```
## Monte carlo ICU model


nursedbeds<-13    #The number of beds on ICU

extrabeds<-2      #The reserve beds on ICU;   1 recovery automatically coded for

factor<-1         #Adjustment factor to alter admission rate where 1 is data driven, >1 is increased and
<1 is reduced.

d<-(0)            #Extend or reduce length of stay

iteration=500     #The number of times to repeat 1.5 year of simulation


#These matrices collect the data for each repeated simulation of 18 months

ads<-matrix(0,1,iteration)          #admissions

fails<-matrix(0,1,iteration)        #failed electives

uns<-matrix(0,1,iteration)          #unsafe days

nurses<-matrix(0,1,iteration)       #number of nurses needed


spill<-matrix(0,1,iteration)        #number of beds occupied > 13

occ<-matrix(0,1,iteration)          #occupancy of 13 bed unit

div<-matrix(0,1,iteration)          #failed emergency

yrs<-matrix(0,1,iteration)

LS<-matrix(0,1,iteration)           #Long stay bed occupancy

vdays<-matrix(0,1,iteration)        #ventilated days

pdays<-matrix(0,1,iteration)        #patient days

LSV<-matrix(0,1,iteration)          #Long stay bed ventilated status

dailybedstatus<-matrix(0,iteration,549)   #number of beds occupied per day for each simulated
18mths

propstatus<-matrix(1,iteration)

dailynursestatus<-matrix(0,iteration,549)


days<-549     # number of days to simulate where 549 days is 18 months


lv_mode<-0  #turns on long vent bypass unit
```

```
 for (reps in 1:iteration){         #number of simulated 18 months to run

   #Setting up model parameters

   b <- nursedbeds+extrabeds+1       #total beds available where the +1 is the recovery ventilated bed

   beds <- matrix(0, 9, b) #%column 1 = type (elec vs emerg), column 2 = LOS, colume 3 = ventilated days, column 4 = days stayed, column 5 = vent days, column 6 = age, column 7 = outcome, column 8 = gender, column 9 - occupied

   longbeds <- matrix(0, 9, 6) #%column 1 = type (elec vs emerg), column 2 = LOS, colume 3 = ventilated days, column 4 = days stayed, column 5 = vent days, column 6 = age, column 7 = outcome, column 8 = gender, column 9 - occupied

   #Setting up matrices for collecting data for each 18 month simulated. These feed into the simulated matrices

   admissions<-matrix(0,1,days)

   discharges<-matrix(0,1,days)

   failed_admissions<- matrix(0, 1, days)

   emerg <- matrix(0, 1, days)

   elec <- matrix(0, 1, days)

   unsafe <-matrix(0, 1, days)

   nursesneeded <-matrix(0, 1, days)

   vent_required <- matrix(0, 1, days)

   occupied <- matrix(0, 1, days)

   lsvoccupied <- matrix(0, 1, days)

   elec_q <-0

   emerg_q <-0

   count<-0

   remainder<-matrix(0, 1, days)

   diverted<-0;

   #This function generates the admission matrices that are worked through the for loop for the 18mth ICU simulation (0 is elective, 1 emergency, and factor is adjustment defined above)
```

```
  elec_referrals <- gen_admit_discrete(0, factor)
  emerg_referrals <-gen_admit_discrete(1, factor)

  patientdata <- matrix(0,9,sum(elec_referrals+emerg_referrals)) #set up a matrix for collecting the patient variables

  #The actual 18mths to start simulate within this for loop
  for (i in 1:days) {

    #Identify longstay patients
    if(lv_mode==1){ #ignore if not in longstay mode
    for (j in 1:b){
      if (beds[5,j]>22) {
        for (lv in 1:3){
          if (longbeds[9,lv]==0){
            longbeds[,lv]=beds[,j]
          }

          if (longbeds[2,lv]<=0) {
            longbeds[1,lv] = 0;longbeds[2,lv] = 0;longbeds[3,lv] = 0;longbeds[4,lv] = 0;longbeds[5,lv] = 0; longbeds[6,lv] = 0;longbeds[7,lv] = 0;longbeds[8,lv] = 0; longbeds[9,lv] = 0;
            discharges[1,i] = discharges[1,i] + 1
          } else {
            longbeds[2,lv] = longbeds[2,lv]-1
            if (longbeds[3,lv]>0) {
              longbeds[3,lv]=longbeds[3,lv]-1
              longbeds[5,lv]=beds[5,lv]+1
            }
          }
        beds[1,j] = 0;beds[2,j] = 0;beds[3,j] = 0;beds[4,j] = 0;beds[5,j] = 0; beds[6,j] = 0;beds[7,j] = 0;beds[8,j] = 0; beds[9,j] = 0;
```

```
    }
   }
  }

  }

 #Identify and assign admissions
  elec_q =elec_q+elec_referrals[i]  # matrix ref 1
  emerg_q =emerg_q+emerg_referrals[i]  # matrix ref 2

  for (j in 1:b){

   #%column 1 = type (elec vs emerg), column 2 = LOS, column 3 = ventilated days, column 4 = days stayed, column 5 = vent days, column 6 = age, column 7 = outcome, column 8 = gender, column 9 - occupied

   if ((beds[9,j]== 0) && emerg_q>0) {
    beds[1,j] = 1; beds[2,j]=LOS(1)+d; beds[3,j] =floor(0.96*beds[2,j]);  beds[4,j] =0; beds[5,j] = 0; beds[6,j]= age(1); beds[7,j]= survival(1); beds[8,j]= gender(1); beds[9,j]=1;
    emerg_q = emerg_q-1
    admissions[i] = admissions[i]+1
    patientdata[,sum(admissions)]=beds[,j]
   }

   if ((beds[9,j]== 0) && elec_q>0 && sum(beds[9,])<=(nursedbeds)){
    beds[1,j] = 0; beds[2,j]=LOS(0)+d; beds[3,j] =floor(0.92*beds[2,j]);  beds[4,j] =0; beds[5,j] = 0; beds[6,j]= age(1); beds[7,j]= survival(0); beds[8,j]= gender(0); beds[9,j]= 1;
    elec_q = elec_q-1;
    admissions[i] = admissions[i]+1
    patientdata[,sum(admissions)]=beds[,j]
   }
```

```
}

#Identify diverted emergencies but only for the last 18 months
if(emerg_q>0){
 if (i>=182){
   diverted = diverted +emerg_q
   count=count+1
   }
}

#counts the number of failed electives per day which includes the number of already waiting elective admissions
failed_admissions[1,i] = elec_q



#Identify discharges
for (j in 1:b){
 if (beds[9,j]>0) {
   #Are they dischargeable
   if (beds[2,j]==0) {#Must be <0 otherwise seen as another potential discharge
     beds[1,j] = 0;beds[2,j] = 0;beds[3,j] = 0;beds[4,j] = 0;beds[5,j] = 0; beds[6,j] = 0;beds[7,j] = 0;beds[8,j] = 0; beds[9,j] = 0;
     discharges[1,i] = discharges[1,i] + 1   #counts the number of discharges
   } else {    #if not dischargable, reduce LOS by 1 day
     beds[2,j] = beds[2,j]-1
     if (beds[3,j]>0) {
       beds[3,j]=beds[3,j]-1
       beds[5,j]=beds[5,j]+1
     }
   }
```

```
 }
}

elec[1,i] = sum(beds[1,]==2)    #counts the number of elective admissions on the ICU
emerg[1,i] = sum(beds[1,]==1)   #counts the number of emergency admissions on the ICU

occupied[1,i] = sum(beds[9,])   #counts the number of occupied beds on the ICU
lsvoccupied[1,i] = sum(longbeds[9,])  #counts the number of occupied long stay beds on the unit/

dailybedstatus[reps,]=occupied[1,]  #stores the occupied status for the simulation

v<- sum(beds[3,]>0) #identiy number of ventilated patients
vent_required[1,i]=v # count number of ventilated patients
n<-(0.5*(sum(beds[9,])-v)+v)  #determine the number of nurses needed where 0.5nurse per non-ventilated and 1 nurse per ventilated

if(sum(beds[9,])>(b-1)){unsafe[1,i]=1   #An unsafe day is when the number of patients exceeds the number of beds -1 recovery bed.
} else{
 if(n>b-3){unsafe[1,i]=1}
}

nursesneeded[1,i] = n+2     #calculates the number of nurses needed for the unit including 1xrunner and 1xcoordinator
dailynursestatus[reps,i]=n+2#tores the number of nurses needed per day per simulation
}

flag = sum(admissions[1,1:181])     #This identifies the number of patients admitted up the the first 6 months which will then be discarded.
```

```
  ads[1,reps] = sum(admissions[182:549] ) #this stores only the numbre of admissions per day for the last 12 months of the simulation


  #Determines the number of new failed admissions per day at the end of the 18mth period.
  #This is to avoid double counting when there is a waiting list e.g. if the size of the waiting list per day is used as the number of failed electives, then the number of failed elective admissions will exceed the number of patients referred
  #This wasn't used for the emergency admissions as they did not normally form a waiting list.
  for(k in  2:549){
   if(failed_admissions[1,k]>failed_admissions[1,k-1]){
    remainder[1,k-1]=failed_admissions[1,k]-failed_admissions[1,k-1]
   }
   else{
    remainder[1,k-1]=0
   }
  }


  #Save data for the simulated 12 months excluding the burn in.
  fails[1,reps]=sum(remainder[182:549])
  uns[1,reps]=sum(unsafe[182:549])
  nurses[1,reps]=mean(nursesneeded[182:549])


  occ[1,reps]=sum(occupied[182:549])#+sum(longbeds[9,])
  div[1,reps]=diverted
  spill[1,reps]=sum((occupied[182:549])>13) # the number of reserve beds used.
  LSV[1,reps]=sum(lsvoccupied[182:549])
  propstatus[reps]=sum(patientdata[1,])/length(patientdata[1,])




  yrs[1,reps] = mean(patientdata[6,flag:length(patientdata[1,])])
  LS[1,reps] = mean(patientdata[2,flag:length(patientdata[1,])])
```

```
  vdays[1,reps]=mean(patientdata[3,flag:length(patientdata[1,])])
  pdays[1,reps]=sum(patientdata[2,flag:length(patientdata[1,])])


}


unsafe_nursing<-(dailynursestatus>=(nursedbeds))
unsafe_nursing=0+(unsafe_nursing*1)
m_nurse_safe<-mean(rowSums(unsafe_nursing[,182:549]))
sd_nurse_safe<-sd(rowSums(unsafe_nursing[,182:549]))


#output data depending on parametric or non-parametric analysis
choice <-1

if(choice==1){
  ##Non parametric
  output<-matrix(0,1,21)

  output[1,1]=factor
  output[1,2]=mean(ads)
  output[1,3]=sd(ads)
  output[1,4]=quantile(fails,0.5)
  output[1,5]=quantile(fails,0.75)
  output[1,6]=quantile(fails, 0.25)
  output[1,7]=quantile(div, 0.5)
  output[1,8]=quantile(div, 0.75)
  output[1,9]=quantile(div, 0.25)
  output[1,10]=quantile(uns,0.5)
  output[1,11]=quantile(uns,0.75)
```

```
  output[1,12]=quantile(uns, 0.25)
  output[1,13]=quantile(spill,0.5)
  output[1,14]=quantile(spill, 0.75)
  output[1,15]=quantile(spill, 0.25)
  output[1,16]=mean(nurses)
  output[1,17]=sd(nurses)
  output[1,18]=mean(occ)/((nursedbeds)*365)
  output[1,19]=sd(occ/((nursedbeds)*365))
  output[1,20]=mean(pdays)/((nursedbeds)*365)
  output[1,21]=sd(pdays)/((nursedbeds)*365)

  write.excel(output)
}

if(choice==2){
  ##parametric
  output<-matrix(0,1,17)

  output[1,1]=factor
  output[1,2]=mean(ads)
  output[1,3]=sd(ads)
  output[1,4]=mean(fails)
  output[1,5]=sd(fails)
  output[1,6]=mean(div)
  output[1,7]=sd(div)
  output[1,8]=mean(uns)
  output[1,9]=sd(uns)
  output[1,10]=mean(nurses)
  output[1,11]=sd(nurses)
  output[1,12]=mean(occ)/((nursedbeds)*365)
  output[1,13]=sd(occ/((nursedbeds)*365))
```

```
   output[1,14]=mean(occ/365)
   output[1,15]=sd(occ/365)
   output[1,16]=mean(spill)
   output[1,17]=sd(spill)

   write.excel(output)
 }
 # beepr::beep(1)



output

#write.table(output,"clipboard")

write.excel(output)

comp<-matrix(0,500,4)
comp[,1]=occ
comp[,2]=fails
comp[,3]=div
comp[,4]=uns
write.table(comp, file="clipboard-274500", sep="\t", col.names=NA )
sum(patientdata[1,])

#write.table(dailybedstatus, file="clipboard-274500", sep="\t", col.names=NA)
```