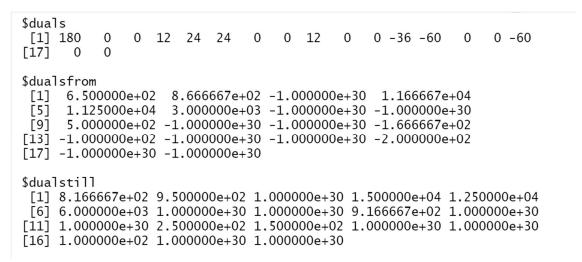1.Solve the problem using lpsolve, or any other equivalent library in R.

Solution : Refer to github for LP solve equations.

2. Identify the shadow prices, dual solution, and reduced costs

Solution: Shadow price, dual solution and reduced cost.

```
$duals
 [1] 180   0   0  12  24  24   0   0  12   0   0 -36 -60   0   0 -60
[17]   0   0

$dualsfrom
 [1]  6.500000e+02  8.666667e+02 -1.000000e+30  1.166667e+04
 [5]  1.125000e+04  3.000000e+03 -1.000000e+30 -1.000000e+30
 [9]  5.000000e+02 -1.000000e+30 -1.000000e+30 -1.666667e+02
[13] -1.000000e+02 -1.000000e+30 -1.000000e+30 -2.000000e+02
[17] -1.000000e+30 -1.000000e+30

$dualstill
 [1] 8.166667e+02 9.500000e+02 1.000000e+30 1.500000e+04 1.250000e+04
 [6] 6.000000e+03 1.000000e+30 1.000000e+30 9.166667e+02 1.000000e+30
[11] 1.000000e+30 2.500000e+02 1.500000e+02 1.000000e+30 1.000000e+30
[16] 1.000000e+02 1.000000e+30 1.000000e+30
```

Shadow Prices:

Constraint	1	2	3	4	5	6	7	8	9
Shadow Price	180	0	0	12	24	24	0	0	12

Shadow prices are dual problem solution

Dual Problem solution:

Constraint	1	2	3	4	5	6	7	8	9
Shadow Price	180	0	0	12	24	24	0	0	12

Reduced Cost:

Product	1 L	2 L	3 L	1 M	2 M	3 M	1 S	2 S	3 S
Reduced Cost	0	0	-36	-60	0	0	-60	0	0

3. Identify the sensitivity of the above prices and costs. That is, specify the range of shadow prices and reduced cost within which the optimal solution will not change.

Shadow Price Sensitivity

Shadow Price	From	Till
180	6.500000e+02	8.166667e+02
0	8.666667e+02	9.500000e+02
0	-1.000000e+30	1.000000e+30
12	1.166667e+04	1.500000e+04
24	1.125000e+04	1.250000e+04
24	3.000000e+03	6.000000e+03
0	-1.000000e+30	1.000000e+30

Reduced Cost Sensitivity

Reduced Cost	From	Till
0	-1.000000e+30	1.000000e+30
0	-1.000000e+30	1.000000e+30
-36	-1.666667e+02	2.500000e+02
-60	-1.000000e+02	1.500000e+02
0	-1.000000e+30	1.000000e+30
0	-1.000000e+30	1.000000e+30
-60	-2.000000e+02	1.000000e+02
0	-1.000000e+30	1.000000e+30
0	-1.000000e+30	1.000000e+30

4. Formulate the dual of the above problem and solve it. Does the solution agree with what you observed for the primal problem?

Solution:

Dual Problem formulation

Minimise:

750 C1 +900 C2 +450 C3 +13000 C4 +12000 C5 +5000 C6 +900 C7 +1200 C8 +750 C9

Subject To:

C1 +12* C4 +C7 +900 *C10 +450* C11 >= 300

C2 +12 *C5 +C7 -750 *C10 >= 300

C3 +12 *C6 +C7 -750 *C11 >= 300

C1 +15 *C4 +C8 +900* C10 +450* C11 >= 360

C2 +15* C5 +C8 -750 *C10 >= 360

$C_3 + 15 * C_6 + C_8 - 750 * C_{11} \geq 360$

$C_1 + 20 * C_4 + C_9 + 900 * C_{10} + 450 * C_{11} \geq 420$

$C_2 + 20 * C_5 + C_9 - 750 * C_{10} \geq 420$

$C_3 + 20 * C_6 + C_9 - 750 * C_{11} \geq 420$

Variables are:

$C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9 \geq 0$

C_{10}, C_{11} = unrestricted