Assignment 4

Prajwal C N

10/23/2021

Problem 1

<u>Formulation:</u>

The minimum objective function can be calculated with unit production costs and unit shipping cost.

To make this problem Balanced Transportation Problem (cases where the total supply is equal to the total demand.), Creating 2 dummy variables in demand of 10. So, we can make supply and demand both equal to 220.

Minimum objective function:

$$Z_{min} = 622X_{11} + 614X_{12} + 630X_{13} + 0X_{14} + 641X_{21} + 645X_{22} + 649X_{23} + 0X_{24};$$

Constraints:

Demand Constraints:

$X_{11} + X_{21} = 80$
$X_{12} + X_{22} = 60$
$X_{13} + X_{23} = 70$
$X_{14} + X_{24} = 10$

Supply Constraints:

$X_{11} + X_{12} + X_{13} + X_{14} = 100$
$X_{21} + X_{22} + X_{23} + X_{24} = 120$

Where, $X_{ij} \geq 0$ (i = 1,2 (i = plant) & j = 1,2,3,4 (j = warehouses))

<u>R Implementation:</u>

```
library(lpSolveAPI)
lprec<-make.lp(0,8)
lp.control(lprec,sense='min')

## $anti.degen
## [1] "fixedvars" "stalling"
##
## $basis.crash
## [1] "none"
##
```

```
## $bb.depthlimit
## [1] -50
##
## $bb.floorfirst
## [1] "automatic"
##
## $bb.rule
## [1] "pseudononint" "greedy"       "dynamic"      "rcostfixing"
##
## $break.at.first
## [1] FALSE
##
## $break.at.value
## [1] -1e+30
##
## $epsilon
##       epsb       epsd      epsel     epsint epsperturb   epspivot
##      1e-10      1e-09      1e-12      1e-07      1e-05      2e-07
##
## $improve
## [1] "dualfeas" "thetagap"
##
## $infinite
## [1] 1e+30
##
## $maxpivot
## [1] 250
##
## $mip.gap
## absolute relative
##    1e-11    1e-11
##
## $negrange
## [1] -1e+06
##
## $obj.in.basis
## [1] TRUE
##
## $pivoting
## [1] "devex"    "adaptive"
##
## $presolve
## [1] "none"
##
## $scalelimit
## [1] 5
##
## $scaling
## [1] "geometric"   "equilibrate" "integers"
##
```

```
## $sense
## [1] "minimize"
##
## $simplextype
## [1] "dual"   "primal"
##
## $timeout
## [1] 0
##
## $verbose
## [1] "neutral"

# Objective function
set.objfn(lprec,c(622,614,630,0,641,645,649,0))

# Constraints
add.constraint(lprec,rep(1,4),"=",100,indices =c(1,2,3,4))
add.constraint(lprec,rep(1,4),"=",120,indices =c(5,6,7,8))
add.constraint(lprec,rep(1,2),"=",80,indices =c(1,5))
add.constraint(lprec,rep(1,2),"=",60,indices =c(2,6))
add.constraint(lprec,rep(1,2),"=",70,indices =c(3,7))
add.constraint(lprec,rep(1,2),"=",10,indices=c(4,8))

# Solution
solve(lprec)

## [1] 0

get.objective(lprec)

## [1] 132790

get.constraints(lprec)

## [1] 100 120  80  60  70  10

get.variables(lprec)

## [1]  0 60 40  0 80  0 30 10
```

Problem 2

Part A:

<u>**Formulation:**</u>

To make this problem Balanced Transportation Problem (cases where the total supply is equal to the total demand.), Creating dummy variable in demand of 2TBD, Because the total number of supply is 276 TBD and demand for it is 274 TBD. In order to balance between supply and demand created dummy variable with demand of 2 TBD.

Objective function:

There are total of 27 decision variables:

$\mathbf{Z_{min} = 1.52\, X_{W1A} + 1.60\, X_{W1B} + 1.40\, X_{W1C} + 1.70\, X_{W2A} + 1.63\, X_{W2B} + 1.55\, X_{W2C} + 1.45\, X_{W3A} + 1.57\, X_{W3B} + 1.30\, X_{W3C} + 5.15\, X_{AR1} + 5.69\, X_{AR2} + 6.13\, X_{AR3} + 5.63\, X_{AR4} + 5.80\, X_{AR5} + 0\, X_{AR6} + 5.12\, X_{BR1} + 5.47\, X_{BR2} + 6.05\, X_{BR3} + 6.12\, X_{BR4} + 5.71\, X_{BR5} + 0 X_{BR6} + 5.32 X_{CR1} + 6.16\, X_{CR2} + 6.25\, X_{CR3} + 6.17\, X_{CR4} + 5.87\, X_{CR5} + 0\, X_{CR6};}$

Constraints:

Supply Constraints:

$\mathbf{X_{W1A} + X_{W1B} + X_{W1C} = 93}$
$\mathbf{X_{W2A} + X_{W2B} + X_{W2C} = 88}$
$\mathbf{X_{W3A} + X_{W3B} + X_{W3C}= 95}$

Demand Constraints:

$\mathbf{X_{AR1}+X_{BR1}+X_{CR1}=30}$
$\mathbf{X_{AR2}+X_{BR2}+X_{CR2}=57}$
$\mathbf{X_{AR3}+X_{BR3}+X_{CR3}=48}$
$\mathbf{X_{AR4}+X_{BR4}+X_{CR4}=91}$
$\mathbf{X_{AR5}+X_{BR5}+X_{CR5}=48}$
$\mathbf{X_{AR6}+X_{BR6}+X_{CR6}=2}$

Constraints from pumps to the refineries:

$\mathbf{X_{W1A} + X_{W2A} + X_{W3A} = X_{AR1} + X_{AR2} + X_{AR3} + X_{AR4} + X_{AR5} + X_{AR6}}$
$\mathbf{X_{W1B}+ X_{W2B}+ X_{W3B} = X_{BR1} + X_{BR2} + X_{BR3} + X_{BR4} + X_{BR5} + X_{BR6}}$
$\mathbf{X_{W1C} + X_{W2C} + X_{W3C}= X_{CR1} + X_{CR2} + X_{CR3} + X_{CR4} + X_{CR5} + X_{CR6}}$

Where Xij>=0; (wells=W1,W2,W3 and pumps=A,B,C and refineries=R1,R2,R3,R4,R5,R6).

R Implementation:

```
lprec<-make.lp(0,27)
lp.control(lprec,sense='min')

## $anti.degen
## [1] "fixedvars" "stalling"
##
## $basis.crash
## [1] "none"
##
## $bb.depthlimit
## [1] -50
##
```

```
## $bb.floorfirst
## [1] "automatic"
##
## $bb.rule
## [1] "pseudononint" "greedy"       "dynamic"      "rcostfixing"
##
## $break.at.first
## [1] FALSE
##
## $break.at.value
## [1] -1e+30
##
## $epsilon
##       epsb       epsd      epsel     epsint epsperturb   epspivot
##      1e-10      1e-09      1e-12      1e-07      1e-05      2e-07
##
## $improve
## [1] "dualfeas" "thetagap"
##
## $infinite
## [1] 1e+30
##
## $maxpivot
## [1] 250
##
## $mip.gap
## absolute relative
##    1e-11    1e-11
##
## $negrange
## [1] -1e+06
##
## $obj.in.basis
## [1] TRUE
##
## $pivoting
## [1] "devex"    "adaptive"
##
## $presolve
## [1] "none"
##
## $scalelimit
## [1] 5
##
## $scaling
## [1] "geometric"   "equilibrate" "integers"
##
## $sense
## [1] "minimize"
##
```

```
## $simplextype
## [1] "dual"   "primal"
##
## $timeout
## [1] 0
##
## $verbose
## [1] "neutral"

# Objective function
set.objfn(lprec,c(1.52,1.60,1.40,1.70,1.63,1.55,1.45,1.57,1.30,5.15,5.12,5.32
,5.69,5.47,6.16,6.13,6.05,6.25,5.63,6.12,6.17,5.80,5.71,5.87,0,0,0))

# Constraints
add.constraint(lprec,c(1,1,1),"=",93,indices = c(1,2,3))
add.constraint(lprec,c(1,1,1),"=",88,indices = c(4,5,6))
add.constraint(lprec,c(1,1,1),"=",95,indices = c(7,8,9))
add.constraint(lprec,c(1,1,1),"=",30,indices = c(10,11,12))
add.constraint(lprec,c(1,1,1),"=",57,indices = c(13,14,15))
add.constraint(lprec,c(1,1,1),"=",48,indices = c(16,17,18))
add.constraint(lprec,c(1,1,1),"=",91,indices = c(19,20,21))
add.constraint(lprec,c(1,1,1),"=",48,indices = c(22,23,24))
add.constraint(lprec,c(1,1,1),"=",2,indices = c(25,26,27))
add.constraint(lprec,c(rep(1,3),rep(-1,6)),"=",0,indices=c(1,4,7,10,13,16,19,
22,25))
add.constraint(lprec,c(rep(1,3),rep(-1,6)),"=",0,indices=c(2,5,8,11,14,17,20,
23,26))
add.constraint(lprec,c(rep(1,3),rep(-1,6)),"=",0,indices=c(3,6,9,12,15,18,21,
24,27))

# Solution
solve(lprec)

## [1] 0

get.objective(lprec)

## [1] 1966.68

get.constraints(lprec)

##  [1] 93 88 95 30 57 48 91 48  2  0  0  0

get.variables(lprec)

##  [1] 93  0  0  0 88  0 28  0 67 30  0  0  0 57  0  0 31 17 91  0  0  0  0
48  0
## [26]  0  2
```

The optimal solution is **1966.68** & from above solution we can infer that **Well 3** can be used to capacity in the optimal schedule.

Part B:

Network diagram corresponding to the solution in Part A.

Wells=W1,W2,W3
Pumps=A,B,C
Refineries=R1,R2,R3,R4,R5,R6