LP Model

2023-09-24

Summary:

a) A maximum revenue obtained of $1780 by making 40 artisanal truffles, 12 handmade chocolate nuggets and 4 gourmet chocolate bars.

b) Chocolate bars, handmade chocolate nuggets and artisanal truffles constrain binding. In terms of feasibility, artisanal truffles have a shadow price of $2 and a range of 47.5 to 51.6 pounds. Chocolate Nuggets: Shadow Price = $30 and Range of feasibility = 30 to 52 Pounds. Chocolate Bars: Shadow Price = $6 and Range of feasibility = 29.1 to 50 Pounds.

c) Range of Optimality: Artisanal Truffles = $20 to $38, Handmade Chocolate Nuggets = $22.5 to $26.67 and Chocolate Bars = $18.75 to $35.00.

```
#Load Required library-lpSolveAPI
library(lpSolveAPI)
```

Problem Statement: A renowned chocolatier, Francesco Schröeder, makes three kinds of chocolate confectionery: artisanal truffles, handcrafted chocolate nuggets, and premium gourmet chocolate bars. He uses the highest quality of cacao butter, dairy cream, and honey as the main ingredients. Francesco makes his chocolates each morning, and they are usually sold out by the early afternoon. For a pound of artisanal truffles, Francesco uses 1 cup of cacao butter, 1 cup of honey, and 1/2 cup of cream. The handcrafted nuggets are milk chocolate and take 1/2 cup of cacao, 2/3 cup of honey, and 2/3 cup of cream for each pound. Each pound of the chocolate bars uses 1 cup of cacao butter, 1/2 cup of honey, and 1/2 cup of cream. One pound of truffles, nuggets, and chocolate bars can be purchased for $35, $25, and $20, respectively. A local store places a daily order of 10 pounds of chocolate nuggets, which means that Francesco needs to make at least 10 pounds of the chocolate nuggets each day. Before sunrise each day, Francesco receives a delivery of 50 cups of cacao butter, 50 cups of honey, and 30 cups of dairy cream. 1) Formulate and solve the LP model that maximizes revenue given the constraints. How much of each chocolate product should Francesco make each morning? What is the maximum daily revenue that he can make? 2) Report the shadow price and the range of feasibility of each binding constraint. 3) If the local store increases the daily order to 25 pounds of chocolate nuggets, how much of each product should Francesco make? We will solve this problem with two approaches: First by directly encoding the variables and coefficients and secondly, by using a .lp file *1.Formulate and solve the LP model that maximizes revenue given the constraints. How much of each chocolate product should Francesco make each morning? What is the maximum daily revenue that he can make? We define for Decision Variables: Let P pounds of Artisanal Truffles, and Q pounds of handcrafted Chocolate nuggets, R pounds of premium gourmet Chocolate bars.

Objective Maximization = 35P + 25Q + 20R

The following constraints

Cacao butter: 1x1 + 1/2x2 + 1x3 <= 50;
Honey: 1x1 + 2/3x2 + 1/2x3 <= 50;
Cream: 1/2x1 + 2/3x2 + 1/2x3 <= 30;
Chocolate nuggets: x2>= 10; x1,x3>=0 (Non negativity)

```
# Create lp object with 0 constraints and 3 decision variables
lprec <- make.lp(0, 3)
# Now create the objective function.
set.objfn(lprec, c(35, 25, 20))
# As the default is a minimization problem, so we change that to maximization
lp.control(lprec,sense='max')
```

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

Then, Adding the constraint values in a model

```
# Adding four constraints
add.constraint(lprec, c(1, 1/2, 1), "<=", 50)
add.constraint(lprec, c(1, 2/3, 1/2), "<=", 50)
add.constraint(lprec, c(1/2, 2/3, 1/2), "<=", 30)
add.constraint(lprec, c(0, 1, 0), ">=", 10)

# Set bounds for variables.
set.bounds(lprec, lower = c(0, 0, 0), columns = c(1, 2, 3))

# To identify the variables and constraints, we can set variable names and
name the constraints
RowNames <- c("CacaoButter", "Honey", "DiaryCream", "NUggetsOrder")
ColNames <- c("AritisanTruffel", "ChocalateNuggets", "ChocalateBars")
```

```
dimnames(lprec) <- list(RowNames, ColNames)
lprec #Printing the model
```

```
## Model name:
##                AritisanTruffel  ChocalateNuggets     ChocalateBars
## Maximize                    35                25                20
## CacaoButter                  1               0.5                 1  <=  50
## Honey                        1    0.666666666667               0.5  <=  50
## DiaryCream                 0.5    0.666666666667               0.5  <=  30
## NUggetsOrder                 0                 1                 0  >=  10
## Kind                       Std               Std               Std
## Type                      Real              Real              Real
## Upper                      Inf               Inf               Inf
## Lower                        0                 0                 0
```

To save the Model

```
write.lp(lprec, filename = "lpmodel.lp", type = "lp")

solve(lprec) #Solving the above problem
```

```
## [1] 0
```

The above 0 indicates its a successful solution To get Objective value

```
get.objective(lprec)
```

```
## [1] 1780
```

```
varV <- get.variables(lprec)
```

Using the LP problem, we created a text file using write.lp statement. Using the read.lp statement, we can take a look at the lpmodel.lp file.

```
x <- read.lp("lpmodel.lp")
x
```

```
## Model name:
##                AritisanTruffel  ChocalateNuggets     ChocalateBars
## Maximize                    35                25                20
## CacaoButter                  1               0.5                 1  <=  50
## Honey                        1    0.666666666667               0.5  <=  50
## DiaryCream                 0.5    0.666666666667               0.5  <=  30
## NUggetsOrder                 0                 1                 0  >=  10
## Kind                       Std               Std               Std
## Type                      Real              Real              Real
## Upper                      Inf               Inf               Inf
## Lower                        0                 0                 0
```

Solving the LP model

```
solve(x)
```

```
## [1] 0
```

```
get.objective(x)    #To get Objective value
```

```
## [1] 1780
```

```
get.variables(x)    #To get Decision variable Values
```

```
## [1] 40 12  4
```

```
get.constraints(x)  #To get Constraint Values
```

```
## [1] 50 50 30 12
```

According to the solution, the revenue is 1780. The first variable value is 40, and the second variable value is 12 and the third variable value is 4.

To get shadow price and reduced cost

```
get.sensitivity.rhs(lprec) # get shadow price
```

```
## $duals
## [1]  2 30  6  0  0  0  0
##
## $dualsfrom
## [1]  4.750000e+01  3.000000e+01  2.916667e+01 -1.000000e+30 -1.000000e+30
## [6] -1.000000e+30 -1.000000e+30
##
## $dualstill
## [1] 5.166667e+01 5.200000e+01 5.000000e+01 1.000000e+30 1.000000e+30
## [6] 1.000000e+30 1.000000e+30
```

```
get.sensitivity.obj(lprec) # get reduced cost
```

```
## $objfrom
## [1] 20.00 22.50 18.75
##
## $objtill
## [1] 38.00000 26.66667 35.00000
```

3) If the local store increases the daily order to 25 pounds of chocolate nuggets, how much of each product should Francesco make?

```
lprec <- make.lp(0, 3)              #Creating lp object with 0 Constraints and
3 Decision variables
set.objfn(lprec, c(35, 25, 20))     #Creating Objective function
lp.control(lprec,sense='max')       #Coverting to Maximization Problem
```

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

Adding the Updated Constraints

```
add.constraint(lprec, c(1, 1/2, 1), "<=", 50)
add.constraint(lprec, c(1, 2/3, 1/2), "<=", 50)
add.constraint(lprec, c(1/2, 2/3, 1/2), "<=", 30)
add.constraint(lprec, c(0, 1, 0), ">=", 25)
```

Set Bounds to Variables

```
set.bounds(lprec, lower = c(0, 0, 0), columns = c(1, 2, 3))  #Not really
needed
```

Model:

```
RowNames <- c("CacaoButter", "Honey", "DiaryCream", "NUggetsOrder")
ColNames <- c("AritisanTruffel", "ChocalateNuggets", "ChocalateBars")
dimnames(lprec) <- list(RowNames, ColNames)
# Now, print out the model
lprec
```

```
## Model name:
##                AritisanTruffel  ChocalateNuggets     ChocalateBars
## Maximize                    35                25                20
## CacaoButter                  1               0.5                 1  <=  50
## Honey                        1    0.666666666667               0.5  <=  50
## DiaryCream                 0.5    0.666666666667               0.5  <=  30
## NUggetsOrder                 0                 1                 0  >=  25
## Kind                       Std               Std               Std
## Type                      Real              Real              Real
## Upper                      Inf               Inf               Inf
## Lower                        0                 0                 0
```

To save the file

```
write.lp(lprec, filename = "chocalte.lp", type = "lp")
```

Solving the LP Problem

```
solve(lprec)
```

```
## [1] 0
```

```
get.objective(lprec)
```

```
## [1] 1558.333
```

```
x <- read.lp("lpmodel.lp") # create an lp object x
x # display x
```

```
## Model name:
##                AritisanTruffel  ChocalateNuggets     ChocalateBars
## Maximize                    35                25                20
## CacaoButter                  1               0.5                 1  <=  50
## Honey                        1    0.666666666667               0.5  <=  50
## DiaryCream                 0.5    0.666666666667               0.5  <=  30
## NUggetsOrder                 0                 1                 0  >=  10
## Kind                       Std               Std               Std
## Type                      Real              Real              Real
## Upper                      Inf               Inf               Inf
## Lower                        0                 0                 0
```

```
solve(lprec)
```

```
## [1] 0
```

```
get.objective(lprec) #To get objective value
```

```
## [1] 1558.333
```

```
get.variables(lprec) #To get values of decision variables
```

```
## [1] 26.66667 25.00000  0.00000
```

```
get.constraints(lprec) #To get constraint RHS values
```

```
## [1] 39.16667 43.33333 30.00000 25.00000
```