**Příklad řešení soustavy rovnic**

```
> A <- matrix(c(3,1,4,6),2,2)
> A
     [,1] [,2]
[1,]    3    4
[2,]    1    6
> y <- matrix(c(4,2),2,1)
> y
     [,1]
[1,]    4
[2,]    2
> x <- solve(A) %*% y
> x
          [,1]
[1,] 1.1428571
[2,] 0.1428571
```

**Otcovský (sire) model**

```
> X <- matrix(c(1,0,1,1,1,0,
+ 0,1,0,0,0,1),6,2)
> X
     [,1] [,2]
[1,]    1    0
[2,]    0    1
[3,]    1    0
[4,]    1    0
[5,]    1    0
[6,]    0    1
> Z <- matrix(c(1,1,0,0,0,0,
+ 0,0,1,1,0,0,
+ 0,0,0,0,1,1),6,3)
> Z
     [,1] [,2] [,3]
[1,]    1    0    0
[2,]    1    0    0
[3,]    0    1    0
[4,]    0    1    0
[5,]    0    0    1
[6,]    0    0    1
> R <- diag(c(1,1,1,1,1,1)*6

+ R <- diag(c(1,1,1,1,1,1)*6>
> R <- diag(c(1,1,1,1,1,1))*6
> R
     [,1] [,2] [,3] [,4] [,5] [,6]
[1,]    6    0    0    0    0    0
[2,]    0    6    0    0    0    0
[3,]    0    0    6    0    0    0
[4,]    0    0    0    6    0    0
[5,]    0    0    0    0    6    0
[6,]    0    0    0    0    0    6
> Va <- 8
> Vo <- Va/4
```

```
> G <- diag(3)*Vo
> G
     [,1] [,2] [,3]
[1,]    2    0    0
[2,]    0    2    0
[3,]    0    0    2
> V <- Z %*% G%*%t(Z) + R
> V
     [,1] [,2] [,3] [,4] [,5] [,6]
[1,]    8    2    0    0    0    0
[2,]    2    8    0    0    0    0
[3,]    0    0    8    2    0    0
[4,]    0    0    2    8    0    0
[5,]    0    0    0    0    8    2
[6,]    0    0    0    0    2    8
> y <-matrix(c(9,12,11,6,7,14),6,1)
> y
     [,1]
[1,]    9
[2,]   12
[3,]   11
[4,]    6
[5,]    7
[6,]   14
> BLUE <- solve(t(X)%*%solve(V)%*%X)%*%(t(X)%*%solve(V)%*%y)
> BLUE
          [,1]
[1,]  8.222222
[2,] 13.055556
> BLUP <- G%*%t(Z)%*%solve(V) %*%(y-(X%*%BLUE))
> BLUP
             [,1]
[1,] -0.05555556
[2,]  0.11111111
[3,] -0.05555556
> # metodou normálních rovnic smíšeného modelu
> XRX <- t(X)%*%solve(R)%*%X
```

```
> XRX
          [,1]      [,2]
[1,] 0.6666667 0.0000000
[2,] 0.0000000 0.3333333
> XRZ <- t(X)%*%solve(R)%*%Z
> XRZ
          [,1]      [,2]      [,3]
[1,] 0.1666667 0.3333333 0.1666667
[2,] 0.1666667 0.0000000 0.1666667
> ZRX <- t(Z)%*%solve(R)%*%X
> ZRX
          [,1]      [,2]
[1,] 0.1666667 0.1666667
[2,] 0.3333333 0.0000000
[3,] 0.1666667 0.1666667
> ZRZG <- t(Z)%*%solve(R)%*%Z + solve(G)
> ZRZG
          [,1]      [,2]      [,3]
[1,] 0.8333333 0.0000000 0.0000000
[2,] 0.0000000 0.8333333 0.0000000
[3,] 0.0000000 0.0000000 0.8333333
> LS1 <-rbind(XRX,ZRX)
> LS1
          [,1]      [,2]
[1,] 0.6666667 0.0000000
[2,] 0.0000000 0.3333333
[3,] 0.1666667 0.1666667
[4,] 0.3333333 0.0000000
[5,] 0.1666667 0.1666667
> LS2 <- rbind(XRZ,ZRZG)
> LS2
          [,1]      [,2]      [,3]
[1,] 0.1666667 0.3333333 0.1666667
[2,] 0.1666667 0.0000000 0.1666667
[3,] 0.8333333 0.0000000 0.0000000
[4,] 0.0000000 0.8333333 0.0000000
[5,] 0.0000000 0.0000000 0.8333333
```

```
> LS <- cbind(LS1,LS2)
> LS
          [,1]      [,2]      [,3]      [,4]      [,5]
[1,] 0.6666667 0.0000000 0.1666667 0.3333333 0.1666667
[2,] 0.0000000 0.3333333 0.1666667 0.0000000 0.1666667
[3,] 0.1666667 0.1666667 0.8333333 0.0000000 0.0000000
[4,] 0.3333333 0.0000000 0.0000000 0.8333333 0.0000000
[5,] 0.1666667 0.1666667 0.0000000 0.0000000 0.8333333
> XRy <- t(X)%*%solve(R)%*%y
> XRy
         [,1]
[1,] 5.500000
[2,] 4.333333
> ZRy <- t(Z)%*%solve(R)%*%y
> ZRy
         [,1]
[1,] 3.500000
[2,] 2.833333
[3,] 3.500000
> PS <- rbind(XRy,ZRy)
> PS
         [,1]
[1,] 5.500000
[2,] 4.333333
[3,] 3.500000
[4,] 2.833333
[5,] 3.500000
> bu <- solve(LS)%*%PS
> bu
            [,1]
[1,]  8.22222222
[2,] 13.05555556
[3,] -0.05555556
[4,]  0.11111111
[5,] -0.05555556
```

## Animal model

```
> h2 <- 0.25
> K <- (1-h2)/h2
> X <- matrix(c(1,1,1,0,0,
+ 0,0,0,1,1,
+ 1,1,0,0,1,
+ 0,0,1,1,0),5,4)
> X
     [,1] [,2] [,3] [,4]
[1,]    1    0    1    0
[2,]    1    0    1    0
[3,]    1    0    0    1
[4,]    0    1    0    1
[5,]    0    1    1    0
> Z <- diag(1,5)
> Z
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    0    0    0    0
[2,]    0    1    0    0    0
[3,]    0    0    1    0    0
[4,]    0    0    0    1    0
[5,]    0    0    0    0    1
> y <- matrix(c(4500,5000,6500,8000,7000),5,1)
> y
     [,1]
[1,] 4500
[2,] 5000
[3,] 6500
[4,] 8000
[5,] 7000
> A <- matrix(c(1,0,0,0,0,0,
+ 0,1,0,0,0.25,0.5,
+ 0,0,1,0,0,0,
+ 0,0,0,1,0,0,
+ 0,0.25,0,0,1,0.5,
+ 0,0.5,0,0,0.5,1),6,6)
```

```
> A
     [,1] [,2] [,3] [,4] [,5] [,6]
[1,]    1 0.00    0    0 0.00  0.0
[2,]    0 1.00    0    0 0.25  0.5
[3,]    0 0.00    1    0 0.00  0.0
[4,]    0 0.00    0    1 0.00  0.0
[5,]    0 0.25    0    0 1.00  0.5
[6,]    0 0.50    0    0 0.50  1.0
> XX <-(tX)%*%X
Error: object 'tX' not found
> XX <-t(X)%*%X
> XX
     [,1] [,2] [,3] [,4]
[1,]    3    0    2    1
[2,]    0    2    1    1
[3,]    2    1    3    0
[4,]    1    1    0    2
> XZ <- t(X)%*%Z
> XZ
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    1    1    0    0
[2,]    0    0    0    1    1
[3,]    1    1    0    0    1
[4,]    0    0    1    1    0
> ZZ <- t(Z)%*%Z
> ZZ
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    0    0    0    0
[2,]    0    1    0    0    0
[3,]    0    0    1    0    0
[4,]    0    0    0    1    0
[5,]    0    0    0    0    1
> AK <- solve(A)*K
> AK
     [,1] [,2] [,3] [,4]          [,5] [,6]
[1,]    3    0    0    0  0.000000e+00    0
[2,]    0    4    0    0  1.665335e-16   -2
```

```
[3,]    0    0    3    0  0.000000e+00    0
[4,]    0    0    0    3  0.000000e+00    0
[5,]    0    0    0    0  4.000000e+00   -2
[6,]    0   -2    0    0 -2.000000e+00    5
> ZX <- t(Z)%*%X
> ZX
     [,1] [,2] [,3] [,4]
[1,]    1    0    1    0
[2,]    1    0    1    0
[3,]    1    0    0    1
[4,]    0    1    0    1
[5,]    0    1    1    0
> Z0 <- matrix(c(0,0,0,0,0),1,5)
> Z0
     [,1] [,2] [,3] [,4] [,5]
[1,]    0    0    0    0    0
> Z00 <- matrix(c(0,0,0,0,0,0),6,1)
> Z00
     [,1]
[1,]    0
[2,]    0
[3,]    0
[4,]    0
[5,]    0
[6,]    0
> ZZZ <- cbind(rbind(ZZ,Z0),Z00)
> ZZZ
     [,1] [,2] [,3] [,4] [,5] [,6]
[1,]    1    0    0    0    0    0
[2,]    0    1    0    0    0    0
[3,]    0    0    1    0    0    0
[4,]    0    0    0    1    0    0
[5,]    0    0    0    0    1    0
[6,]    0    0    0    0    0    0
> ZAK <- ZZZ+AK
> ZAK
     [,1] [,2] [,3] [,4]          [,5] [,6]
```

```
[1,]    4    0    0    0  0.000000e+00    0
[2,]    0    5    0    0  1.665335e-16   -2
[3,]    0    0    4    0  0.000000e+00    0
[4,]    0    0    0    4  0.000000e+00    0
[5,]    0    0    0    0  5.000000e+00   -2
[6,]    0   -2    0    0 -2.000000e+00    5
> 01 <- matrix(c(0,0,0,0),4,1)
Error in 1 <- matrix(c(0, 0, 0, 0), 4, 1) :
  invalid (do_set) left-hand side to assignment
> X01 <- matrix(c(0,0,0,0),4,1)
> XZ0 <- cbind(XZ,X01)
> XZ0
     [,1] [,2] [,3] [,4] [,5] [,6]
[1,]    1    1    1    0    0    0
[2,]    0    0    0    1    1    0
[3,]    1    1    0    0    1    0
[4,]    0    0    1    1    0    0
> Z01 <- matrix(c(0,0,0,0),1,4)
> ZX0 <- rbind(ZX,Z01)
> ZX0
     [,1] [,2] [,3] [,4]
[1,]    1    0    1    0
[2,]    1    0    1    0
[3,]    1    0    0    1
[4,]    0    1    0    1
[5,]    0    1    1    0
[6,]    0    0    0    0
> LS1 <- rbind(XX,ZX0)
> LS1 <- rbind(XZ0,ZAK)
> LS1 <- rbind(XX,ZX0)
> LS2 <- rbind(XZ0,ZAK)
> LS <- cbind(LS1,LS2)
> LS
      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]          [,9] [,10]
 [1,]    3    0    2    1    1    1    1    0  0.000000e+00     0
 [2,]    0    2    1    1    0    0    0    1  1.000000e+00     0
 [3,]    2    1    3    0    1    1    0    0  1.000000e+00     0
```

```
 [4,]    1    1    0    2    0    0    1    1  0.000000e+00      0
 [5,]    1    0    1    0    4    0    0    0  0.000000e+00      0
 [6,]    1    0    1    0    0    5    0    0  1.665335e-16     -2
 [7,]    1    0    0    1    0    0    4    0  0.000000e+00      0
 [8,]    0    1    0    1    0    0    0    4  0.000000e+00      0
 [9,]    0    1    1    0    0    0    0    0  5.000000e+00     -2
[10,]    0    0    0    0    0   -2    0    0 -2.000000e+00      5
> Xy <- t(X)%*%y
> Xy
      [,1]
[1,] 16000
[2,] 15000
[3,] 16500
[4,] 14500
> Zy <- t(Z)%*%y
> Zy
     [,1]
[1,] 4500
[2,] 5000
[3,] 6500
[4,] 8000
[5,] 7000
> PS <- rbind(Xy,Zy,0)
> PS
       [,1]
 [1,] 16000
 [2,] 15000
 [3,] 16500
 [4,] 14500
 [5,]  4500
 [6,]  5000
 [7,]  6500
 [8,]  8000
 [9,]  7000
[10,]     0
> invLS <- solve(LS)
Error in solve.default(LS) :
```

```
  system is computationally singular: reciprocal condition number = 1.23358e-17
```

**Protože matice LS je singulární (má nulový determinant), nelze ji invertovat standardním způsobem. Řešením je úprava matice LS, nebo použít zobecněnou inverzi.**

**Zde je potřeba načíst balíček MASS, aby bylo možné použít příkaz pro zobecněnou inverzi.**

```
> bu <- ginv(LS)%*%PS
> bu
             [,1]
 [1,] 2302.23138
 [2,] 4229.74702
 [3,] 2547.96760
 [4,] 3984.01080
 [5,]  -87.54974
 [6,]   47.47015
 [7,]   53.43945
 [8,]  -53.43945
 [9,]   61.96703
[10,]   43.77487
>
```