```
#Appendix 1: R Code
#Coleman Strickland
#Final Project

#import statements
library(queueing)
library(MASS)

rm(list=ls())
setwd("/Users/colemanstrickland/Documents/Coleman/GradSchool/Stochs2")

#function for implementing M/M/1: Inputs: data set, range of incidents
by number, equipment indentified
fire_queue<-function(infile, first_incident, last_incident,
equipment1, equipment2){
  fire<-read.csv(infile, as.is=T)
  fire<-subset(fire, (fire$Incident.>=first_incident &
fire$Incident.<=last_incident) & (fire$Apparatus==equipment1 |
fire$Apparatus==equipment2))

  #head(fire)
  #fire<-subset(fire, fire$District==4)

  Alarm_Time_New<-c()
  Arrival_Time_New<-c()
  Dispatch_Time_New<-c()
  Next_Dispatch_Time_New<-c()
  Clear_Time_New<-c()
  Incident<-c()
  Incident_Type<-c()
  Equipment<-c()
  District<-c()
  for (i in 1:length(fire$Incident.)){
    test<-toString(fire$Alarm_Time[i])
    z<-strptime(test, "%m/%d/%y  %H:%M:%S")
    Alarm_Time_New[i]<-as.numeric(z, units="secs")

    test<-toString(fire$Dispatch_Time[i])
    z<-strptime(test, "%m/%d/%y  %H:%M:%S")
    z<-as.POSIXlt(z, tz="EST" )
    Dispatch_Time_New[i]<-as.numeric(z, units="secs")

    test<-toString(fire$Dispatch_Time[i+1])
    z<-strptime(test, "%m/%d/%y  %H:%M:%S")
    z<-as.POSIXlt(z, tz="EST" )
    Next_Dispatch_Time_New[i]<-as.numeric(z, units="secs")

    test<-toString(fire$Arrival_Time[i])
    z<-strptime(test, "%m/%d/%y  %H:%M:%S")
    z<-as.POSIXlt(z, tz="EST" )
```

```
    Arrival_Time_New[i]<-as.numeric(z, units="secs")

    test<-toString(fire$Clear_Time[i])
    z<-strptime(test, "%m/%d/%y  %H:%M:%S")
    z<-as.POSIXlt(z, tz="EST" )
    Clear_Time_New[i]<-as.numeric(z, units="secs")

    Incident[i]<-fire$Incident.[i]
    Equipment[i]<-fire$Apparatus[i]
    District[i]<-fire$District[i]
    Incident_Type[i]<-fire$Incident.Type.Code[i]
  }

  fire_new<-c()
  fire_new <- data.frame(Incident, Incident_Type, Equipment,
Alarm_Time_New, Dispatch_Time_New, Arrival_Time_New, Clear_Time_New,
Next_Dispatch_Time_New, District)
  #tail(fire_new) #check for next_dispatch time

  #fire_new<-na.omit(fire_new)
  #head(fire_new)

  #calculate the difference of times between columns and place values
in the data frame
  fire_new$Avg_Trans<-(fire_new$Arrival_Time_New-
fire_new$Dispatch_Time_New)/60
  fire_new$Avg_Dispatch<-(fire_new$Dispatch_Time_New-
fire_new$Alarm_Time_New)/60
  fire_new$Avg_Clear<-(fire_new$Clear_Time_New-
fire_new$Arrival_Time_New)/60
  fire_new$Avg_Clear2<-(fire_new$Clear_Time_New-
fire_new$Dispatch_Time_New)/60
  fire_new$Avg_Next_Call<-(fire_new$Next_Dispatch_Time_New-
fire_new$Dispatch_Time_New)/60 ######
  fire_new$Avg_Cancelled<-(fire_new$Clear_Time_New-
fire_new$Dispatch_Time_New)/60

  #head(fire_new) #check

  #filter the times that are negative or unreasonable
  average_transition_times<-fire_new$Avg_Trans[fire_new$Avg_Trans>0 &
fire_new$Avg_Trans<45]
  average_dispatch_times<-
fire_new$Avg_Dispatch[fire_new$Avg_Dispatch>=0 &
fire_new$Avg_Dispatch<5]
  average_clear_times<-fire_new$Avg_Clear[fire_new$Avg_Clear>=0 &
fire_new$Avg_Clear<720]
  average_clear_times2<-fire_new$Avg_Clear2[fire_new$Avg_Clear2>=0 &
fire_new$Avg_Clear2<720]
  average_next_call_times<-
```

```
fire_new$Avg_Next_Call[fire_new$Avg_Next_Call>=0 &
fire_new$Avg_Next_Call<12*60]

  #find the averages of these times
  trans_time<-mean(na.omit(average_transition_times))
  #trans_time

  dispatch_time<-mean(na.omit(average_dispatch_times))
  #dispatch_time

  clear_time<-mean(na.omit(average_clear_times))
  #clear_time

  clear_time2<-mean(na.omit(average_clear_times2))
  #clear_time2

  next_call_time<-mean(na.omit(average_next_call_times))
  #next_call_time

  #overall service for District 4 including T4 and A4
  m<-NewInput.MMC(lambda=1/next_call_time, mu=1/(clear_time2), c=1)
  ro<-RO(QueueingModel(m))
  lq<-Lq(QueueingModel(m))
  w<-W(QueueingModel(m))
  #summary(QueueingModel(district_4))
return_values<-c()
return_values[1]<-ro
return_values[2]<-lq
return_values[3]<-w
return_values[4]<-next_call_time
return_values[5]<-clear_time2
return_values[6]<-trans_time
return_values[7]<-clear_time
return_values[8]<-
length(na.omit(unique(fire_new$Incident[((fire_new$District==4) |
(fire_new$District!=4))])))
return(return_values)} # Outputs: list of values: ro, lq, w, inter-
arrival and service time, transit time, count of incidents

#2011: F:1100001   L:1122044
#2012: F:1200001   L:1222041
#2013: F:1300012   L:1322183
#2014: F:1400015   L:1423231
#2015: F:1500005   L:1523757
#2016: F:1523762   L:1624587

#########################################################################
#########################
#All Equipment
#2011
```

```
all_2011<-fire_queue("Original.csv", 1100001, 1122044, "A4","T4")
#2012
all_2012<-fire_queue("Original.csv", 1200001, 1222041, "A4","T4")
#2013
all_2013<-fire_queue("Original.csv", 1300012, 1322183, "A4","T4")
#2014
all_2014<-fire_queue("Original.csv", 1400015, 1423231, "A4","T4")
#2015
all_2015<-fire_queue("Original.csv", 1500005, 1523757, "A4","T4")
#2016
all_2016<-fire_queue("Original.csv", 1523762, 1624587, "A4","T4")
#2011-2016
fire_queue("Original.csv", 1100001, 1624587, "A4","T4")
#PLOTS:
par(bg = 'grey')
#incident count
incident_num<-
c(all_2011[8],all_2012[8],all_2013[8],all_2014[8],all_2015[8],all_2016
[8])
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, incident_num, col="red", ylim =range(0,5000),
ylab="Incident Count" ,
     xlab = "Years", main="Incident Counts by Year (Station 4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,5000,1000),lwd=3)
text(years, incident_num, paste(round(incident_num, 3)), cex=0.8,
pos=3)
lines(years, incident_num, col="blue")
#utilization rate
ro<-
c(all_2011[1],all_2012[1],all_2013[1],all_2014[1],all_2015[1],all_2016
[1])*100
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, ro, col="red", ylim =range(0,100), ylab="Utilzation Rate
(%)" ,
     xlab = "Years", main="Utilization Rate by Year (Station 4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,100,20),lwd=3)
text(years, ro, paste(round(ro, 3)), cex=0.8, pos=3)
lines(years,ro, col="blue")
#service rate
w<-
c(all_2011[3],all_2012[3],all_2013[3],all_2014[3],all_2015[3],all_2016
[3])
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, w, col="red", ylim =range(0,60), ylab="Service Time
(min)" ,
     xlab = "Years", main="Time in System by Year (Station 4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,60,10),lwd=3)
```

```
text(years, w, paste(round(w, 3)), cex=0.8, pos=3)
lines(years,w, col="blue")
#trans time
transit<-
c(all_2011[6],all_2012[6],all_2013[6],all_2014[6],all_2015[6],all_2016
[6])
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, transit, col="red", ylim =range(0,6), ylab="Transit Time
(min)" ,
     xlab = "Years", main="Transit Time by Year (Station 4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,6,1),lwd=3)
text(years, transit, paste(round(transit, 3)), cex=0.8, pos=3)
lines(years,transit, col="blue")
########################################################################
######################
#A4
#2011
a4_2011<-fire_queue("Original.csv", 1100001, 1122044, "A4","A4")
#2012
a4_2012<-fire_queue("Original.csv", 1200001, 1222041, "A4","A4")
#2013
a4_2013<-fire_queue("Original.csv", 1300012, 1322183, "A4","A4")
#2014
a4_2014<-fire_queue("Original.csv", 1400015, 1423231, "A4","A4")
#2015
a4_2015<-fire_queue("Original.csv", 1500005, 1523757, "A4","A4")
#2016
a4_2016<-fire_queue("Original.csv", 1523762, 1624587, "A4","A4")
#2011-2016
fire_queue("Original.csv", 1100001, 1624587, "A4","A4")
#PLOTS:
#incident number:
incident_num<-
c(a4_2011[8],a4_2012[8],a4_2013[8],a4_2014[8],a4_2015[8],a4_2016[8])
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, incident_num, col="red", ylim =range(0,5000),
ylab="Incident Count" ,
     xlab = "Years", main="Incident Counts by Year (A4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,5000,1000),lwd=3)
text(years, incident_num, paste(round(incident_num, 3)), cex=0.8,
pos=3)
lines(years, incident_num, col="blue")
#utilization rate
ro<-
c(a4_2011[1],a4_2012[1],a4_2013[1],a4_2014[1],a4_2015[1],a4_2016[1])*1
00
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, ro, col="red", ylim =range(0,100), ylab="Utilzation Rate
```

```
(%)" ,
     xlab = "Years", main="Utilization Rate by Year (A4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,100,20),lwd=3)
text(years, ro, paste(round(ro, 3)), cex=0.8, pos=3)
lines(years,ro, col="blue")
#service rate
w<-
c(a4_2011[3],a4_2012[3],a4_2013[3],a4_2014[3],a4_2015[3],a4_2016[3])
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, w, col="red", ylim =range(0,60), ylab="Service Time
(min)" ,
     xlab = "Years", main="Time in System by Year (A4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,60,10),lwd=3)
text(years, w, paste(round(w, 3)), cex=0.8, pos=3)
lines(years,w, col="blue")
#trans time
transit<-
c(a4_2011[6],a4_2012[6],a4_2013[6],a4_2014[6],a4_2015[6],a4_2016[6])
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, transit, col="red", ylim =range(0,6), ylab="Transit Time
(min)" ,
     xlab = "Years", main="Transit Time by Year (A4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,6,1),lwd=3)
text(years, transit, paste(round(transit, 3)), cex=0.8, pos=3)
lines(years,transit, col="blue")
########################################################################
######################
#T4
#2011
t4_2011<-fire_queue("Original.csv", 1100001, 1122044, "T4","T4")
#2012
t4_2012<-fire_queue("Original.csv", 1200001, 1222041, "T4","T4")
#2013
t4_2013<-fire_queue("Original.csv", 1300012, 1322183, "T4","T4")
#2014
t4_2014<-fire_queue("Original.csv", 1400015, 1423231, "T4","T4")
#2015
t4_2015<-fire_queue("Original.csv", 1500005, 1523757, "T4","T4")
#2016
t4_2016<-fire_queue("Original.csv", 1523762, 1624587, "T4","T4")
#2011-2016
fire_queue("Original.csv", 1100001, 1624587, "T4","T4")
#PLOTS:
#incident number:
incident_num<-
c(t4_2011[8],t4_2012[8],t4_2013[8],t4_2014[8],t4_2015[8],t4_2016[8])
years<-c(2011,2012,2013,2014,2015,2016)
```

```
plot(years, incident_num, col="red", ylim =range(0,5000),
ylab="Incident Count" ,
     xlab = "Years", main="Incident Counts by Year (T4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,5000,1000),lwd=3)
text(years, incident_num, paste(round(incident_num, 3)), cex=0.8,
pos=3)
lines(years, incident_num, col="blue")
#utilization rate
ro<-
c(t4_2011[1],t4_2012[1],t4_2013[1],t4_2014[1],t4_2015[1],t4_2016[1])*1
00
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, ro, col="red", ylim =range(0,100), ylab="Utilzation Rate
(%)" ,
     xlab = "Years", main="Utilization Rate by Year (T4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,100,20),lwd=3)
text(years, ro, paste(round(ro, 3)), cex=0.8, pos=3)
lines(years,ro, col="blue")
#service rate
w<-
c(t4_2011[3],t4_2012[3],t4_2013[3],t4_2014[3],t4_2015[3],t4_2016[3])
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, w, col="red", ylim =range(0,60), ylab="Service Time
(min)" ,
     xlab = "Years", main="Time in System by Year (T4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,60,10),lwd=3)
text(years, w, paste(round(w, 3)), cex=0.8, pos=3)
lines(years,w, col="blue")
#trans time
transit<-
c(t4_2011[6],t4_2012[6],t4_2013[6],t4_2014[6],t4_2015[6],t4_2016[6])
years<-c(2011,2012,2013,2014,2015,2016)
plot(years, transit, col="red", ylim =range(0,6), ylab="Transit Time
(min)" ,
     xlab = "Years", main="Transit Time by Year (T4)" )
axis(side=1,at=seq(2011,2016,1),lwd=3)
axis(side=2,at=seq(0,6,1),lwd=3)
text(years, transit, paste(round(transit, 3)), cex=0.8, pos=3)
lines(years,transit, col="blue")
######################################################################
######################
#Inter-Arrival,Service Times, # of Incidents, ro, w, and Lq by Year
i_a_all<-
c(all_2011[4],all_2012[4],all_2013[4],all_2014[4],all_2015[4],all_2016
[4])
i_a_all
s_all<-
```

```
c(all_2011[5],all_2012[5],all_2013[5],all_2014[5],all_2015[5],all_2016
[5])
s_all
num_incidents_all<-
c(all_2011[8],all_2012[8],all_2013[8],all_2014[8],all_2015[8],all_2016
[8])
num_incidents_all
ro_all<-
c(all_2011[1],all_2012[1],all_2013[1],all_2014[1],all_2015[1],all_2016
[1])
ro_all
w_all<-
c(all_2011[3],all_2012[3],all_2013[3],all_2014[3],all_2015[3],all_2016
[3])
w_all
lq_all<-
c(all_2011[2],all_2012[2],all_2013[2],all_2014[2],all_2015[2],all_2016
[2])
lq_all

#A4
i_a_a<-
c(a4_2011[4],a4_2012[4],a4_2013[4],a4_2014[4],a4_2015[4],a4_2016[4])
i_a_a
s_a<-
c(a4_2011[5],a4_2012[5],a4_2013[5],a4_2014[5],a4_2015[5],a4_2016[5])
s_a
num_incidents_a<-
c(a4_2011[8],a4_2012[8],a4_2013[8],a4_2014[8],a4_2015[8],a4_2016[8])
num_incidents_a
ro_a<-
c(a4_2011[1],a4_2012[1],a4_2013[1],a4_2014[1],a4_2015[1],a4_2016[1])
ro_a
w_a<-
c(a4_2011[3],a4_2012[3],a4_2013[3],a4_2014[3],a4_2015[3],a4_2016[3])
w_a
lq_a<-
c(a4_2011[2],a4_2012[2],a4_2013[2],a4_2014[2],a4_2015[2],a4_2016[2])
lq_a

#T4
i_a_t<-
c(t4_2011[4],t4_2012[4],t4_2013[4],t4_2014[4],t4_2015[4],t4_2016[4])
i_a_t
s_t<-
c(t4_2011[5],t4_2012[5],t4_2013[5],t4_2014[5],t4_2015[5],t4_2016[5])
s_t
num_incidents_t<-
c(t4_2011[8],t4_2012[8],t4_2013[8],t4_2014[8],t4_2015[8],t4_2016[8])
num_incidents_t
```

```
ro_t<-
c(t4_2011[1],t4_2012[1],t4_2013[1],t4_2014[1],t4_2015[1],t4_2016[1])
ro_t
w_t<-
c(t4_2011[3],t4_2012[3],t4_2013[3],t4_2014[3],t4_2015[3],t4_2016[3])
w_t
lq_t<-
c(t4_2011[2],t4_2012[2],t4_2013[2],t4_2014[2],t4_2015[2],t4_2016[2])
lq_t

#incident count average increase rate %
((2929 - 3176)/3176 + (3016-2929)/2929 + (3368-3016)/3016 +
(3538-3368)/3368 + (3797-3538)/3538)/5

knitr::stitch('Final_Project2.r')
```