MARKETING ANALYTICS IN R: STATISTICAL MODELING

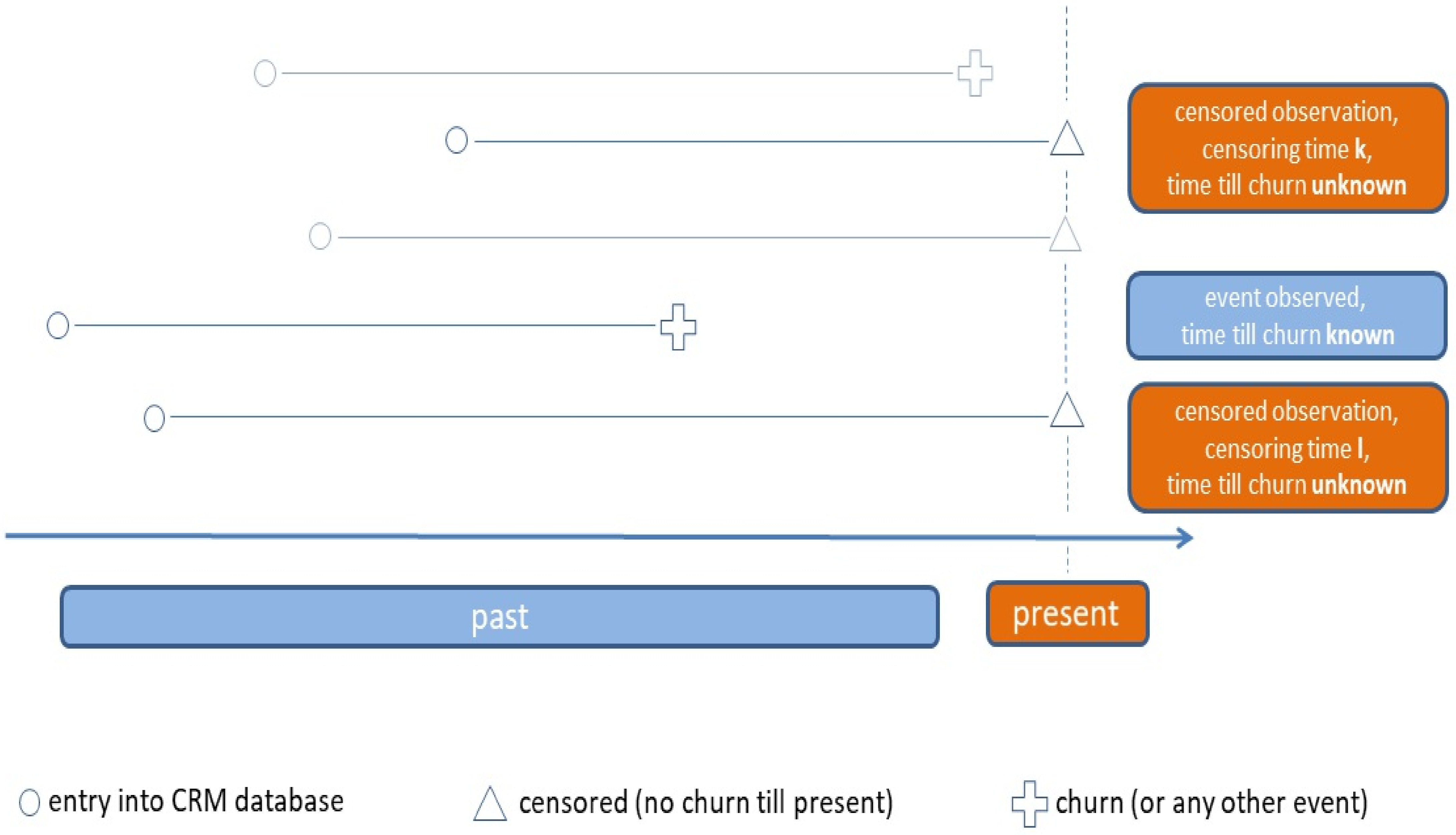
Survival Analysis in Customer Relationship Management

Verena Pflieger
Data Scientist at INWT Statistics

CENSORED
CENSORED

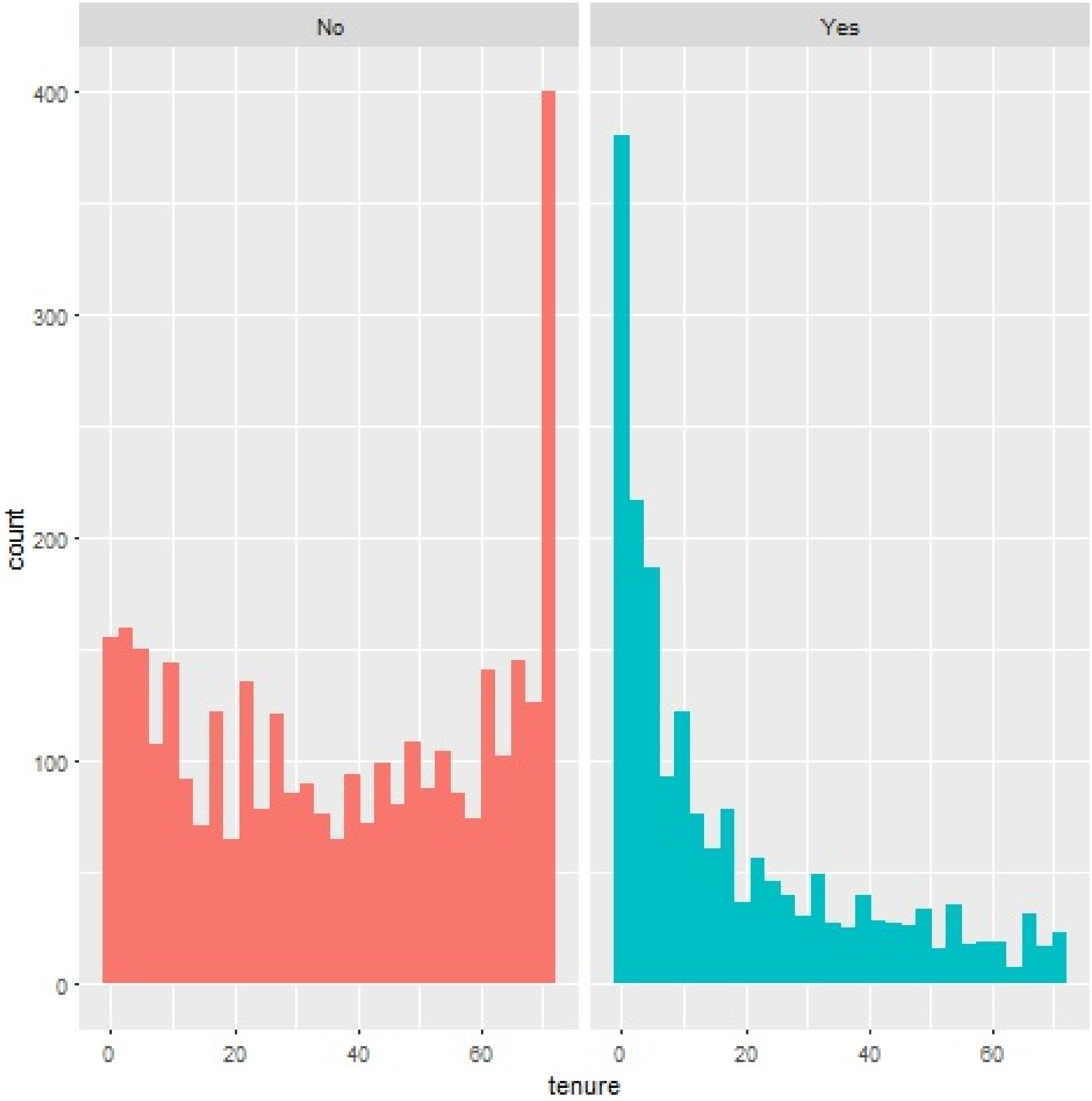
Advantages survival model

- less aggregation
- allows us to model when an event takes place
- no arbitrarily set timeframe
- deeper insights into customer relations


censored observation,
censoring time **k**,
time till churn **unknown**
event observed,
time till churn **known**
censored observation,
censoring time **l**,
time till churn **unknown**
past
present
○ entry into CRM database
△ censored (no churn till present)
✚ churn (or any other event)

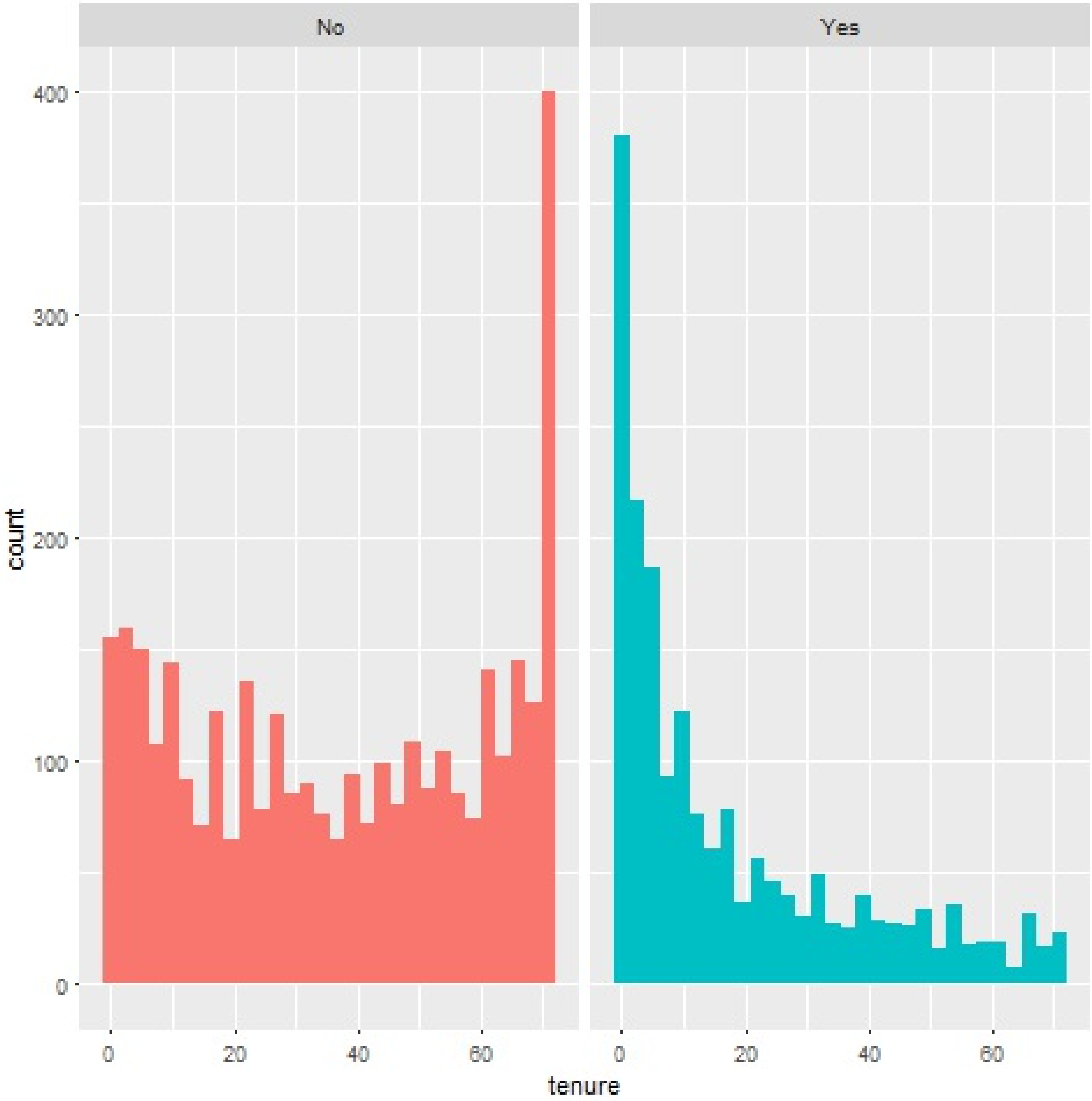
Data for Survival Analysis

```
Classes 'tbl_df', 'tbl' and 'data.frame':    5311 obs. of  11 variables:
 $ customerID      : Factor w/ 7043 levels "0002-ORFBO","0003-MKNFE",..: 2565 ..
 $ gender          : Factor w/ 2 levels "Female","Male": 2 2 1 1 2 ...
 $ SeniorCitizen   : Factor w/ 2 levels "No","Yes": 1 1 1 1 1 ...
 $ Partner         : Factor w/ 2 levels "No","Yes": 1 1 1 1 2 ...
 $ Dependents      : Factor w/ 2 levels "No","Yes": 1 1 1 1 1 ...
 $ tenure          : num  2 45 2 8 22 28 62 13 16 58 ...
 $ StreamingMovies : Factor w/ 3 levels "No","No internet service",..: 1 1 1 ...
 $ PaperlessBilling: Factor w/ 2 levels "No","Yes": 2 1 2 2 1 ...
 $ PaymentMethod   : Factor w/ 4 levels "Bank transfer (automatic)", ...: 4 2 ..
 $ MonthlyCharges  : num  53.9 42.3 70.7 99.7 89.1 ...
 $ churn           : num  1 0 1 1 0 1 0 0 0 0 ...
```


No
Yes
count
400
300
200
100
0
0
20
40
60
0
20
40
60
tenure

Tenure Time

```
library(ggplot2)

plotTenure <- dataSurv %>%
    mutate(churn = churn %>% factor(labels = c("No", "Yes"))) %>%

ggplot() +
    geom_histogram(aes(x = tenure,
                 fill = factor(churn))) +
   facet_grid( ~ churn) +
   theme(legend.position = "none")
plotTenure
```


No
Yes
count
400
300
200
100
0
0
20
40
60
0
20
40
60
tenure

MARKETING ANALYTICS IN R: STATISTICAL MODELING

Let's practice!

MARKETING ANALYTICS IN R: STATISTICAL MODELING

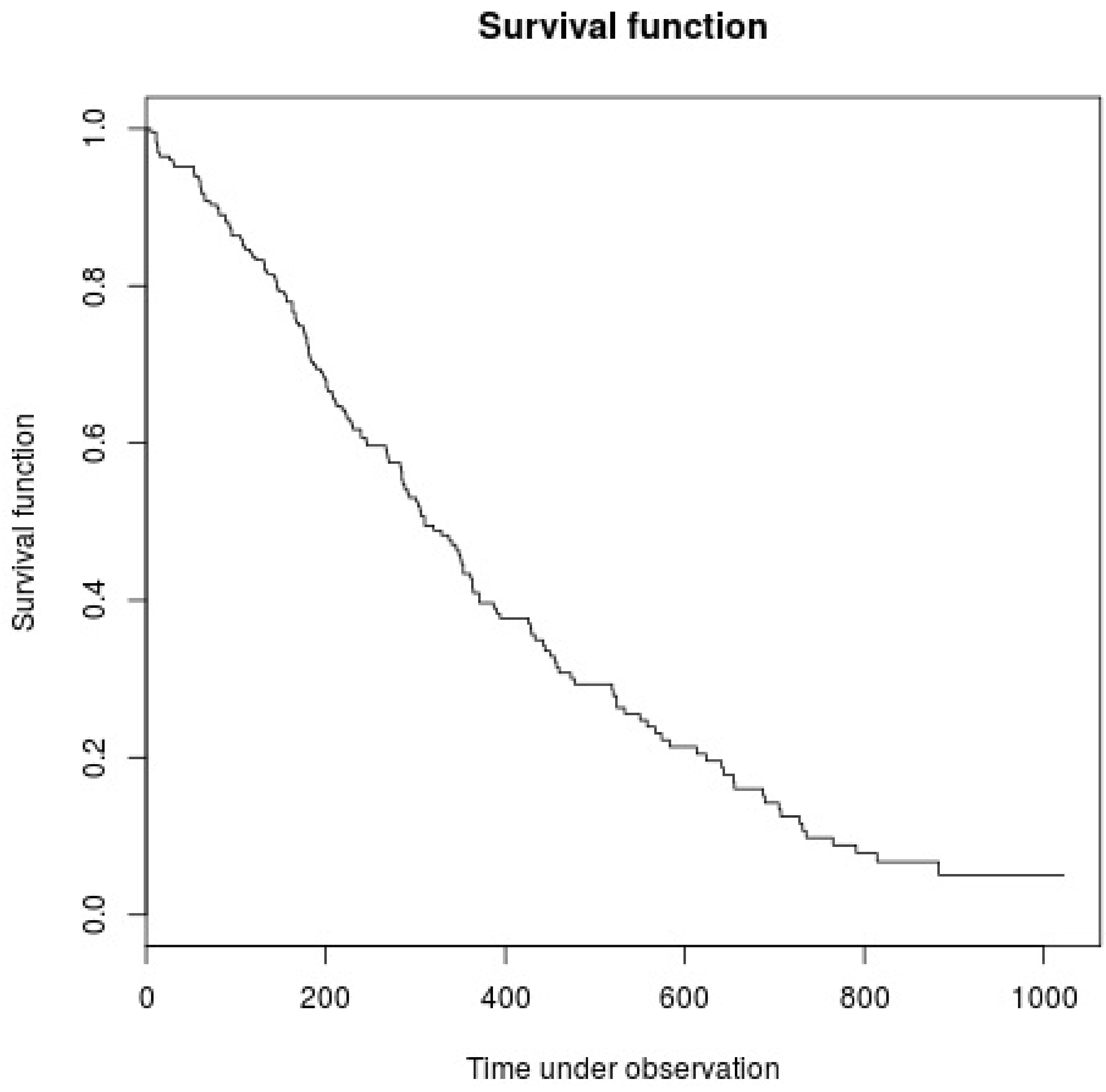
Survival Curve Analysis by Kaplan-Meier

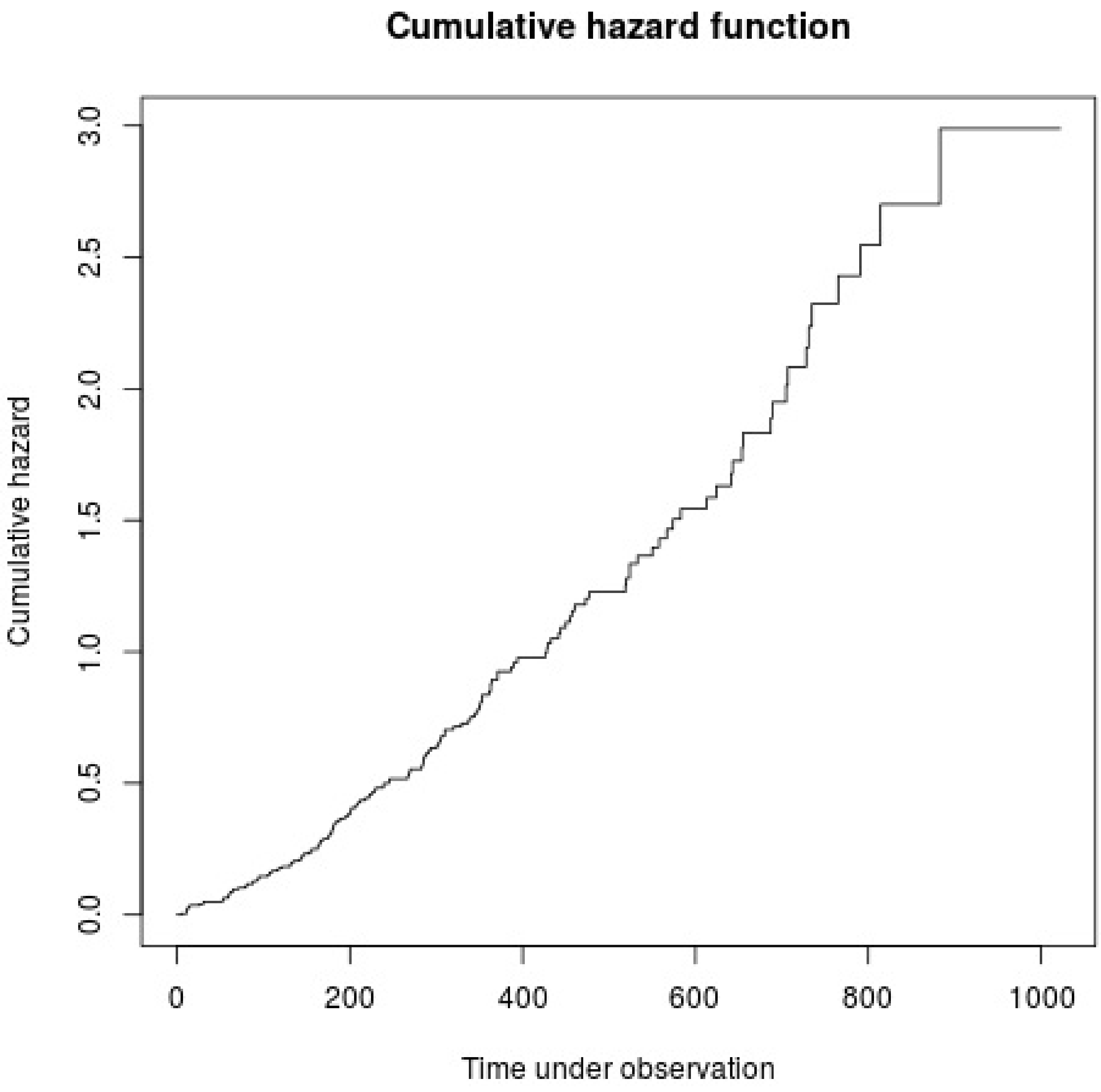
Verena Pflieger
Data Scientist at INWT Statistics

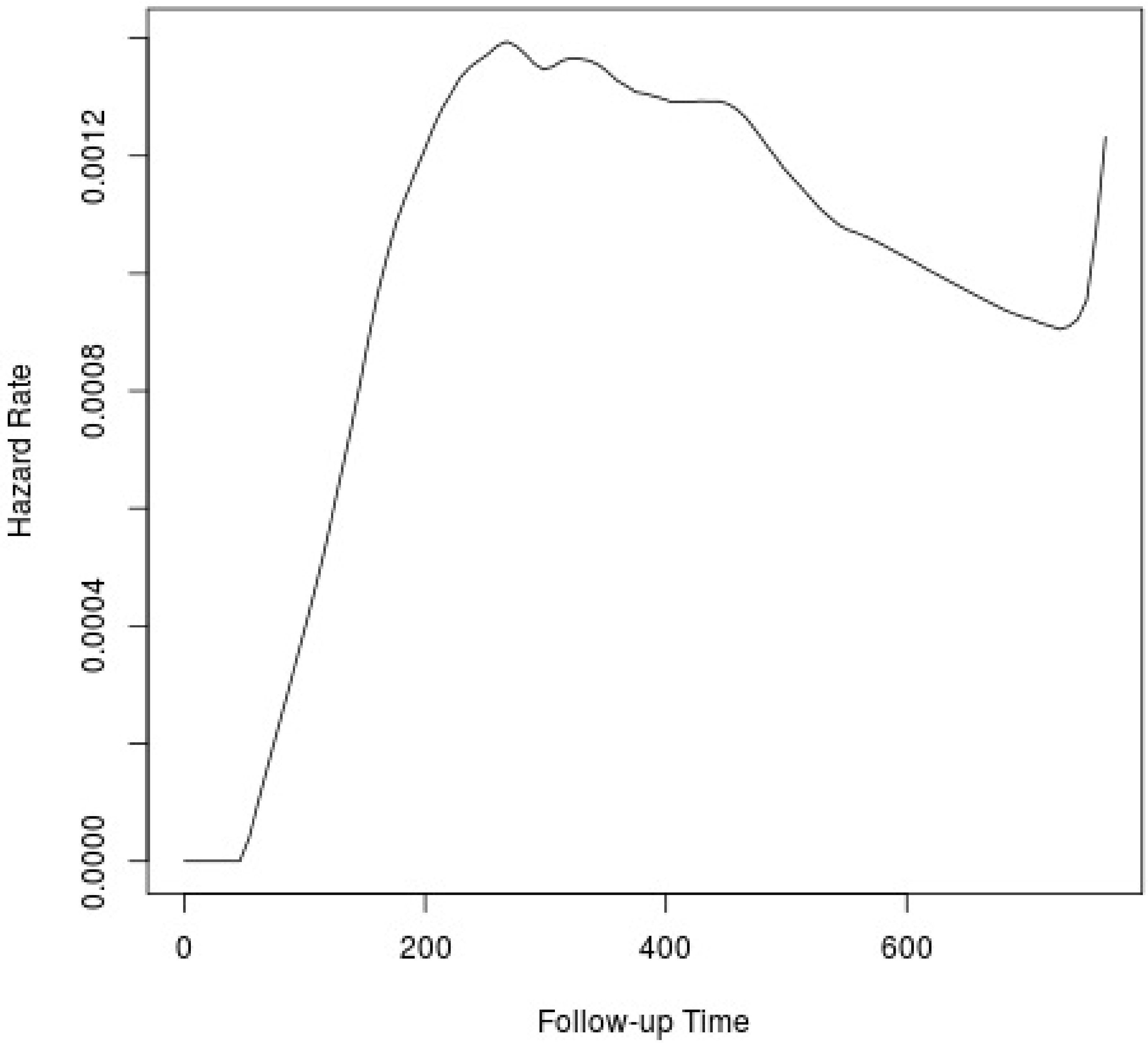
Survival Object I

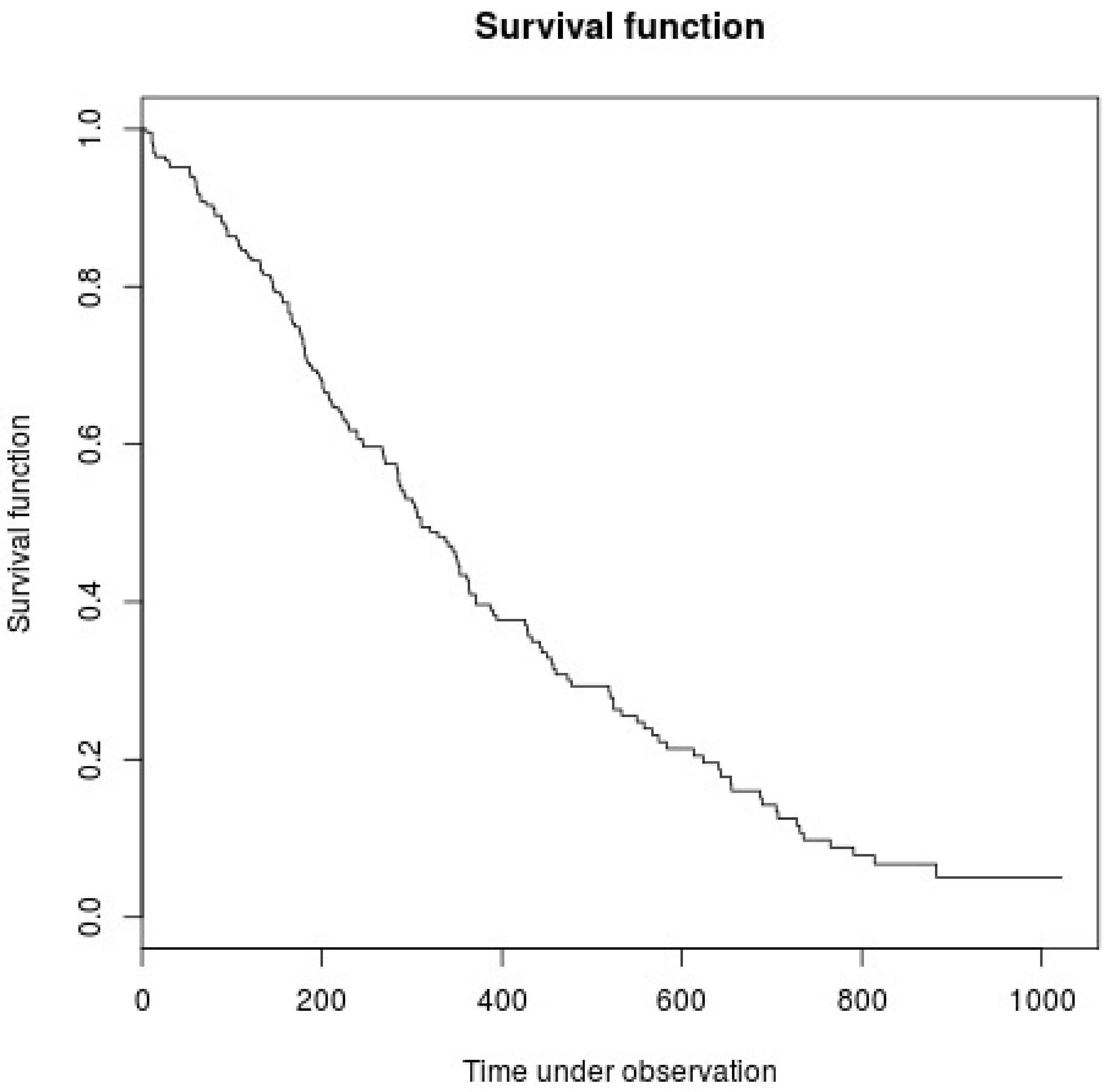
```
cbind(dataSurv %>% select(tenure, churn),
      surv = Surv(dataSurv$tenure, dataSurv$churn)) %>% head(10)
```

```
   tenure churn surv
1       1     0   1+
2      34     0  34+
3       2     1   2
4      45     0  45+
5       2     1   2
6       8     1   8
7      22     0  22+
8      10     0  10+
9      28     1  28
10     16     0  16+
```


Survival function
Survival function
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
Time under observation


Cumulative hazard function
Cumulative hazard
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
200
400
600
800
1000
Time under observation


Hazard Rate
0.0000
0.0004
0.0008
0.0012
0
200
400
600
Follow-up Time


Survival function
Survival function
0.0
0.2
0.4
0.6
0.8
1.0
0
200
400
600
800
1000
Time under observation

Kaplan-Meier Analysis

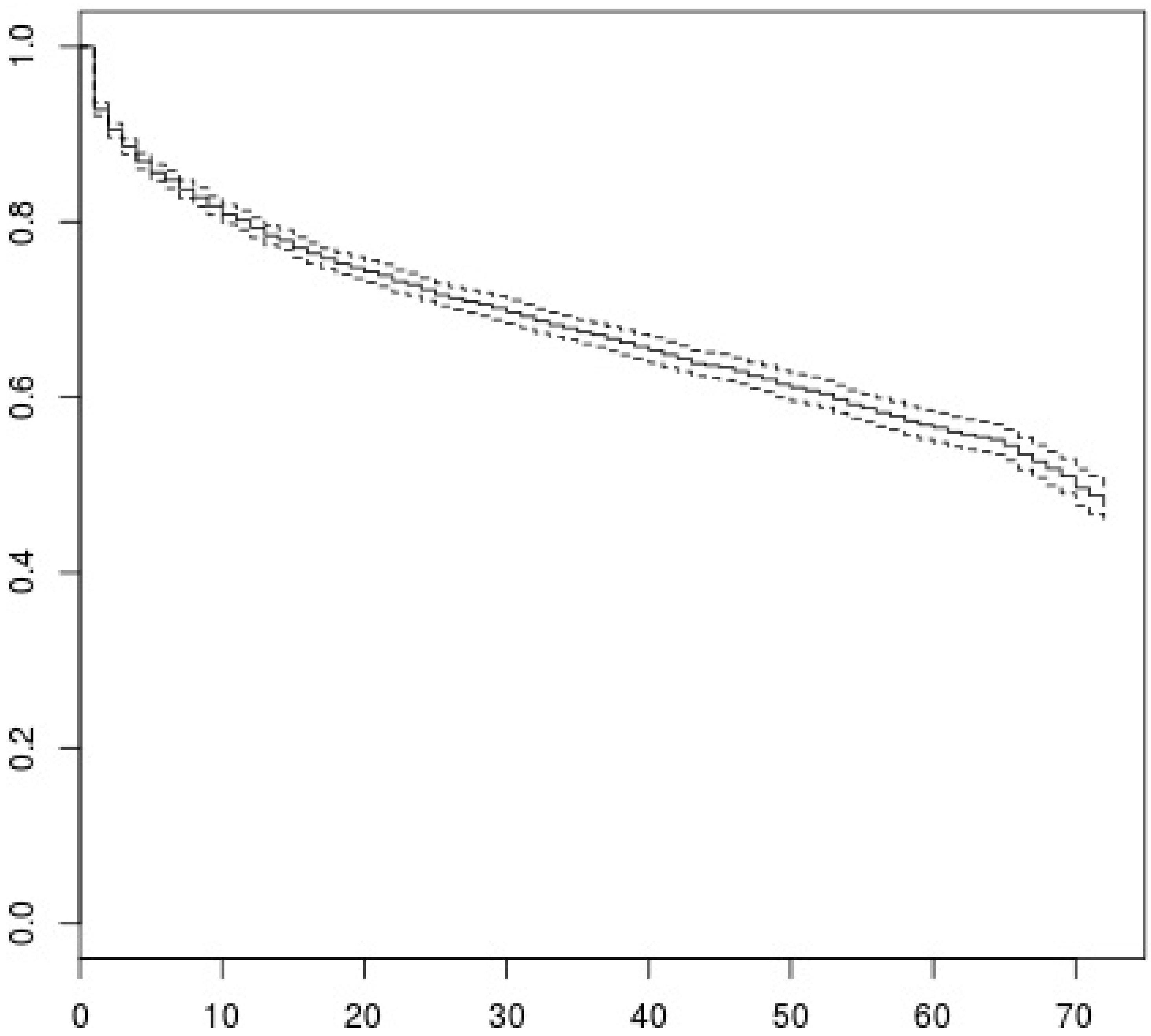
```
fitKM <- survfit(Surv(dataSurv$tenure, dataSurv$churn) ~ 1,
                 type = "kaplan-meier")
fitKM$surv
```

```
 [1] 0.9284504 0.9045343 0.8859371 0.8692175 0.8561374
 [6] 0.8478775 0.8372294 0.8283385 0.8184671 0.8086794
[11] 0.8018542 0.7933760 0.7847721 0.7792746 0.7707060
[16] 0.7641548 0.7580075 0.7522632 0.7476436 0.7432153
[21] 0.7389925 0.7321989 0.7288777 0.7228883 0.7168003
[26] 0.7127809 0.7092320 0.7059049 0.7016930 ...
```

Printing the Survfit Object

```
> print(fitKM)
Call: survfit(formula = Surv(dataSurv$tenure, dataSurv$churn) ~ 1,
    type = "kaplan-meier")

      n  events  median 0.95LCL 0.95UCL
   5311    1869      70      68      72
```

```
plot(fitKM)
```

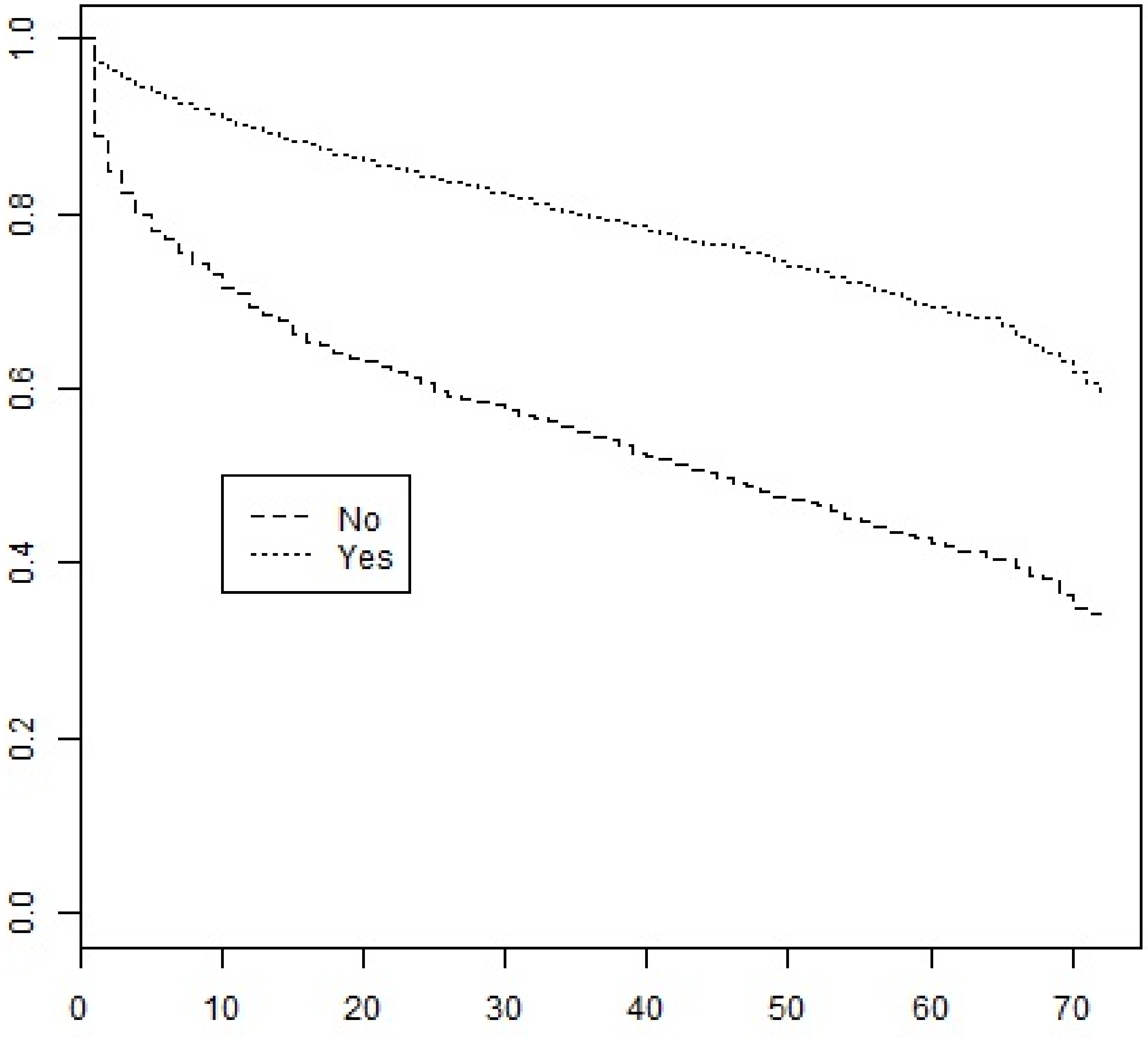


Kaplan-Meier with Categorial Covariate

```
fitKMstr <- survfit(Surv(tenure, churn) ~ Partner,
                    data = dataSurv)
```

```
> print(fitKMstr)
Call: survfit(formula = Surv(tenure, churn) ~ Partner, data = dataSurv)

               n events median 0.95LCL 0.95UCL
Partner=No  2828   1200     45      41      50
Partner=Yes 2483    669     NA      NA      NA
```

```
plot(fitKMstr, lty = 2:3)
legend(10, .5, c("No", "Yes"), lty = 2:3)
```



MARKETING ANALYTICS IN R: STATISTICAL MODELING

Let's practice!

MARKETING ANALYTICS IN R: STATISTICAL MODELING

Cox PH Model with Constant Covariates

Verena Pflieger
Data Scientist at INWT Statistics

Model Assumptions

Model definition: $\lambda(t|x) = \lambda(t) * exp(x'\beta)$

No shape of underlying hazard $\lambda(t)$ assumed

Relative hazard function $exp(x'\beta)$ constant over time

Fitting a Survival Model

```
library(rms)
units(dataSurv$tenure) <- "Month"
dd <- datadist(dataSurv)
options(datadist = "dd")
```

```
fitCPH1 <- cph(Surv(tenure, churn) ~ gender  +
                 SeniorCitizen + Partner + Dependents +
                 StreamMov + PaperlessBilling + PayMeth +
                 MonthlyCharges,
               data = dataSurv,
               x = TRUE, y = TRUE, surv = TRUE,
               time.inc = 1)
```

Summary of Survival Model

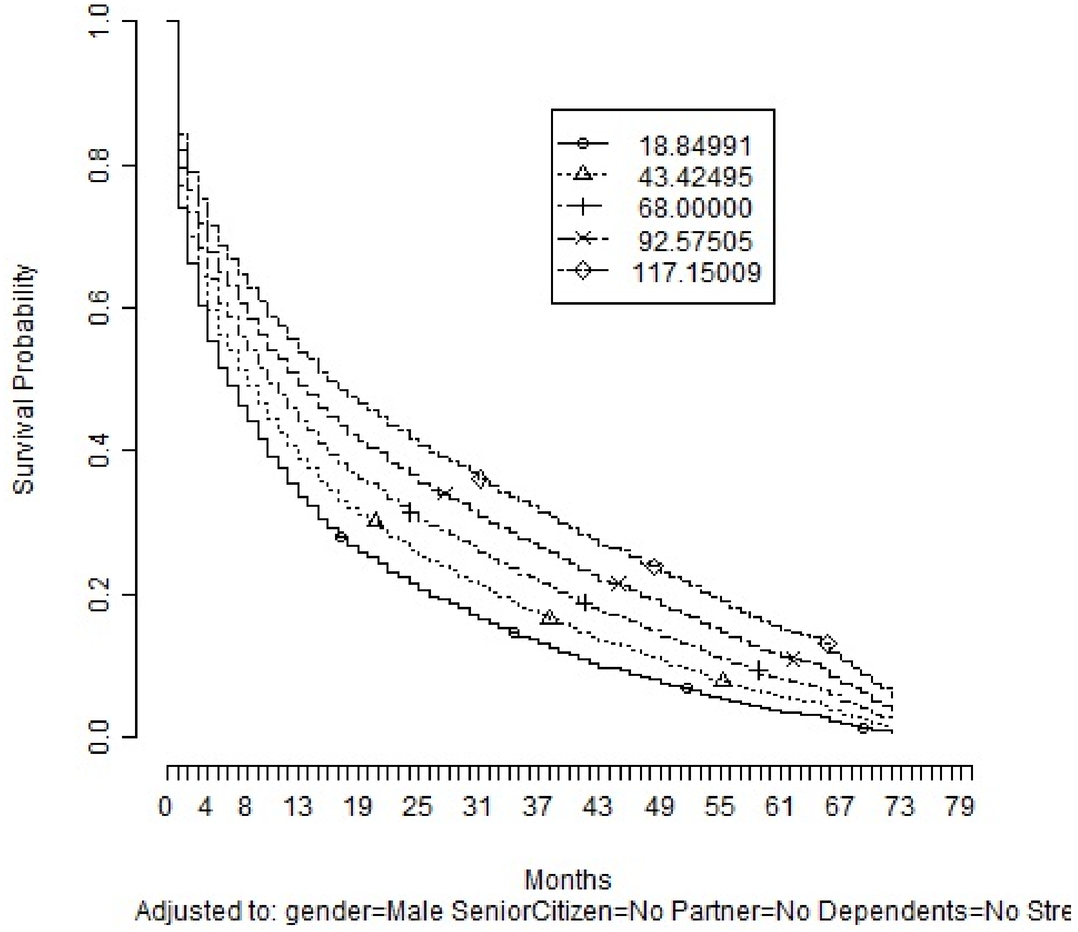
```
Cox Proportional Hazards Model
  cph(formula = Surv(tenure, churn) ~ gender + ..., data = dataSurv,
  x = TRUE, y = TRUE, surv = TRUE, time.inc = 1)

                      Model Tests       Discrimination
                                           Indexes
 Obs       5311    LR chi2    1366.98    R2       0.228
 Events    1869    d.f.            11    Dxy      0.496
 Center -0.3964    Pr(> chi2)  0.0000    g        1.125
                   Score chi2 1355.12    gr       3.082
                   Pr(> chi2)  0.0000

                             Coef    S.E.   Wald Z Pr(>|Z|)
 gender=Male                 -0.0326 0.0464  -0.70 0.4817
 SeniorCitizen=Yes            0.2066 0.0556   3.71 0.0002
 Partner=Yes                 -0.7433 0.0545 -13.65 <0.0001
 Dependents=Yes              -0.2072 0.0681  -3.04 0.0023
 StreamMov=NoIntServ         -1.4504 0.1168 -12.41 <0.0001
 StreamMov=Yes               -0.4139 0.0556  -7.44 <0.0001
 PaperlessBilling=Yes         0.4056 0.0563   7.21 <0.0001
 PayMeth=CreditCard(auto) -0.0889 0.0905  -0.98 0.3264
 PayMeth=ElektCheck           1.1368 0.0712  15.97 <0.0001
 PayMeth=MailedCheck          0.7800 0.0875   8.92 <0.0001
 MonthlyCharges              -0.0058 0.0013  -4.45 <0.0001
```

Interpretation of Coefficients

```
> exp(fitCPH1$coefficients)
             gender=Male        SeniorCitizen=Yes
               0.9679156                1.2294357
             Partner=Yes           Dependents=Yes
               0.4755412                0.8128759
     StreamMov=NoIntServ            StreamMov=Yes
               0.2344695                0.6610708
    PaperlessBilling=Yes PayMeth=CreditCard(auto)
               1.5001646                0.9149822
      PayMeth=ElektCheck      PayMeth=MailedCheck
               3.1168997                2.1814381
          MonthlyCharges
               0.9942395
```

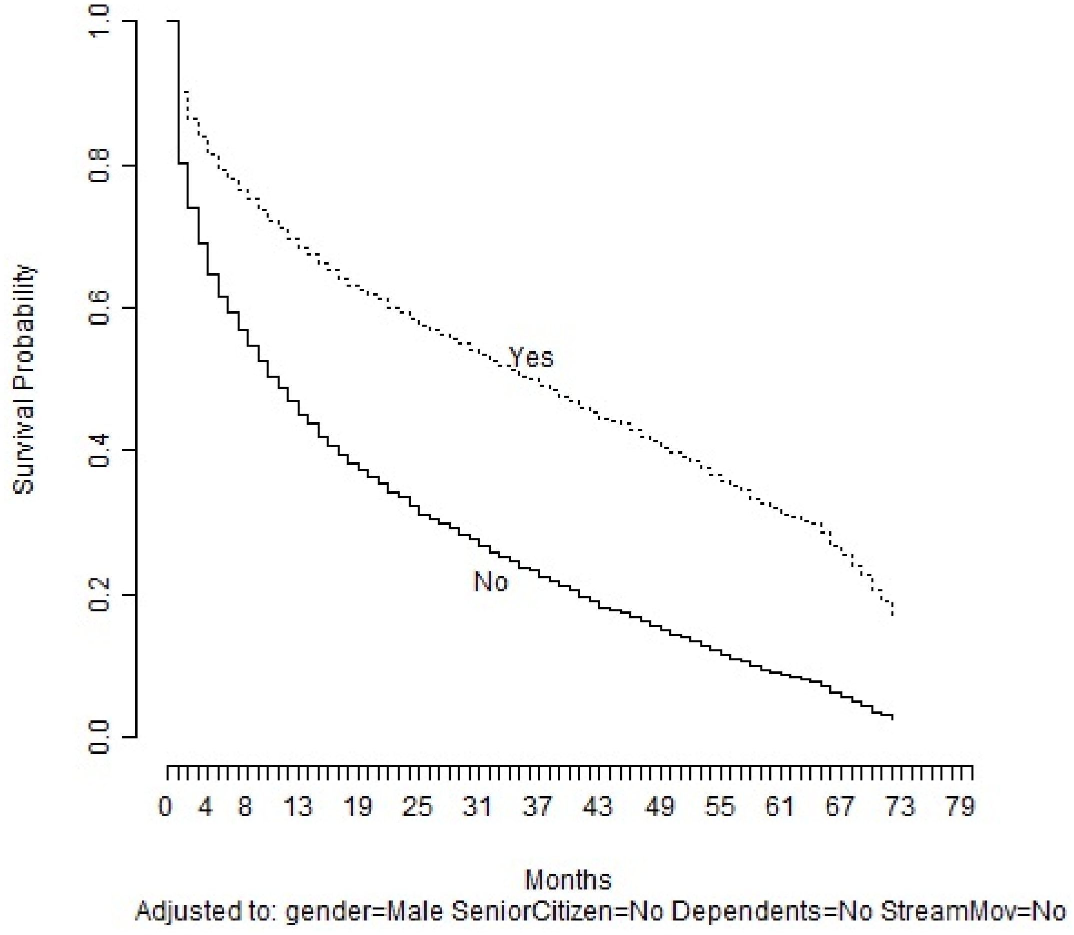
Survival Probabilities by MonthlyCharges

```
survplot(fitCPH1, MonthlyCharges, label.curves = list(keys = 1:5))
```



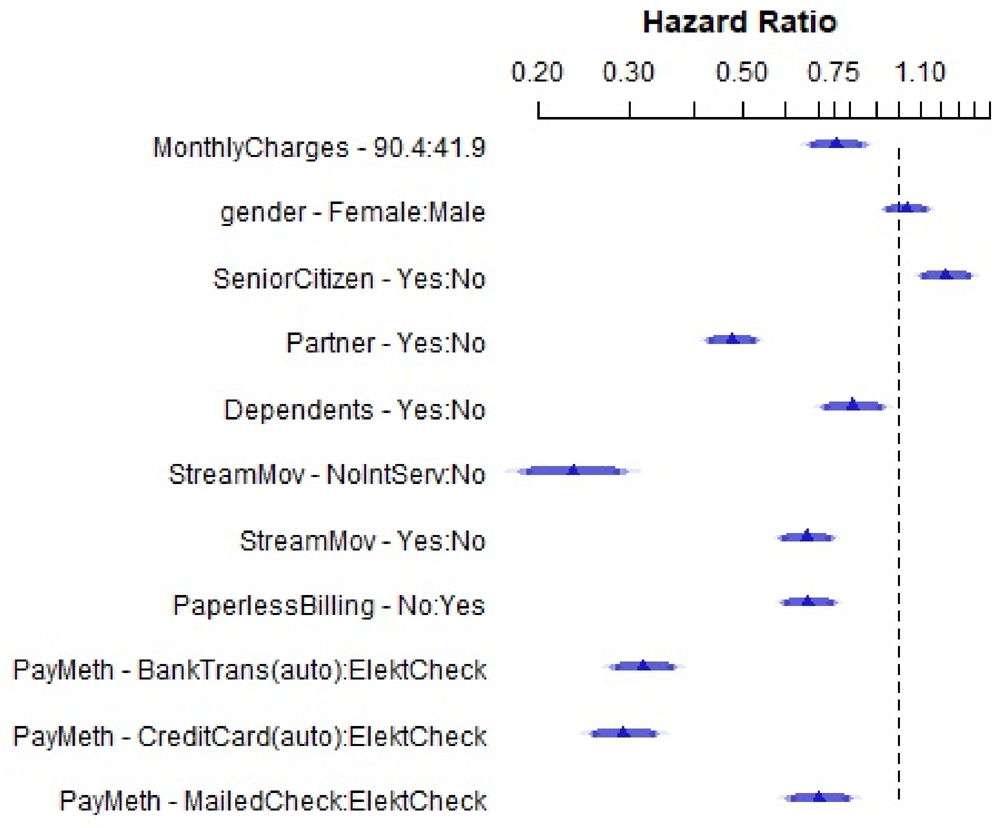
Survival Probabilities by Partner

```
survplot(fitCPH1, Partner)
```



Visualization of Hazard Ratios

```
plot(summary(fitCPH1), log = TRUE)
```



MARKETING ANALYTICS IN R: STATISTICAL MODELING

Let's practice!

MARKETING ANALYTICS IN R: STATISTICAL MODELING

Checking Model Assumptions and Making Predictions

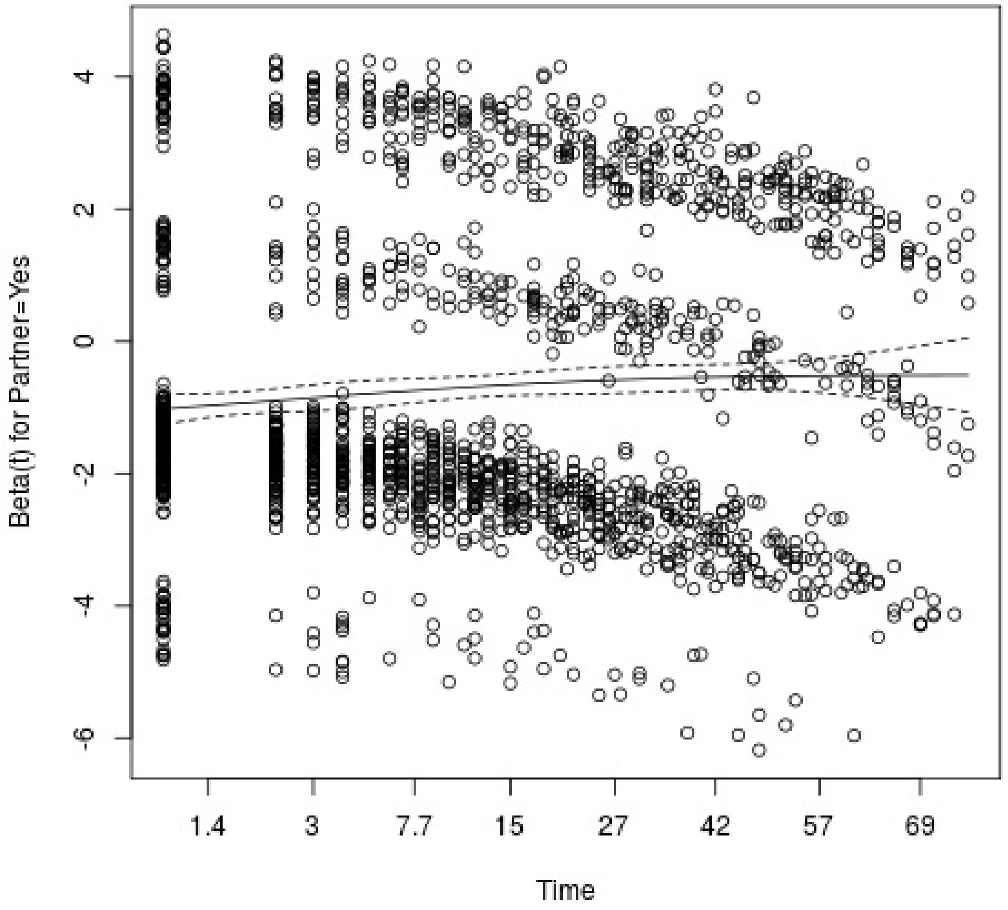
Verena Pflieger
Data Scientist at INWT Statistics

Test of PH Assumption

```
testCPH1 <- cox.zph(fitCPH1)
print(testCPH1)
                               rho   chisq        p
gender=Male                 0.0317   1.884 1.70e-01
SeniorCitizen=Yes           0.0587   6.507 1.07e-02
Partner=Yes                 0.0752  10.116 1.47e-03
Dependents=Yes              0.0131   0.314 5.75e-01
StreamMov=NoIntServ        -0.0448   3.588 5.82e-02
StreamMov=Yes               0.0827  12.174 4.85e-04
PaperlessBilling=Yes        0.0180   0.611 4.34e-01
PayMeth=CreditCard(auto)    0.0253   1.198 2.74e-01
PayMeth=ElektCheck         -0.0427   3.427 6.41e-02
PayMeth=MailedCheck        -0.0851  13.069 3.00e-04
MonthlyCharges              0.1268  25.778 3.83e-07
GLOBAL                          NA 217.172 0.00e+00
```

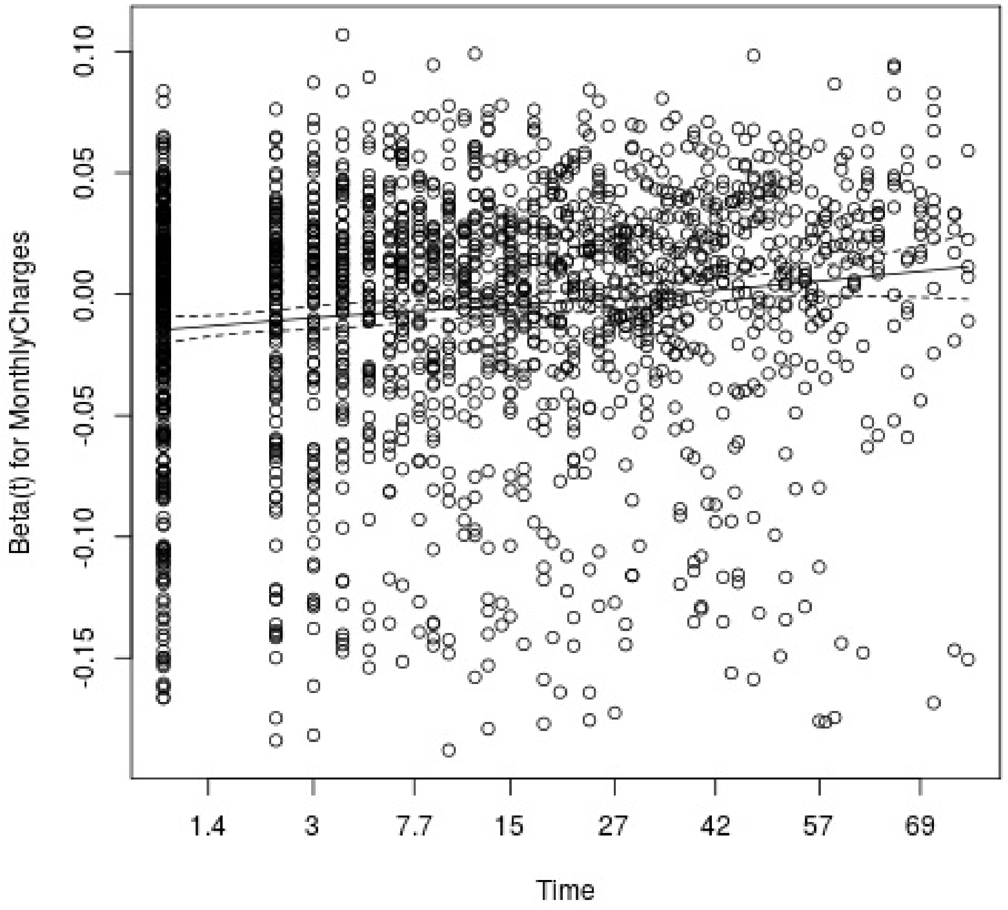
Proportional Hazards for Partner

```
plot(testCPH1, var = "Partner=Yes")
```



Proportional Hazards for MonthlyCharges

```
plot(testCPH1, var = "MonthlyCharges")
```



General Remarks on Tests

- cox.zph()-test conservative
- sensitive to number of observations
- different gravity of violations

What if PH Assumption is Violated?

- stratified analysis

```
fitCPH2 <- cph(Surv(tenure, churn) ~ MonthlyCharges +
                 SeniorCitizen + Partner + Dependents +
                 StreamMov + Contract,
               stratum = "gender = Male",
               data = dataSurv, x = TRUE, y = TRUE, surv = TRUE)
```

- time-dependent coefficients

Validating the Model

```
validate(fitCPH1,
         method = "crossvalidation",
         B = 10, pr = FALSE)
```

```
      index.orig training   test optimism index.corrected  n
R2        0.2277   0.2279 0.2277   0.0002          0.2276 10
                            ...
```

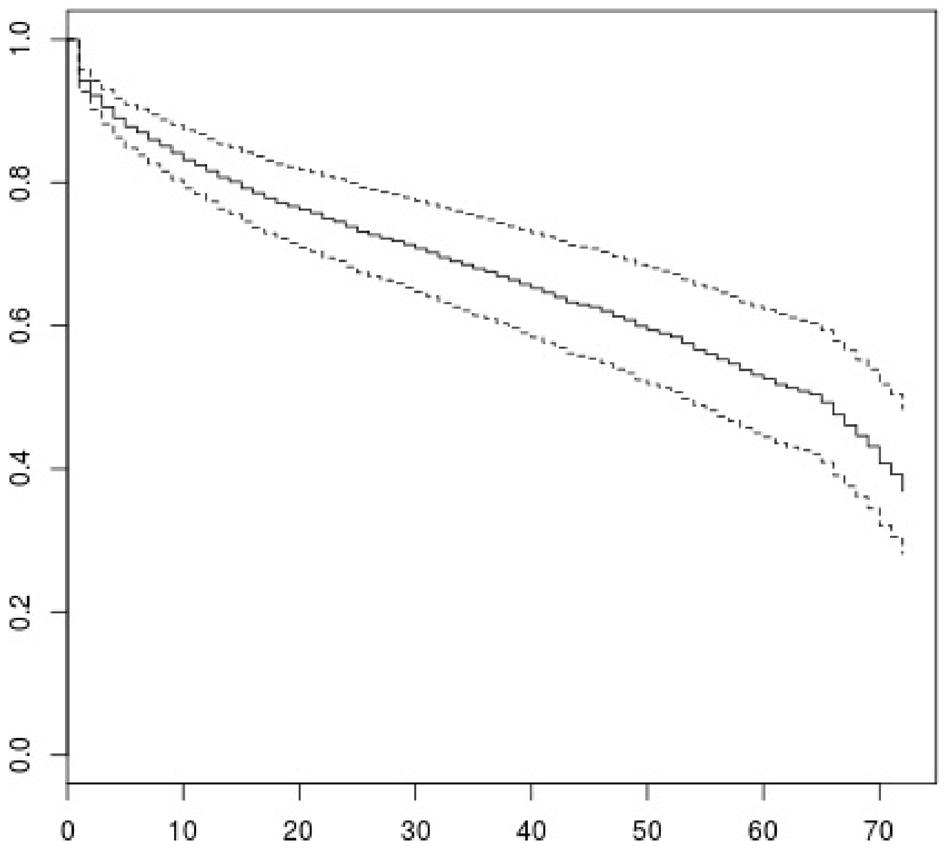
Probability not to Churn at Certain Timepoint

```
oneNewData <- data.frame(gender = "Female",
                             SeniorCitizen = "Yes",
                             Partner = "No",
                             Dependents = "Yes",
                             StreamMov = "Yes",
                             PaperlessBilling = "Yes",
                             PayMeth = "BankTrans(auto)",
                             MonthlyCharges = 37.12)
```

```
> str(survest(fitCPH1, newdata = oneNewData, times = 3))
List of 5
 $ time   : num 3
 $ surv   : num 0.905
 $ std.err: num 0.0136
 $ lower  : num 0.881
 $ upper  : num 0.93
```

Survival Curve for new Customer

```
plot(survfit(fitCPH1,
        newdata = oneNewData))
```



Predicting Expected Time until Churn

```
> print(survfit(fitCPH1,
+         newdata = oneNewData))
Call: survfit(formula = fitCPH1, newdata = oneNewData)

      n  events  median 0.95LCL 0.95UCL
   5311    1869      65      53      72
```

Learnings

	Learnings about survival analyis
You have learned...	to visualize the tenure times of customers
	to model the time to an event and extract factors influencing it
	how to validate the model
	how to make predictions

	Learnings from the model
You have learned...	that being senior citizen increases the probability to churn by 23%
	that a one-unit increase in monthly charges decreases the hazard of churning by about 1%

MARKETING ANALYTICS IN R: STATISTICAL MODELING

It is up to you now!