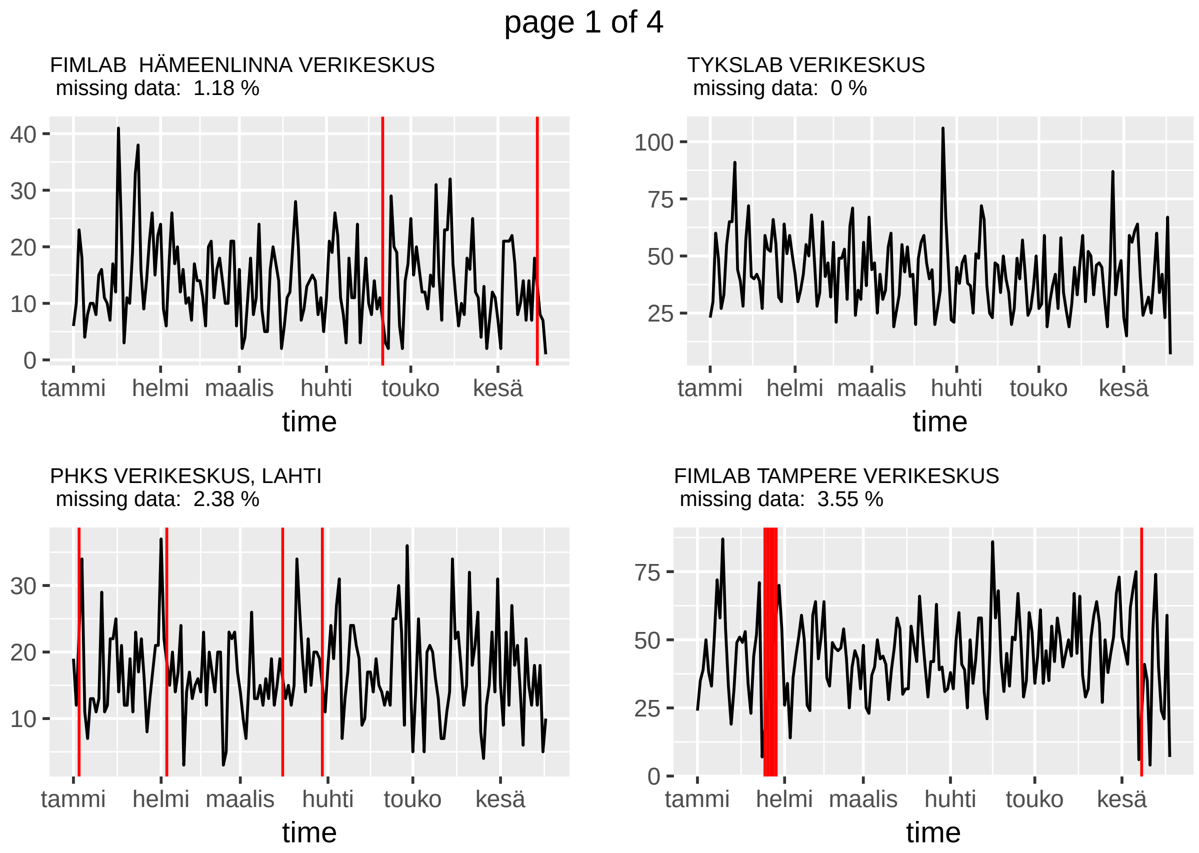
VAASAN KS VERIKESKUS
missing data: 2.46 %

ISLAB KUOPIO VERIKESKUS
missing data: 0 %



These are daily red cell product usage data from each hospital. A red line means a missing data point. The missing data point might just be a zero, which is most probable with RAUMA. Let's limit our explorations to 2019 for now. This probably means we'll have to exclude RAUMA.

```
hospitals <- c("FIMLAB  HÄMEENLINNA VERIKESKUS", "PHKS VERIKESKUS, LAHTI", "TYKSLAB VERIKESKUS",
              "FIMLAB TAMPERE VERIKESKUS", "FIMLAB VERIKESKUS, JYVÄSKYLÄ", "KYMKS VERIKESKUS, KOTKA", "
              "SEINÄJOEN KS VERIKESKUS", "VAASAN KS VERIKESKUS", "NORDLAB KOKKOLA VERIKESKUS", "ISLAB KU
              "NORDLAB OULU VERIKESKUS", "NORDLAB ROVANIEMI VERIKESKUS", "SATADIAG VERIKESKUS, PORI")

plots <- list()
i = 0
for(hospital in hospitals){
   i <- i + 1
  hospital.data <- ketju[ketju$hospital == hospital, ]
  hospital.usage <- aggregate(hospital.data$pcs, by = list(hospital.data$time), sum)
  colnames(hospital.usage) <- c("time", "pcs")
  hospital.usage <- hospital.usage[hospital.usage$time >= as.Date("2019-01-01"), ]
  temp <- make_whole(hospital.usage)
  hospital.whole <- temp[[1]]
  hospital.missing <- temp[[2]]

  # Plot
  hospital.plot <- ggplot() +
    geom_line(data = hospital.whole, aes(x = time, y = pcs)) +
    geom_vline(xintercept = hospital.missing, color = "red") +
    ggtitle(paste(hospital, "\n missing data: ", round(length(hospital.missing)/length(hospital.whole$p
    theme(plot.title = element_text(size = 8)) +
    ylab("")

  plots[[i]] <- hospital.plot

}

ml <- marrangeGrob(plots, nrow=2, ncol=2)
ml
```



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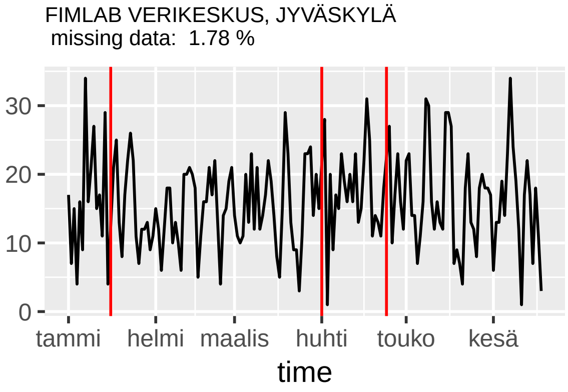
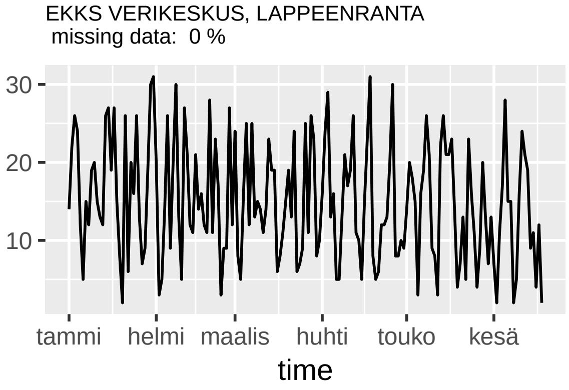
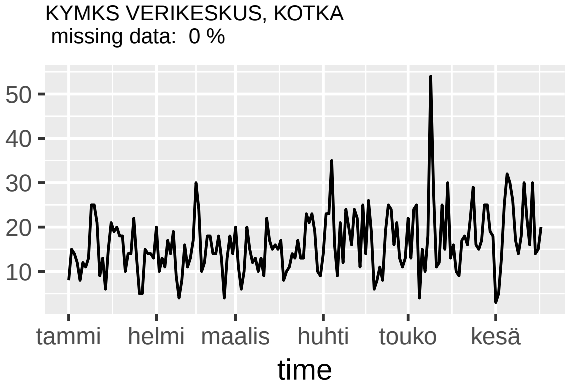
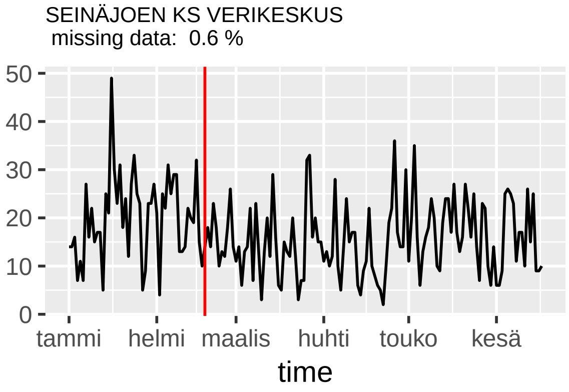

FIMLAB VERIKESKUS, JYVÄSKYLÄ
missing data: 1.78 %


EKKS VERIKESKUS, LAPPEENRANTA
missing data: 0 %


KYMKS VERIKESKUS, KOTKA
missing data: 0 %


SEINÄJOEN KS VERIKESKUS
missing data: 0.6 %

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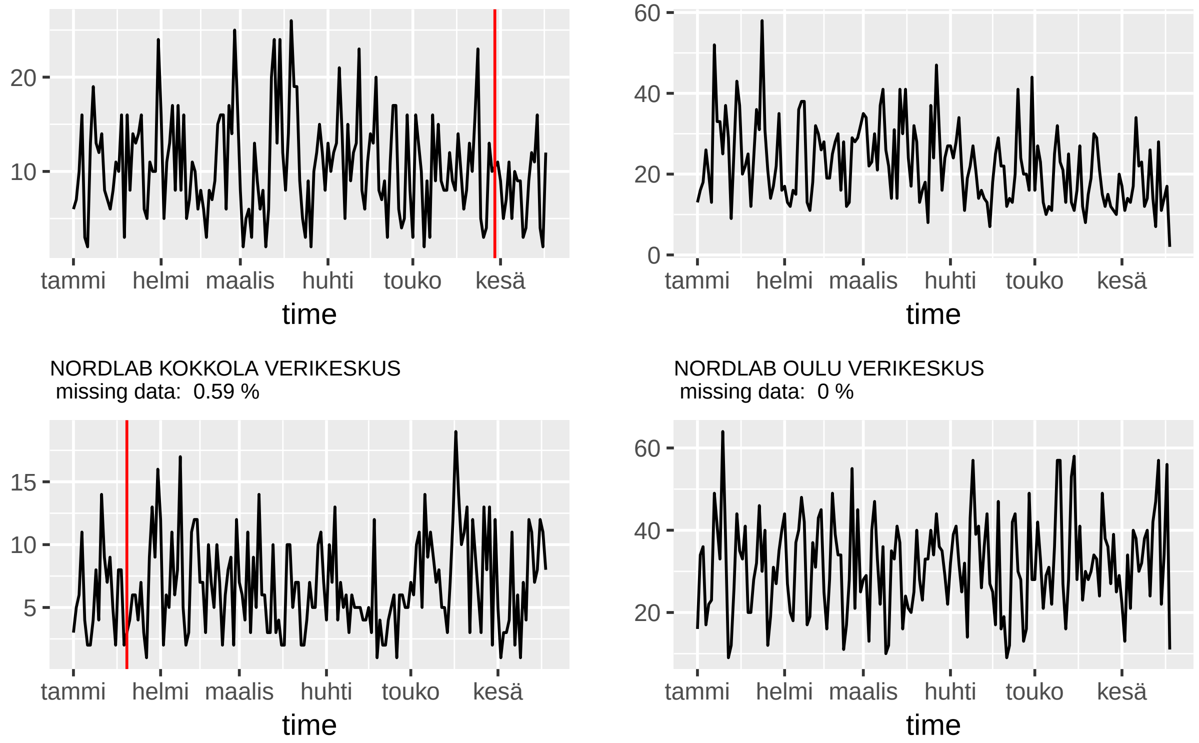
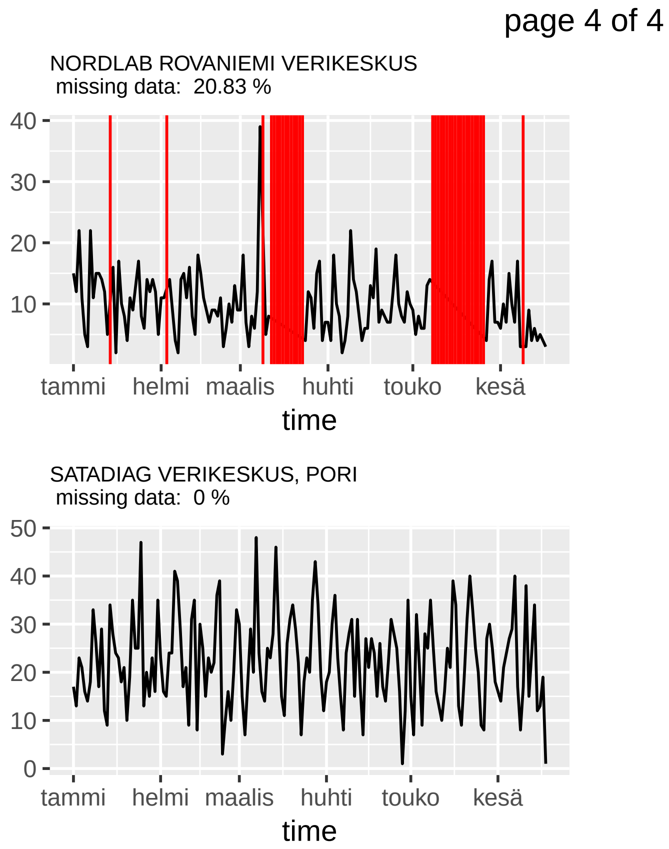


VAASAN KS VERIKESKUS
missing data: 0.6 %

ISLAB KUOPIO VERIKESKUS
missing data: 0 %

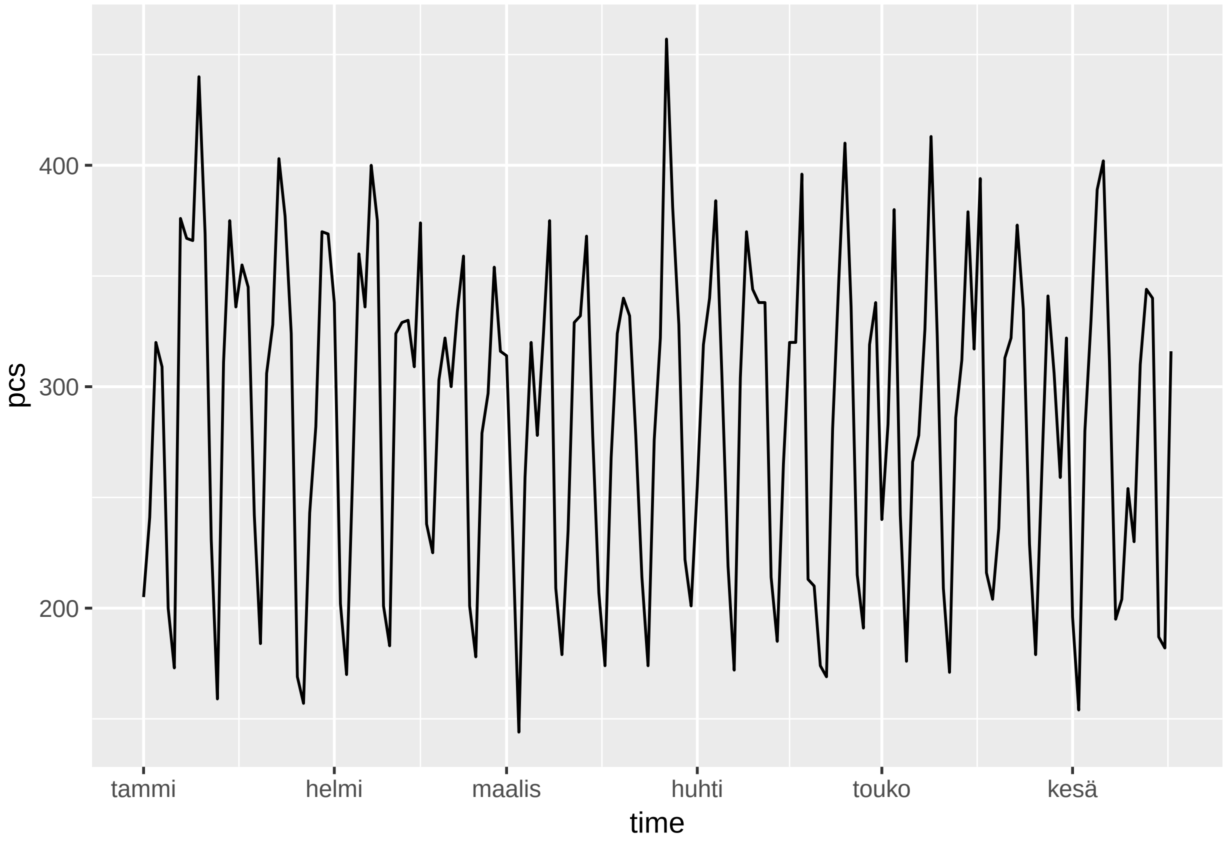
NORDLAB KOKKOLA VERIKESKUS
missing data: 0.59 %

NORDLAB OULU VERIKESKUS
missing data: 0 %

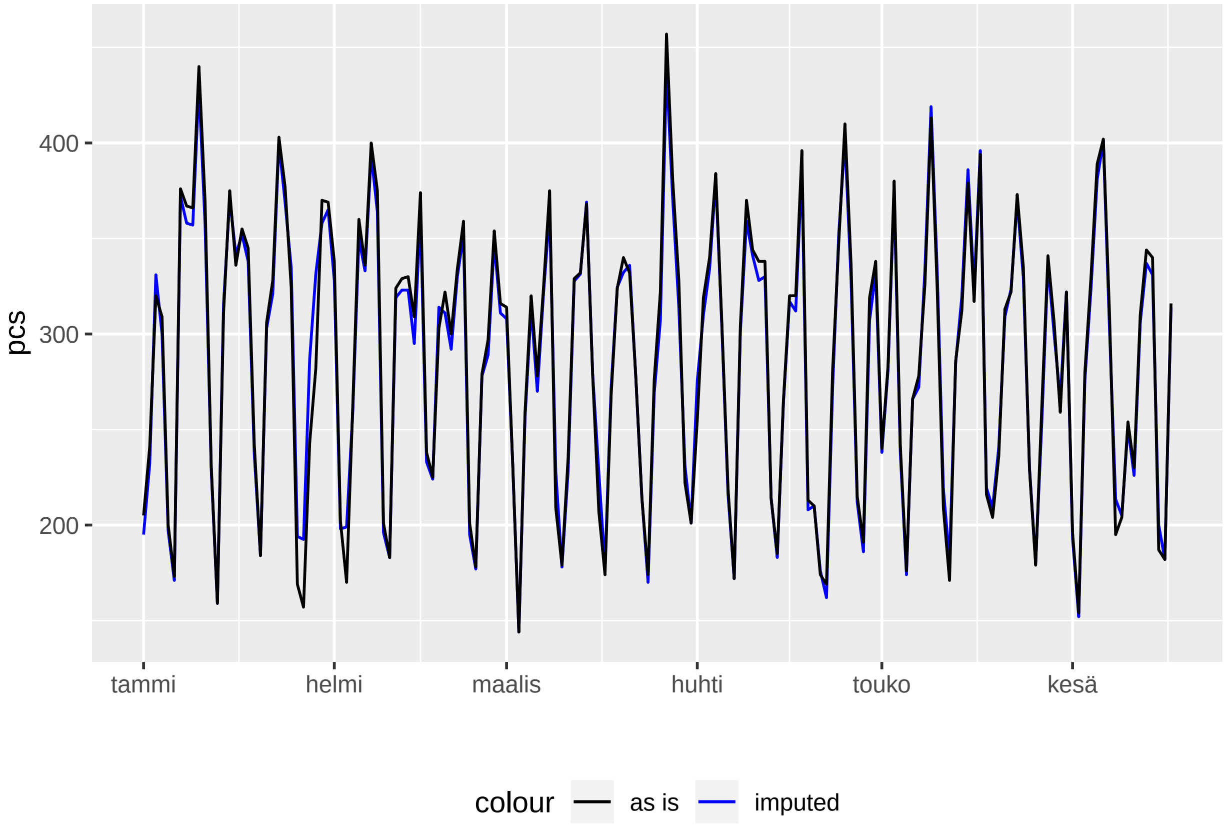


There is a “clear” weekly seasonality in most hospitals, and it is more pronounced where a lot of blood is used.

Total usage across all hospitals (in 2019, *without imputation*)



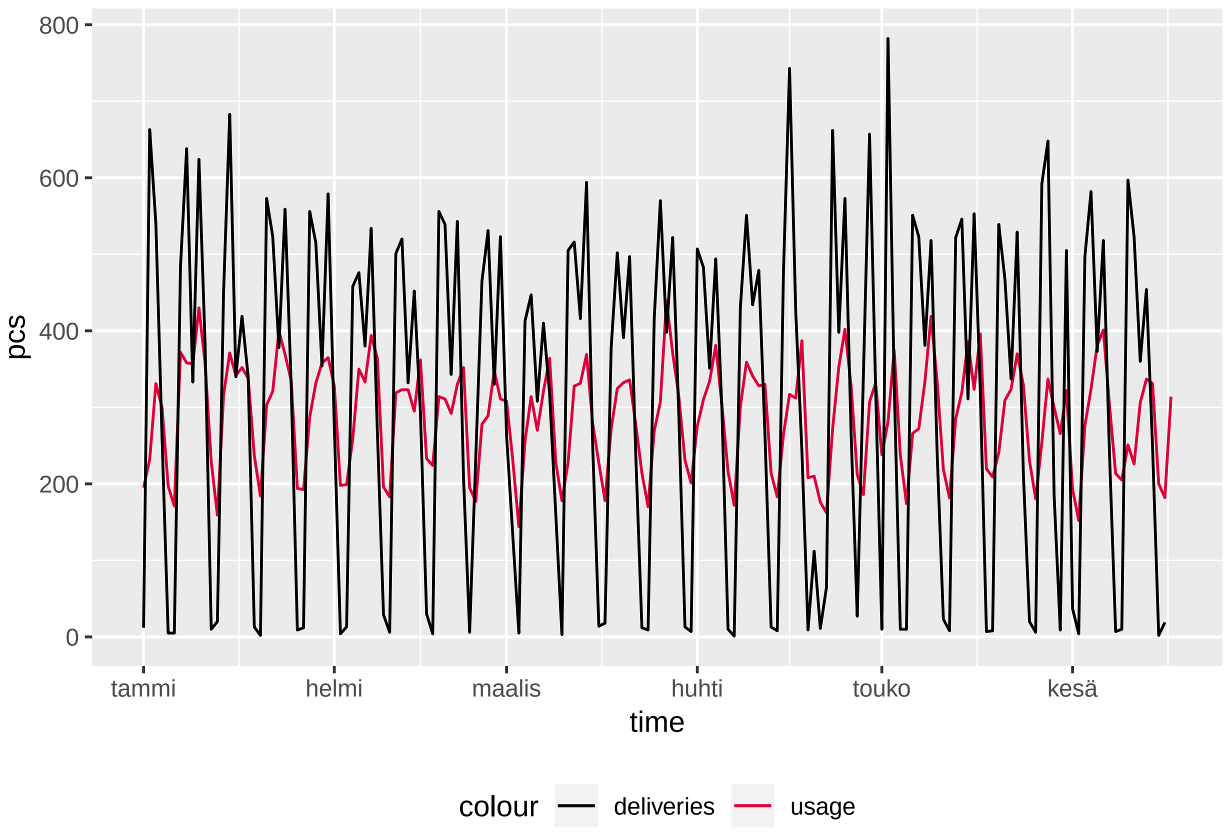
Difference in total usage *with and without imputation*



The imputed series does not differ significantly from the raw series, so we can probably use either.

Deliveries and usage 2019

```
ggplot() +
  geom_line(data = total.usage[total.usage$time >= "2019-01-01", ], aes(x = time, y = pcs, colour = "usa
  geom_line(data = deliv[deliv$time >= "2019-01-01", ], aes(x = time, y = deliveries, colour = "deliveri
  scale_colour_manual(values = c("black", "#DF013A")) +
  theme(legend.position = "bottom")
```



```
combined <- data.frame(usage = head(total.usage[total.usage$time >= "2018-01-01", ]$pcs, 521), deliveri

# Same week avg diff
diff0 <- 0
for(i in seq(from = 7, to = 469, by = 7)){
  diff0 <- diff0 + (sum(combined$usage[i:(i+6)]) - sum(combined$deliveries[i:(i+6)]))
}
avg0 <- diff0/67

# Next week sum
diff1 <- 0
for(i in seq(from = 7, to = 469, by = 7)){
  diff1 <- diff1 + (sum(combined$usage[i:(i+6)]) - sum(combined$deliveries[(i+7):(i+13)]))
}
avg1 <- diff1/67

# Second week sum
diff2 <- 0
for(i in seq(from = 7, to = 469, by = 7)){
  diff2 <- diff2 + (sum(combined$usage[i:(i+6)]) - sum(combined$deliveries[(i+14):(i+20)]))
}
avg2 <- diff2/67

# Third week sum
diff3 <- 0
for(i in seq(from = 7, to = 469, by = 7)){
  diff3 <- diff3 + (sum(combined$usage[i:(i+6)]) - sum(combined$deliveries[(i+21):(i+27)]))
}
avg3 <- diff3/67

cat(paste("Same week average diff: ", round(avg0, digits = 2), "\n",
            "Next week average diff: ", round(avg1, digits = 2), "\n",
            "Second week average diff: ", round(avg2, digits = 2), "\n",
            "Third week average diff: ", round(avg3, digits = 2)))
```

```
## Same week average diff:  -212.83
##  Next week average diff:  -217.87
##  Second week average diff:  -217.28
##  Third week average diff:  -213.69
```

Same week difference seems to be the smallest, but only by a very small margin. The difference constitutes a 10.79 % error, which is slightly higher than what we want. Let's go to the daily level and see what happens.

```
# Same day avg diff
ddiff0 <- 0
for(i in seq(from = 7, to = 469, by = 1)){
  ddiff0 <- ddiff0 + (combined$usage[i] - combined$deliveries[i])
}
davg0 <- ddiff0/462

# Next day diff
ddiff1 <- 0
for(i in seq(from = 7, to = 469, by = 1)){
  ddiff1 <- ddiff1 + (combined$usage[i] - combined$deliveries[i+1])
}
davg1 <- ddiff1/462

# Second day diff
ddiff2 <- 0
for(i in seq(from = 7, to = 469, by = 1)){
  ddiff2 <- ddiff2 + (combined$usage[i] - combined$deliveries[i+2])
}
davg2 <- ddiff2/462

# Third day diff
ddiff3 <- 0
for(i in seq(from = 7, to = 469, by = 1)){
  ddiff3 <- ddiff3 + (combined$usage[i] - combined$deliveries[i+3])
}
davg3 <- ddiff3/462

# Fourth day diff
ddiff4 <- 0
for(i in seq(from = 7, to = 469, by = 1)){
  ddiff4 <- ddiff4 + (combined$usage[i] - combined$deliveries[i+4])
}
davg4 <- ddiff4/462

# Fifth day diff
```

```r
ddiff5 <- 0
for(i in seq(from = 7, to = 469, by = 1)){
  ddiff5 <- ddiff5 + (combined$usage[i] - combined$deliveries[i+5])
}
davg5 <- ddiff5/462

# Sixth day diff
ddiff6 <- 0
for(i in seq(from = 7, to = 469, by = 1)){
  ddiff6 <- ddiff6 + (combined$usage[i] - combined$deliveries[i+6])
}
davg6 <- ddiff6/462

cat(paste("Same day average diff: ", round(davg0, digits = 2), "\n",
          "Next day average diff: ", round(davg1, digits = 2), "\n",
          "Second day average diff: ", round(davg2, digits = 2), "\n",
          "Third day average diff: ", round(davg3, digits = 2), "\n",
          "Fourth day average diff: ", round(davg4, digits = 2), "\n",
          "Fifth day average diff: ", round(davg5, digits = 2), "\n",
          "Sixth day average diff: ", round(davg6, digits = 2)
          )
    )
```

```
## Same day average diff:  -30.52 
##  Next day average diff:  -31.74 
##  Second day average diff:  -31.07 
##  Third day average diff:  -29.97 
##  Fourth day average diff:  -30.63 
##  Fifth day average diff:  -30.25 
##  Sixth day average diff:  -29.77
```

Same +10 % difference.

Forecasting usage

```r
ts.usage <- ts(total.usage$pcs, start = c(2018, 1), frequency = 365)

# Features: weekdays
mon <- rep(c(1, 0, 0, 0, 0, 0, 0), 52)
tue <- rep(c(0, 1, 0, 0, 0, 0, 0), 52)
wed <- rep(c(0, 0, 1, 0, 0, 0, 0), 52)
thu <- rep(c(0, 0, 0, 1, 0, 0, 0), 52)
fri <- rep(c(0, 0, 0, 0, 1, 0, 0), 52)
sat <- rep(c(0, 0, 0, 0, 0, 1, 0), 52)

usage.feature.matrix <- matrix(c(mon, tue, wed, thu, fri, sat),
                              ncol = 6,
                              byrow = FALSE)

usage.e <- tsCV(ts.usage, farima, h = 1)
usage.crit <- cMAPE(usage.e, ts.usage)
usage.mape <- mean(abs(100*usage.e/ts.usage), na.rm = TRUE)
usage.rmse <- sqrt(mean(usage.e^2, na.rm = TRUE))

# Table
usagebench <- matrix(c(usage.crit, usage.mape, usage.rmse),
                    ncol = 3,
                    byrow = TRUE)

colnames(usagebench) <- c("cMAPE", "MAPE", "RMSE")
rownames(usagebench) <- c("DynReg")
kable(usagebench, "markdown")
```

	cMAPE	MAPE	RMSE
DynReg	26.29518	17.23969	61.10245