# Betweenness Centrality

## Contents

# 003 Relation hacthery broiler

## Betweenness Centrality

| ImportantCity | BetweennessScore |
|---|---|
| Staphorst_C023 | 6557.04 |
| Hof van Twente_C023 | 5698.80 |
| Bernheze_C023 | 2721.23 |
| Stadskanaal_D345 | 2204.05 |
| Ede_C023 | 1840.52 |
| Dalfsen_C023 | 1731.07 |
| Heerhugowaard_D345 | 1524.22 |
| Utrechtse Heuvelrug_C023 | 1294.56 |
| Eersel_C023 | 1167.89 |
| Mill en Sint Hubert_D345 | 1110.76 |
| Borsele_D345 | 1088.16 |
| Hardenberg_C023 | 1008.08 |
| Raalte_D345 | 910.56 |
| Oss_C023 | 823.28 |
| Doetinchem_D345 | 809.31 |
| Achtkarspelen_D345 | 806.96 |
| Ooststellingwerf_D345 | 779.31 |
| Sint Anthonis_C023 | 562.94 |
| Eersel_D345 | 543.71 |
| Midden-Drenthe_C023 | 538.11 |

## Network Visualization

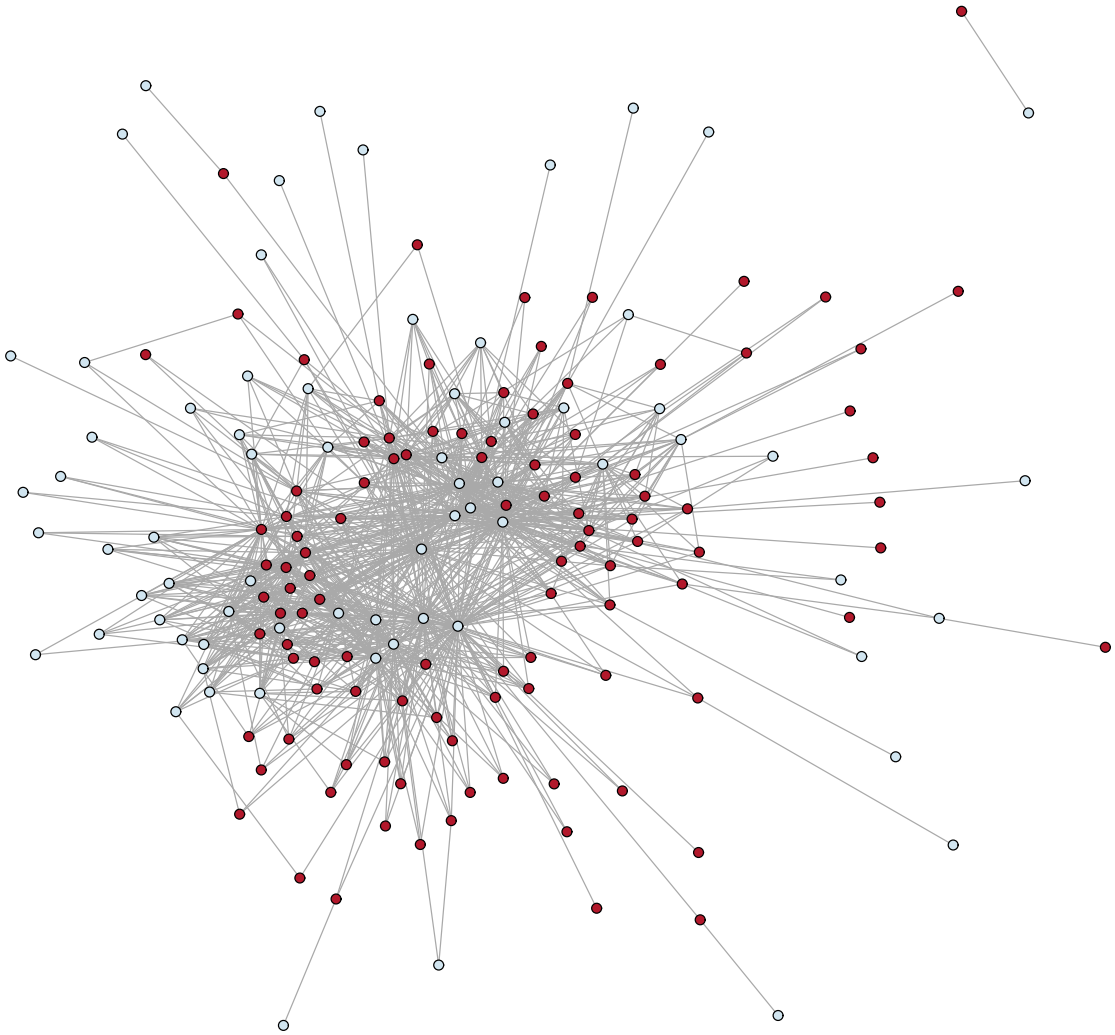

Figure 1: Network

**#B2182B:** D345, **#D1E5F0:** C023

# 004 Relation broiler-slaughterhouse

## Betweenness Centrality

| ImportantCity | BetweennessScore |
|---|---|
| Nijkerk_3_E468 | 4013.98 |
| Grootegast._E468 | 3155.01 |
| Zuidplas_E468 | 702.96 |
| Someren_D345 | 698.32 |
| Hardenberg_D345 | 667.49 |
| Peel en Maas_D345 | 632.94 |
| Oldebroek_E468 | 575.01 |
| Hof van Twente_E468 | 560.67 |
| Nunspeet_E468 | 381.45 |
| Stichtse Vecht_E468 | 303.58 |
| Midden-Drenthe_D345 | 294.50 |
| Zeewolde_E468 | 292.01 |
| Leudal_D345 | 268.36 |
| Deventer_D345 | 241.66 |
| Doetinchem_E468 | 230.15 |
| Borger-Odoorn_D345 | 218.59 |
| Putten_E468 | 216.57 |
| Barneveld_1_E468 | 208.79 |
| Ede_D345 | 201.52 |
| Hof van Twente_D345 | 180.28 |

## Network Visualization

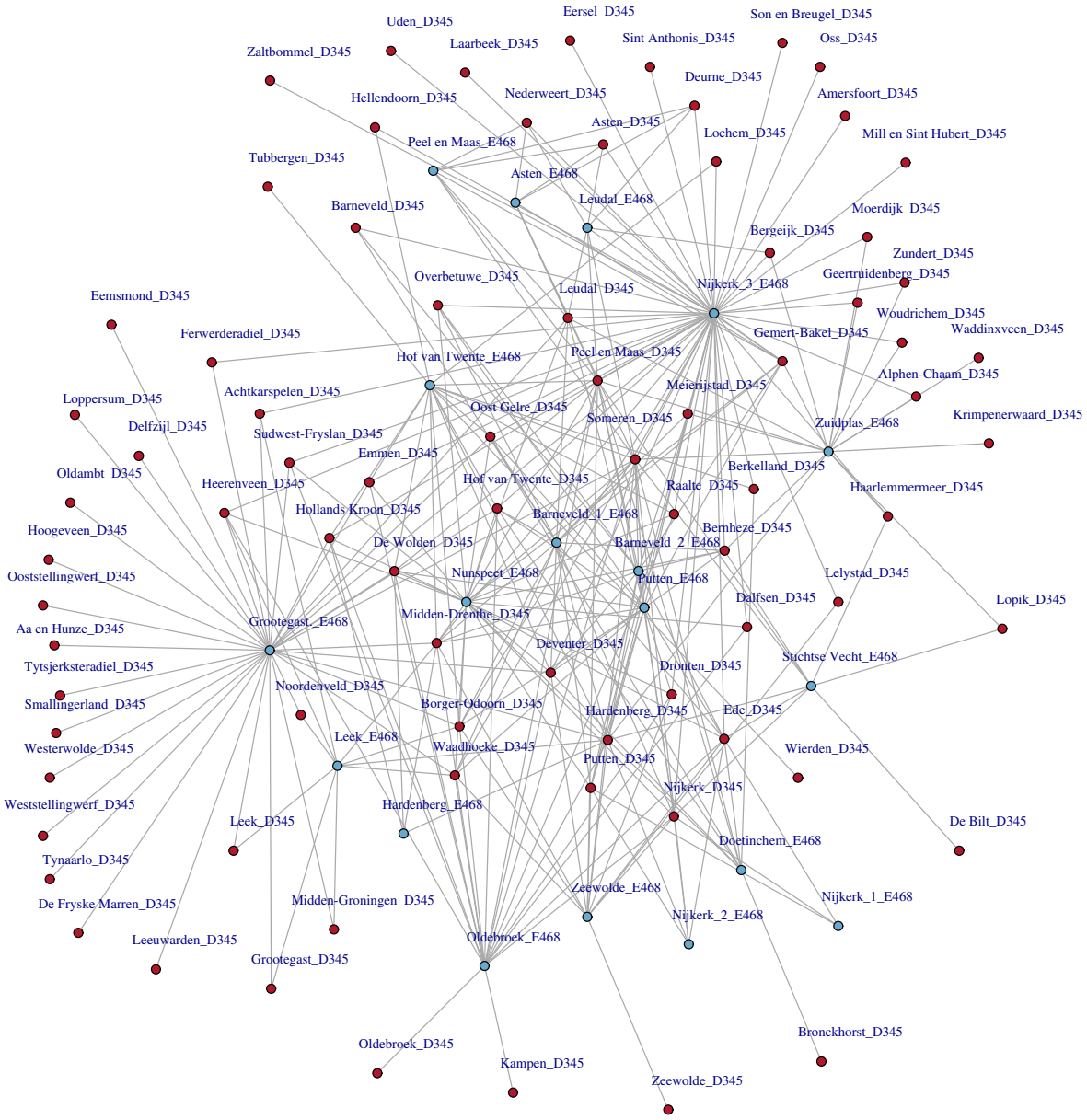


Figure 2: Network

**#B2182B:** D345, **#67A9CF:** E468

# 005 Relation broiler-processor

## Betweenness Centrality

| ImportantCity | BetweennessScore |
|---|---|
| Hoogeveen_F5679 | 5004.998 |
| Son en Breugel_F5679 | 4623.488 |
| Zoetermeer_F5679 | 4351.310 |
| Eersel_1_F5679 | 4293.488 |
| Ede_F5679 | 2776.884 |
| Ermelo_F5679 | 2747.599 |
| Ooststellingwerf_F5679 | 1570.728 |
| Aalten_D345 | 404.319 |
| Emmen_D345 | 338.803 |
| Cranendonck_D345 | 330.028 |
| Waadhoeke_F5679 | 314.235 |
| Hoogeveen_D345 | 163.566 |
| Buren_D345 | 145.038 |
| Bergeijk_D345 | 122.934 |
| Dalfsen_D345 | 122.934 |
| Borger-Odoorn_D345 | 114.556 |
| Echt-Susteren_D345 | 100.410 |
| Delfzijl_D345 | 92.690 |
| Deurne_D345 | 83.664 |
| Bronckhorst_F5679 | 29.071 |

## Network Visualization

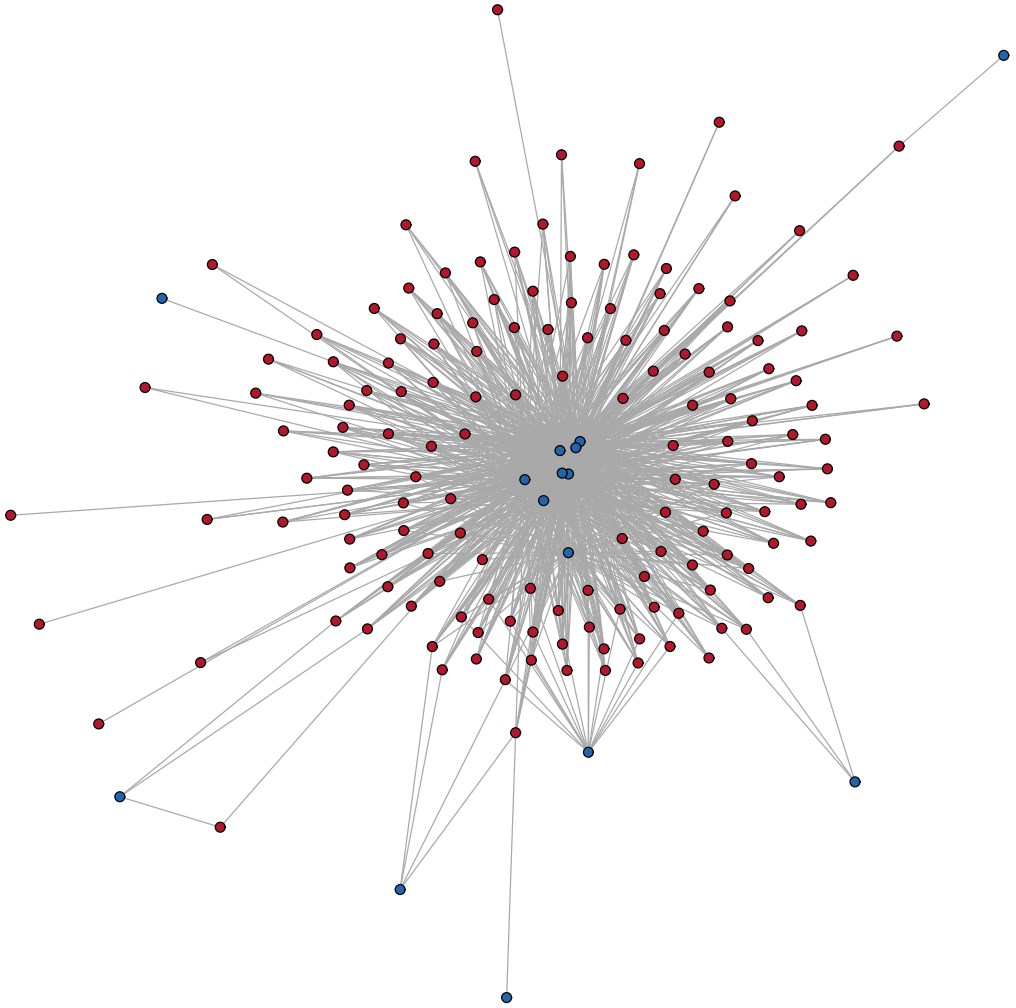

Figure 3: Network

**#B2182B:** D345, **#2166AC:** F5679

# 006 Relation Slaugtherhouse-processor

## Betweenness Centrality

| ImportantCity | BetweennessScore |
|---|---|
| Nijkerk_3_E468 | 223.917 |
| Zuidplas_E468 | 105.784 |
| Doetinchem_E468 | 93.220 |
| Barneveld_1_E468 | 56.240 |
| Barneveld_2_E468 | 56.240 |
| Putten_E468 | 56.240 |
| Best_F5679 | 51.668 |
| Midden-Drenthe_F5679 | 51.668 |
| Roosendaal_F5679 | 51.668 |
| Oss_F5679 | 51.668 |
| Zuidplas_1_F5679 | 51.668 |
| Bodegraven_F5679 | 51.668 |
| Cuijk_F5679 | 51.668 |
| Veenendaal_F5679 | 51.668 |
| Rotterdam_F5679 | 51.668 |
| Woudenberg_F5679 | 51.668 |
| Someren_1_F5679 | 51.668 |
| Someren_F5679 | 41.063 |
| Nunspeet_E468 | 38.253 |
| Zeewolde_E468 | 38.253 |

## Network Visualization

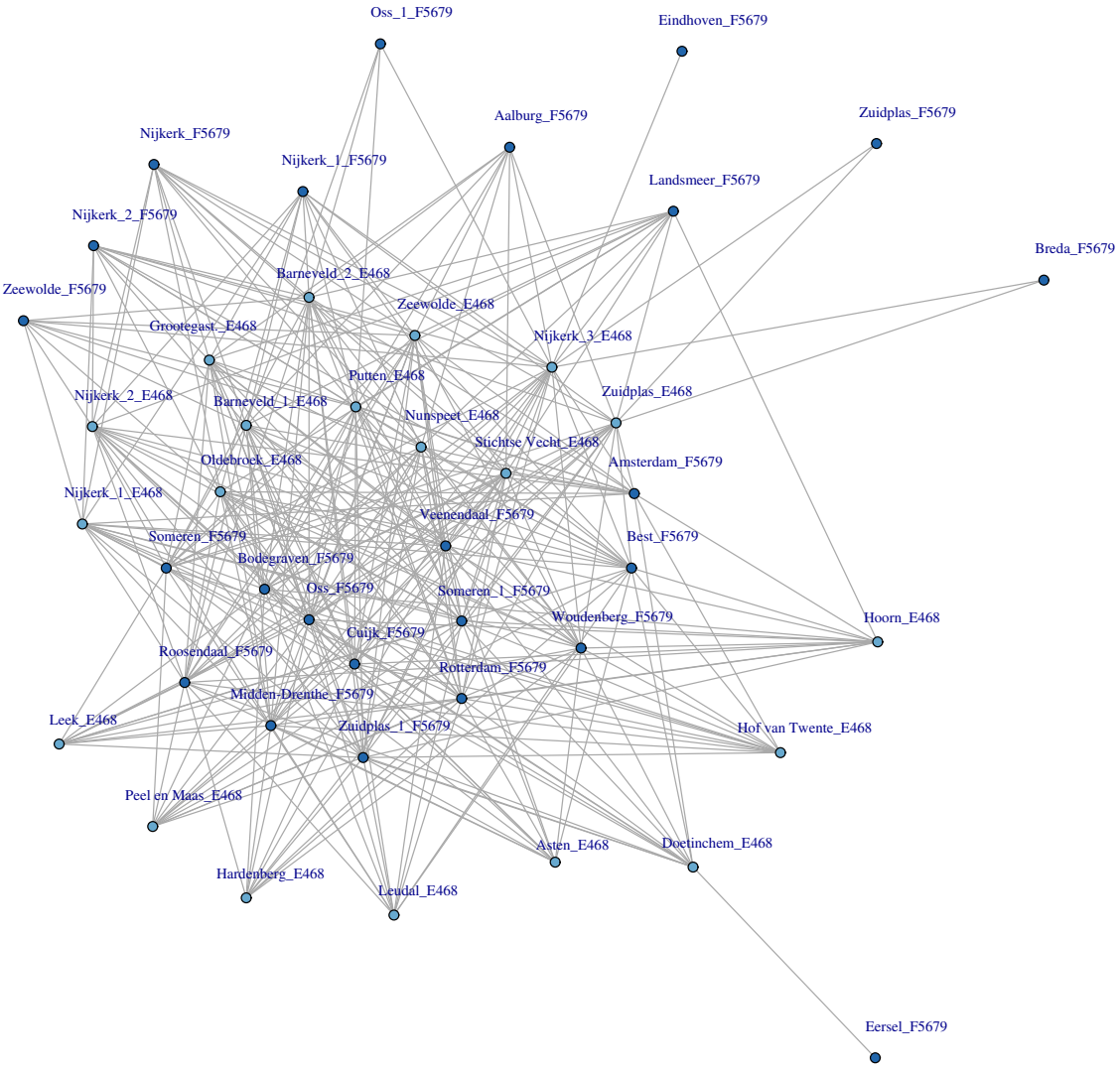


Figure 4: Network

**#67A9CF:** E468, **#2166AC:** F5679

# 007 Relation Processor Retailer

## Betweenness Centrality

| ImportantCity | BetweennessScore |
|---|---|
| Hoogeveen_F5679 | 10980.6 |
| Cuijk_F5679 | 10430.3 |
| Veenendaal_F5679 | 10430.3 |
| Zoetermeer_F5679 | 10152.6 |
| Someren_1_F5679 | 9948.1 |
| Son en Breugel_F5679 | 9948.1 |
| Eersel_1_F5679 | 9948.1 |
| Ede_F5679 | 9468.8 |
| Bodegraven_F5679 | 9368.0 |
| Ermelo_F5679 | 9324.1 |
| Zuidplas_1_F5679 | 9304.7 |
| Woudenberg_F5679 | 9200.2 |
| Roosendaal_F5679 | 8006.6 |
| Ooststellingwerf_F5679 | 7579.3 |
| Oss_F5679 | 7560.1 |
| Rotterdam_F5679 | 5878.4 |
| Best_F5679 | 5460.3 |
| Midden-Drenthe_F5679 | 3329.3 |
| Amsterdam_G007 | 1785.9 |
| Waadhoeke_F5679 | 1670.1 |

## Network Visualization

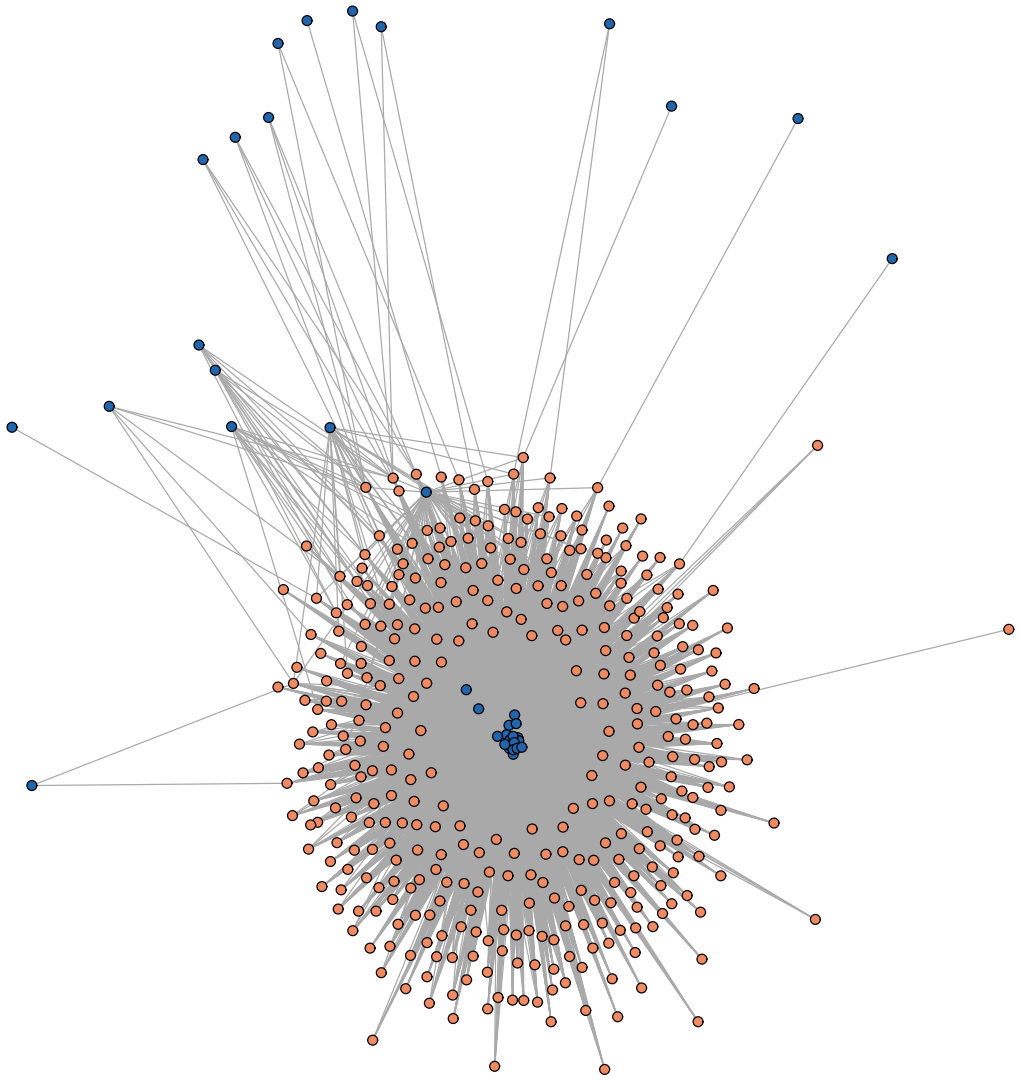

Figure 5: Network

**#EF8A62:** G007, **#2166AC:** F5679

# 008 Slaughterhouse Importer Exporter

## Betweenness Centrality

| ImportantCity | BetweennessScore |
|---|---|
| Importer_H009 | 183 |
| Exportert_H009 | 15 |
| Barneveld_1_E468 | 3 |
| Putten_E468 | 3 |
| Grootegast._E468 | 3 |
| Nijkerk_1_E468 | 3 |
| Nijkerk_2_E468 | 3 |
| Zeewolde_E468 | 3 |

## Network Visualization

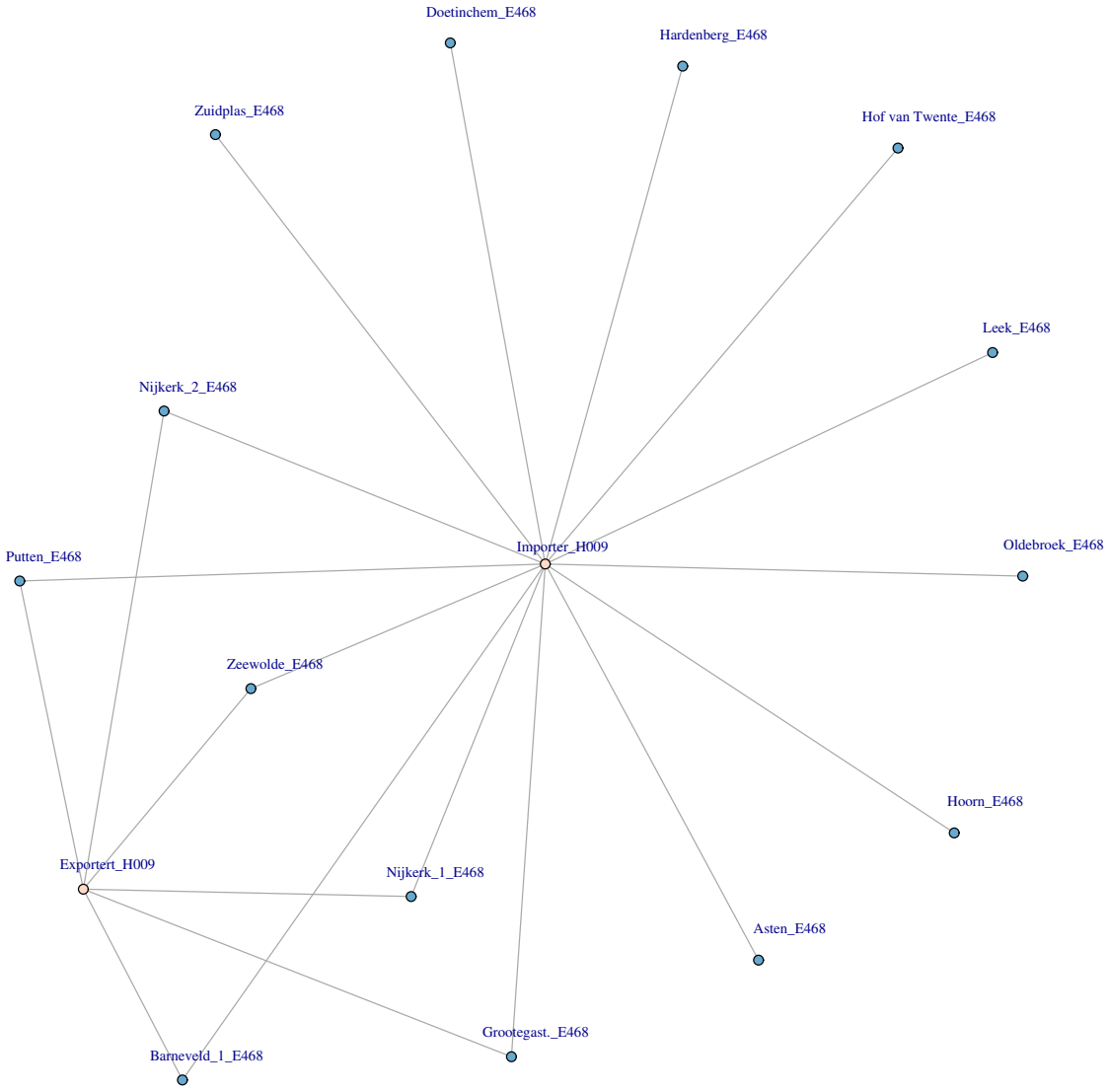


Figure 6: Network

**#FDDBC7:** H009, **#67A9CF:** E468

# 009 Processor Importer Exporter

## Betweenness Centrality

| ImportantCity | BetweennessScore |
|---|---|
| Importer_H009 | 216 |
| Exportert_H009 | 36 |
| Zeewolde_F5679 | 11 |
| Someren_F5679 | 11 |
| Zuidplas_1_F5679 | 11 |
| Kollumerland en Nieuwkruisland_F5679 | 11 |

## Network Visualization

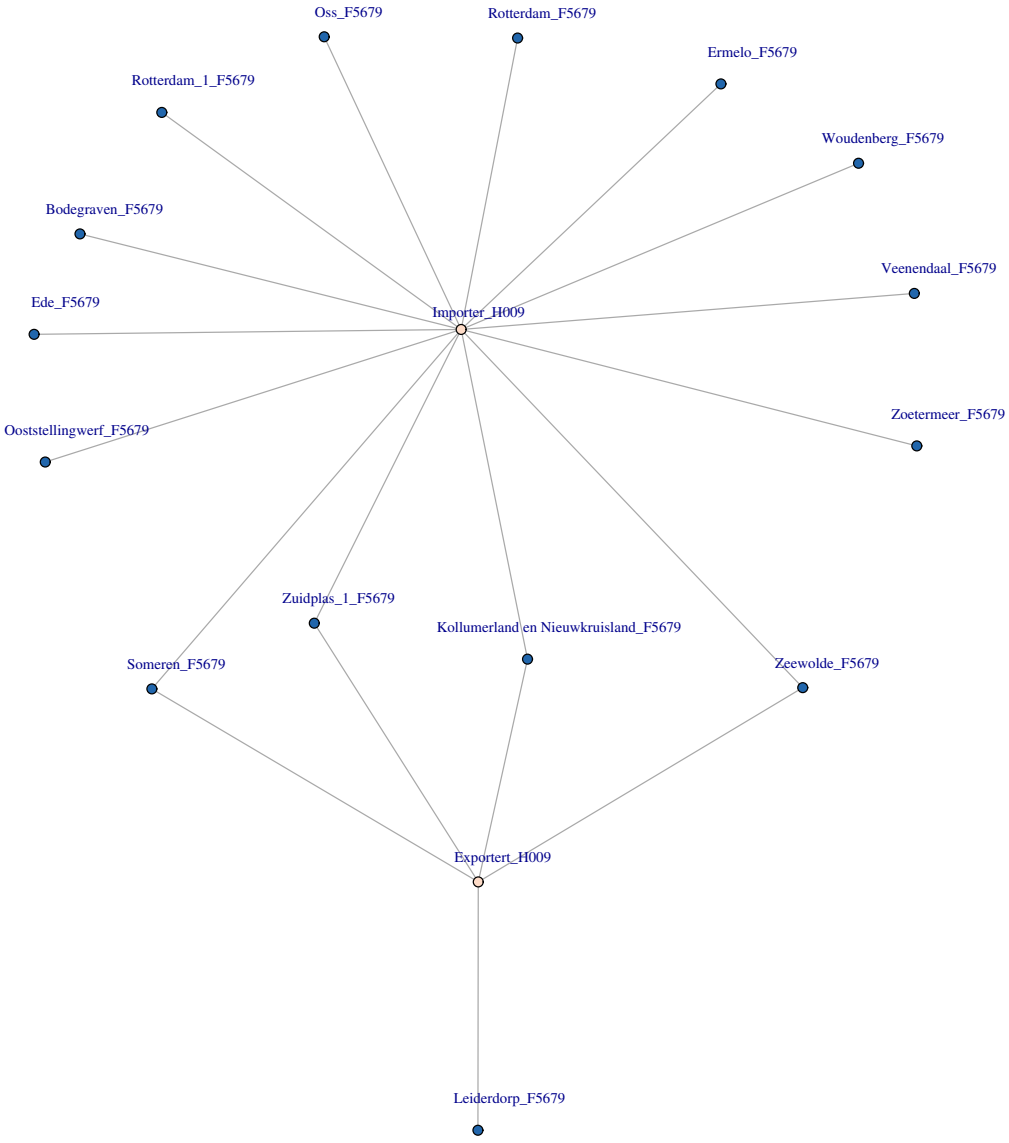


Figure 7: Network

**#FDDBC7:** H009, **#2166AC:** F5679

# All Cities

## Betweenness Centrality

| ImportantCity | BetweennessScore |
|---|---|
| Hoogeveen_F5679 | 52270.6 |
| Zoetermeer_F5679 | 50062.3 |
| Son en Breugel_F5679 | 49657.7 |
| Eersel_1_F5679 | 48538.2 |
| Ede_F5679 | 41363.4 |
| Ermelo_F5679 | 40065.4 |
| Ooststellingwerf_F5679 | 29646.2 |
| Zuidplas_1_F5679 | 11242.7 |
| Veenendaal_F5679 | 11242.4 |
| Cuijk_F5679 | 11092.4 |
| Bodegraven_F5679 | 10078.5 |
| Woudenberg_F5679 | 9890.1 |
| Roosendaal_F5679 | 8466.1 |
| Oss_F5679 | 8110.3 |
| Stadskanaal_D345 | 7540.7 |
| Waadhoeke_F5679 | 6486.8 |
| Rotterdam_F5679 | 6304.0 |
| Best_F5679 | 5750.3 |
| Heerhugowaard_D345 | 5278.1 |
| Staphorst_C023 | 5224.0 |

## Network Visualization (First 20 Cities)

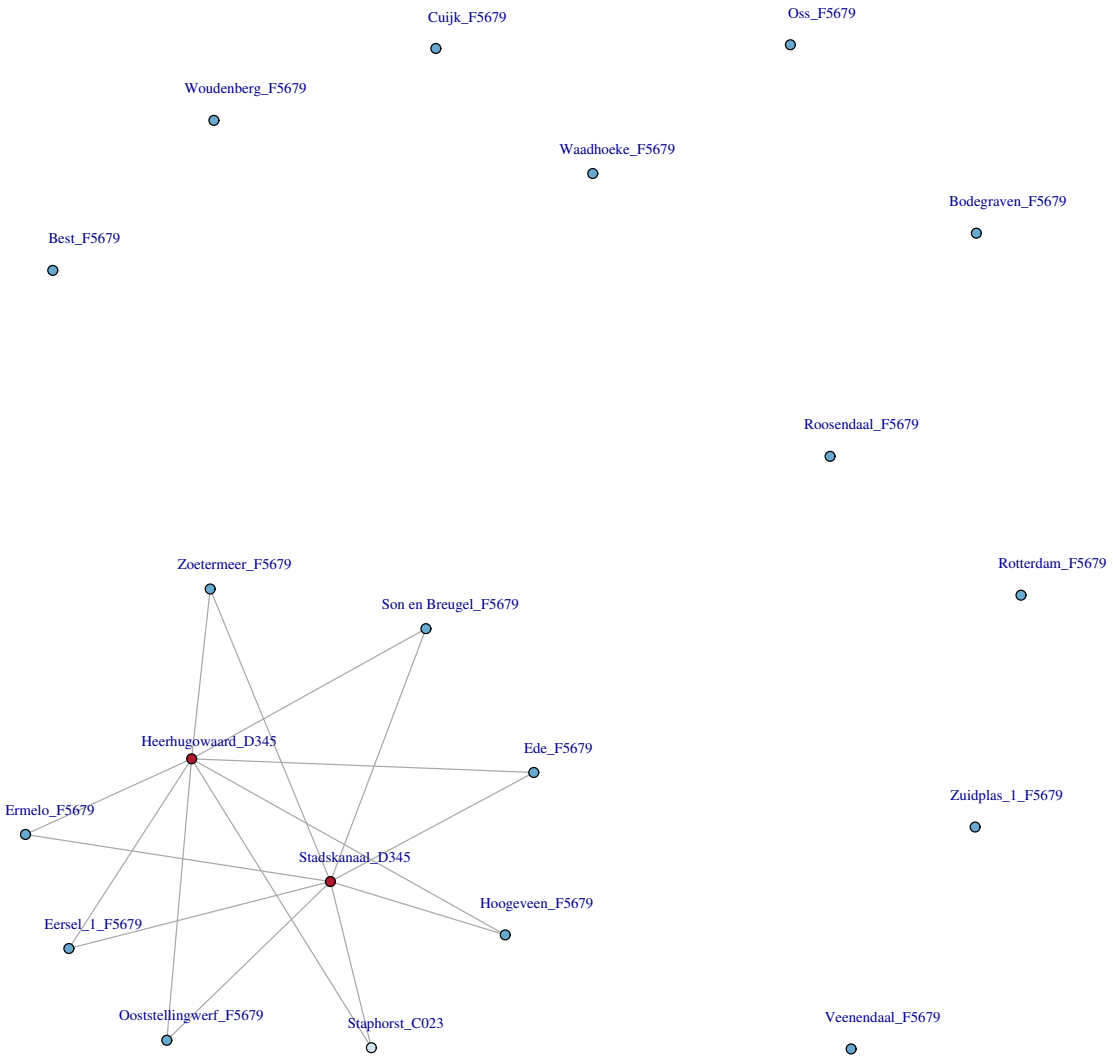


Figure 8: Network

**#B2182B:** D345, **#D1E5F0:** C023, **#67A9CF:** F5679

## Network Visualization

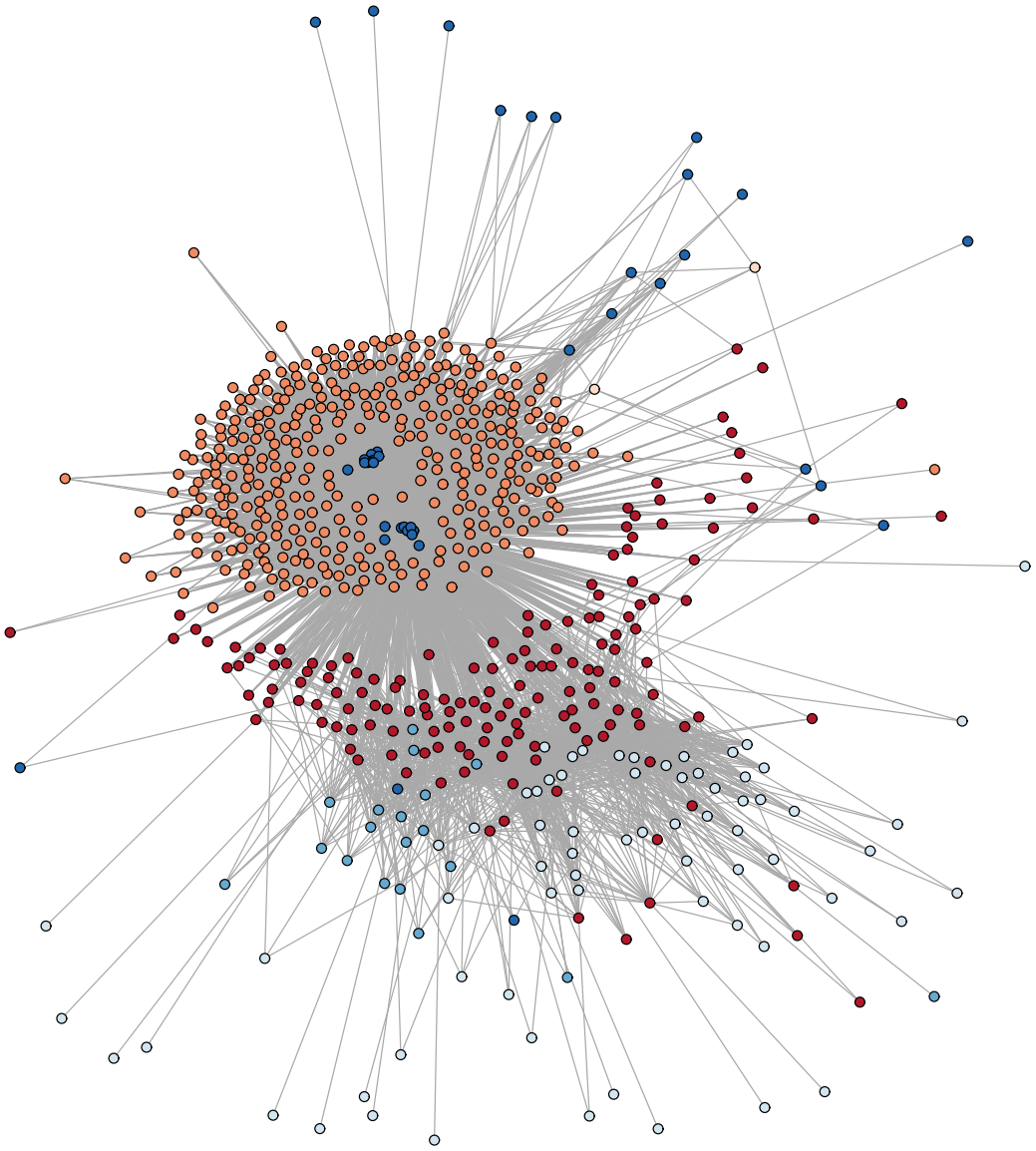

Figure 9: Network
**#B2182B:** D345, **#EF8A62:** G007, **#FDDBC7** H009, **#D1E5F0:** C023, **#67A9CF:** E468, **#2166AC:** F5679

# Network R code

```
require(pacman)
p_load(tidyverse, data.table, sna, plyr, readxl, tibble, RColorBrewer)

Read_Excel <- function(filename){
  # Read excel file
  # Author: Shuai Hao
  # Args:
  #     filename: excel file under the current directory
  # Returns:
  #     data frame
  SheetNames <- excel_sheets(filename)
  SheetName <- SheetNames[SheetNames%in%c("relations", "Relation",
                                          "relation", "relaton")]
  Dat <- read_excel(filename, sheet=SheetName)
  Dat <- Dat[-nrow(Dat), -ncol(Dat)]
  colnames(Dat)[1] <- "rowname"
  Dat <- column_to_rownames(Dat)
  return(Dat)
}


Wide_To_Long <- function(filename){
  # Convert Wide form to Long form
  # Author: Shuai Hao
  # Args:
  #     filename: excel file under the current directory
  # Returns:
  #     data frame with long form
  Relations <- c("relations", "Relation", "relation", "relaton")
  SheetNames <- excel_sheets(filename)
  SheetName_Rel <- SheetNames[SheetNames%in%Relations]
  Rel_Dat <- read_excel(filename, sheet=SheetName_Rel)
  Rel_Dat <- Rel_Dat[-nrow(Rel_Dat), -ncol(Rel_Dat)]
  colnames(Rel_Dat)[1] <- "from"
  Dis_Dat <- read_excel(filename, sheet="distance")
  colnames(Dis_Dat)[1] <- "from"
  Rel_Long <- gather(Rel_Dat, to, Relations, -from)
  Dis_Long <- gather(Dis_Dat, to, Distance, -from)
  Dat <- full_join(Rel_Long, Dis_Long)
  filename <- gsub(".xlsx", "", filename)
  Dat$FileName <- filename
  write.csv(Dat, paste0("Long_", filename, ".csv"), row.names = FALSE)
  return(Dat)
}

Mutate_Network <- function(data, end){
  # Calculate betweenness score and mutate the network data
  # Author: Shuai Hao
  # Args:
  #     data: a data frame
  #     end: the first n cities to choose
  # Returns:
  #     Betweenness score and network data
  Mat1 <- matrix(0, nrow(data), nrow(data),
                 dimnames = list(rownames(data), rownames(data)))
  Mat2 <- matrix(0, ncol(data), ncol(data),
                 dimnames = list(names(data), names(data)))

  NetworkDat <- rbind(cbind(Mat1, data), cbind(t(data), Mat2))
  allz <- which(colSums(NetworkDat)<1)
  if(length(allz)==0){
    NetworkDat <- NetworkDat
  }else{
    NetworkDat <- NetworkDat[-allz, -allz]
  }
```

```
  Res <- betweenness(NetworkDat)
  City <- rownames(NetworkDat)[order(Res, decreasing = TRUE)]
  CityDat <- data.frame(ImportantCity=City,
                        BetweennessScore=sort(Res, decreasing = TRUE))
  CityDat <- CityDat%>%
    filter(BetweennessScore!=0)
  return(list(NetworkDat, CityDat[1:end, ]))
}

filenames <- dir(pattern=".xlsx")
ResList1 <- llply(filenames, Read_Excel)

names(ResList1[[1]]) <- paste0(names(ResList1[[1]]), "_C023")
rownames(ResList1[[1]]) <- paste0(rownames(ResList1[[1]]), "_D345")

names(ResList1[[2]]) <- paste0(names(ResList1[[2]]), "_E468")
rownames(ResList1[[2]]) <- paste0(rownames(ResList1[[2]]), "_D345")

names(ResList1[[3]]) <- paste0(names(ResList1[[3]]), "_F5679")
rownames(ResList1[[3]]) <- paste0(rownames(ResList1[[3]]), "_D345")

names(ResList1[[4]]) <- paste0(names(ResList1[[4]]), "_F5679")
rownames(ResList1[[4]]) <- paste0(rownames(ResList1[[4]]), "_E468")

names(ResList1[[5]]) <- paste0(names(ResList1[[5]]), "_F5679")
rownames(ResList1[[5]]) <- paste0(rownames(ResList1[[5]]), "_G007")

names(ResList1[[6]]) <- paste0(names(ResList1[[6]]), "_E468")
rownames(ResList1[[6]]) <- paste0(rownames(ResList1[[6]]), "_H009")

names(ResList1[[7]]) <- paste0(names(ResList1[[7]]), "_F5679")
rownames(ResList1[[7]]) <- paste0(rownames(ResList1[[7]]), "_H009")

Sep.Net <- llply(ResList1, Mutate_Network, end=20)

# Combine 3, 4
ResList1 <- llply(ResList1, rownames_to_column, var="rowname")
Dat1 <- full_join(ResList1[[1]], ResList1[[2]], by="rowname")

# Combine 5, 6 and 7
Dat2 <- full_join(ResList1[[3]], ResList1[[4]], by="rowname")
Dat3 <- rbind(Dat2, ResList1[[5]][, names(Dat2)])
InterSet <- intersect(names(Dat3), names(ResList1[[7]]))
Dat4 <- rbind(Dat3[, InterSet], ResList1[[7]][, InterSet])
# Combine 1, 2, 3, 4, 5, 6 and 7
Dat5 <- full_join(Dat1, Dat4, by="rowname")
Dat6 <- full_join(Dat5, ResList1[[6]], by="rowname")
Dat6[is.na(Dat6)] <- 0

Dat6 <- column_to_rownames(Dat6)
Dat6 <- Dat6%>%select(-contains("_E468.y"))
names(Dat6) <- gsub("_E468.x", "_E468", names(Dat6))
DuplCity <- intersect(names(Dat6), rownames(Dat6))
Dat6 <- Dat6[!rownames(Dat6)%in%DuplCity, ]
write.csv(Dat6, "CityFullList.csv", row.names=FALSE)
CityDat <- Mutate_Network(Dat6, end=20)

Names <- as.character(CityDat[[2]][, 1])
SubNetworkDat <- CityDat[[1]][rownames(CityDat[[1]])%in%Names,
                              names(CityDat[[1]])%in%Names]

require(igraph)
col=brewer.pal(n = 6, name = "RdBu")
Ecolors <- rep(c(col[1], col[4]), c(106, 70))
G1<-graph_from_adjacency_matrix(as.matrix(Sep.Net[[1]][[1]]), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.label=NA, vertex.color=Ecolors,
```

```
       canvas.width = 1000, canvas.height = 1000)

Ecolors <- rep(c(col[1], col[5]), c(79, 19))
G1<-graph_from_adjacency_matrix(as.matrix(Sep.Net[[2]][[1]]), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.color=Ecolors,
       canvas.width = 1000, canvas.height = 1000)

Ecolors <- rep(c(col[1], col[6]), c(152, 15))
G1<-graph_from_adjacency_matrix(as.matrix(Sep.Net[[3]][[1]]), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.label=NA, vertex.color=Ecolors,
       canvas.width = 1000, canvas.height = 1000)

Ecolors <- rep(c(col[5], col[6]), c(20, 24))
G1<-graph_from_adjacency_matrix(as.matrix(Sep.Net[[4]][[1]]), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.color=Ecolors,
       canvas.width = 1000, canvas.height = 1000)

Ecolors <- rep(c(col[2], col[6]), c(378, 38))
G1<-graph_from_adjacency_matrix(as.matrix(Sep.Net[[5]][[1]]), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.label=NA, vertex.color=Ecolors,
       canvas.width = 1000, canvas.height = 1000)

Ecolors <- rep(c(col[3], col[5]), c(2, 14))
G1<-graph_from_adjacency_matrix(as.matrix(Sep.Net[[6]][[1]]), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.color=Ecolors,
       canvas.width = 1000, canvas.height = 1000)

Ecolors <- rep(c(col[3], col[6]), c(2, 15))
G1<-graph_from_adjacency_matrix(as.matrix(Sep.Net[[7]][[1]]), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.color=Ecolors,
       canvas.width = 1000, canvas.height = 1000)

Ecolors <- rep(c(col[1], col[4], col[5]), c(2, 1, 17))
G1<-graph_from_adjacency_matrix(as.matrix(SubNetworkDat), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.color=Ecolors,
       canvas.width = 1000, canvas.height = 1000)

Ecolors <- rep(col, c(158, 378, 2, 69, 19, 40))
G1<-graph_from_adjacency_matrix(as.matrix(CityDat[[1]]), mode="undirected")
tkplot(G1, vertex.size=4,vertex.label.cex=0, vertex.label.dist=2,
       vertex.label=NA, vertex.color=Ecolors,
       canvas.width = 1000, canvas.height = 1000)
```