

# Supply Chain and Logistics Analytics

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## 1. Problem statement:

Green Mills Inc., which operates and owns many lumber mills in North-western United States, is currently considering expanding its operations to Chile in order to reduce the total costs associated with raw material procurement. Therefore, the management of the company wants to analyse the cost implications for the backward vertical integration through the analysis of the range of the aggregate production planning strategies including the chase, level and mixed production planning strategies.

## 2. Following analysis to be done :

1. Determine the workforce and production schedule based on a chase, level and mixed policy that meet the forecasted demand at minimum total cost
2. Present a comparison between the three plans and recommend the most attractive option based on minimizing total costs.
3. Perform a sensitivity analysis on the following based on the mixed policies
  - a. Hiring costs increase by 25%
  - b. Inventory costs increase by 25%

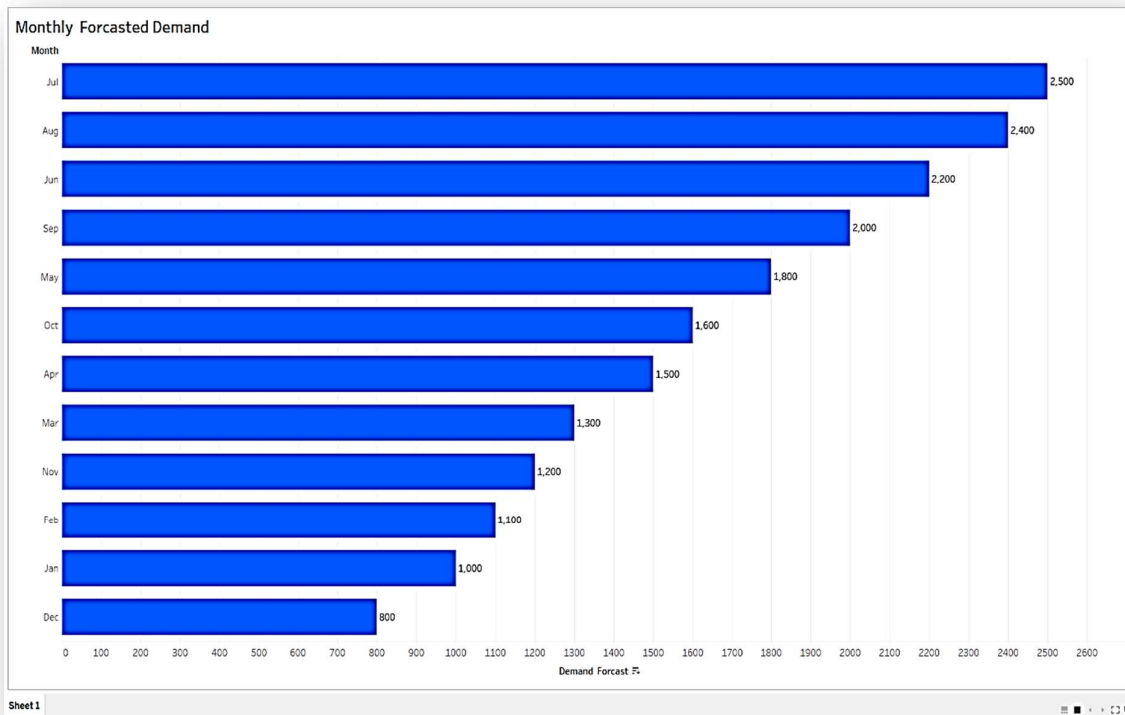
## 3. Strategy Formulation:

Demand Calculation- Total demand has been forecasted of 19,400,000 board feet for next 12 months. Thus, average monthly demand would be 1,616,670 board feet, whereas last 2 months ' demand is 1,200,000 & 800,000 board feet. Maximum available shipping capacity is 1500000 Board feet Per month.

Demand Forecast		
Month	Demand Forecast	Average
Jan	10,00,000	
Feb	11,00,000	
Mar	13,00,000	
Apr	15,00,000	
May	18,00,000	
Jun	22,00,000	
Jul	25,00,000	16,16,667
Aug	24,00,000	
Sep	20,00,000	
Oct	16,00,000	
Nov	12,00,000	
Dec	8,00,000	
Total	1,94,00,000	

Low – Dec , Max Jul

Forecasted values of July shows the max value and Dec is the min value



## Additional details

Parameters	Validations	Remarks
Estimated Production cost	150	Per thousand board feet
Shipping cost	50	Per thousand board feet
Maximum Shipping capacity	1500000	Board feet Per month
Work Hours	160	Monthly
Single Worker Produce	50000	Board feet Per month
Currently deployed employees	20	Total employees
Maximum Inventory capacity	3000000	Monthly
Max over time is allowed 25% of regular work hours	40	Monthly per employee
Hiring and Training cost	1000	Per employee
Lay off Cost	500	Per employee
Back lording is not permitted	N/A	Not Allowed
Hours Required Per Unit	312.5	Total hours(160)/Total Output(50000)
Regular monthly wage per worker	7500	Paid 150 for every 1000 board feet ( per board feet =150/100)*50000
Over time wage per hour	62.5	

## Constraints

Following are the constraints we have considered to perform the solver

1. Workforce size for each month is based on hiring and layoffs
2. Production (in hours) for each month cannot exceed capacity (in hours)
3. Overtime hours should not exceed with maximum overtime hours
4. Ending Inventory should not exceed the capacity of defined capacity of inventory.
5. Unit production, should not exceed more than shipping capacity

## Decision Variables

We have considered till Jan to Dec all these variables

1.  $W_t$  = Number of employees in month  $t$ ,  $t = 1, \dots, 12$
2.  $H_t$  = Number of employees hired at the beginning of month  $t$ ,  $t = 1, \dots, 12$
3.  $L_t$  = Number of employees laid off at the beginning of month  $t$ ,  $t = 1, \dots, 12$
4.  $P_t$  = Production in units of shovels in month  $t$ ,  $t = 1, \dots, 12$
5.  $I_t$  = Inventory at the end of month  $t$ ,  $t = 1, \dots, 12$
6.  $C_t$  = Number of units required for month  $t$ ,  $t = 1, \dots, 12$
7.  $O_t$  = Number of overtime hours worked in month  $t$ ,  $t = 1, \dots, 12$

## Basic Strategies

Chase (the demand) strategy; produce at the instantaneous demand rate

Chase strategy: Carrying low levels of inventory requires capacity to vary with seasonal variation in demand or enough capacity to cover peak demand during season.

In this plan we have tried to produce the required output at par to meet the demand, in the cost part we have included

- Regular Labour cost that is 150 per board feet, to produce 50000 BF using 160 work hours per workman hence it is  $150/1000 \times 50000 = \$7500$  Regular monthly wage per worker the same is multiplied with number workers available
- Overtime labour cost : We have considered \$62.5 for overtime each hour (\$200 per 1000 board feet, hence it is  $200/1000 = 0.2$  ( $160/50000 = 312$ ) Hours Required Per Unit = 312 or  $200/3.2$  (1000 board feet can be produced using 3.2 hours)
- Hiring and training cost per employee it is \$1000
- Firing Cost is \$500
- Holding Cost for inventory is \$25 per 1000 BF
- Shipping Cost is 50 per 1000BF

A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Jan 20	Feb 20	Mar 22	Apr 20	May 22	Jun 21	Jul 20	Aug 22	Sep 22	Oct 20	Nov 21	Dec 20	Total
Working days													
Demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Hours Required Per Unit	312.5	312	312	312	312	312	312	312	312	312	312	312	
Regular hours per month per worker	160	160	160	160	160	160	160	160	160	160	160	160	
Over time hours per month per worker	40	40	40	40	40	40	40	40	40	40	40	40	
Regular monthly wage per worker	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	
Over time wage per hour	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	
Hiring Cost per worker	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
Lay off Cost per worker	500	500	500	500	500	500	500	500	500	500	500	500	
Holding Cost	25	25	25	25	25	25	25	25	25	25	25	25	
Beginning workers	20	20	20	20	20	20	20	20	20	20	20	20	
Cumulation hours	200	200	200	200	200	200	200	200	200	200	200	200	
Beginning workers	20	20	20	20	20	20	20	20	20	20	20	20	
Workers Hired	1933	125	2125	2515	2905	3490	4270	4855	4660	3880	3100	2320	1540
Workers laid off	0	0	0	0	0	0	0	0	0	0	0	0	0
Workers Available	1953	125	2145	2535	2925	3510	4290	4875	4680	3900	3120	2340	1560
Regular hours available	312500	343200	405600	468000	561600	686400	780000	748800	624000	499200	374400	249600	
Over time hour used	0	0	0	0	0	0	0	0	0	0	0	0	
Maximum over time hours	78125	85800	101400	117000	140400	171600	195000	187200	156000	124800	93600	62400	
Available hour for production	312500	343200	405600	468000	561600	686400	780000	748800	624000	499200	374400	249600	
Production capacity per unit	1000	1100	1300	1500	1800	2200	2500	2400	2000	1600	1200	800	
Beginning of Inventory	0	0	0	0	0	0	0	0	0	0	0	0	
Units Produced	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Available to meet the demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Ending Inventory	0	0	0	0	0	0	0	0	0	0	0	0	
Maximum Inventory capacity	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	
Shipping Capacity	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	
Cost													
Regular Labour cost	14648437.5	16087500	19012500	21937500	26325000	32175000	36562500	35100000	29250000	23400000	17550000	11700000	283748437.5
Over time labour cost	0	0	0	0	0	0	0	0	0	0	0	0	0
Hiring Cost	1933125	2125000	2515000	2905000	3490000	4270000	4855000	4660000	3880000	3100000	2320000	1540000	37593125
Firing Cost	0	0	0	0	0	0	0	0	0	0	0	0	0
Holding Cost	0	0	0	0	0	0	0	0	0	0	0	0	0
Shipping Cost	20000	22000	26000	30000	36000	44000	50000	48000	40000	32000	24000	16000	388000
Total	16601562.5	18234500	21553500	24872500	29851000	36489000	41467500	39808000	33170000	26532000	19894000	13256000	321729562.5

These are the constraint we have taken

Solver Parameters

Set Objective:

\$N\$43

To:

Max

Min

Value Of:

0

By Changing Variable Cells:

\$B\$18:\$M\$18,\$B\$19:\$M\$19,\$B\$22:\$M\$22,\$B\$29:\$M\$29,\$B\$32:\$M\$32

Subject to the Constraints:

\$B\$22:\$M\$22 <= \$B\$23:\$M\$23

\$B\$29:\$M\$29 <= \$B\$26:\$M\$26

\$B\$29:\$M\$29 <= \$B\$34:\$M\$34

\$B\$30:\$M\$30 >= \$B\$31:\$M\$31

\$B\$32:\$M\$32 <= \$M\$33

Add

Change

Delete

Reset All

Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Simplex LP

Options

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Help

Solve

Close

The cost of chase plan is 321729562.5

Level strategy; produce at the rate of long run average demand

Leveling capacity forces inventory to build up in anticipation of seasonal variation in demand

	Jan 20	Feb 20	Mar 22	Apr 20	May 22	Jun 21	Jul 20	Aug 22	Sep 22	Oct 20	Nov 21	Dec 20	Total
Working days													
Demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Hours Required Per Unit	312.5	312	312	312	312	312	312	312	312	312	312	312	312
Regular hours per month per worker	160	160	160	160	160	160	160	160	160	160	160	160	
Over time hours per month per workers	40	40	40	40	40	40	40	40	40	40	40	40	
Regular monthly wage per worker	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	
Over time wage per hour	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	
Hiring Cost per worker	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
Lay off Cost per worker	500	500	500	500	500	500	500	500	500	500	500	500	
Holding Cost	25	25	25	25	25	25	25	25	25	25	25	25	
Beginning workers	20	20	20	20	20	20	20	20	20	20	20	20	
Cumulation hours	200	200	200	200	200	200	200	200	200	200	200	200	
Beginning workers	20	1953.125	1953.125	20	20	20	20	20	20	20	20	20	
Workers Hired	1933.125	0	581.875	0	3490	0	4855	0	3880	0	2320	0	
Workers laid off	0	1953.125	0	20	0	20	0	20	0	20	0	20	
Workers Available	1953.125	0	2535	0	3510	0	4875	0	3900	0	2340	0	
Regular hours available	312500	0	405600	0	561600	0	780000	0	624000	0	374400	0	
Over time hour used	0	0	0	0	0	0	0	0	0	0	0	0	
Maximum over time hours	78125	0	101400	0	140400	0	195000	0	156000	0	93600	0	
Available hour for production	312500	0	405600	0	561600	0	780000	0	624000	0	374400	0	
Production capacity per unit	1000	0	1300	0	1800	0	2500	0	2000	0	1200	0	
Beginning of Inventory	0	1,100		1,500		2,200		2,400		1,600		800	
Units Produced	1,000	0	1,300	0	1,800	0	2,500	0	2,000	0	1,200	0	
Available to meet the demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Ending Inventory	1,100	0	1,500	0	2,200	0	2,400	0	1,600	0	800	0	
Maximum Inventory capacity	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	
Shipping Capacity	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	
Cost													
Regular Labour cost	14648437.5	0	19012500	0	26325000	0	36562500	0	29250000	0	17550000	0	143348437.5
Over time labour cost	0	0	0	0	0	0	0	0	0	0	0	0	
Hiring & Training Cost	1933125	0	581875	0	3490000	0	4855000	0	3880000	0	2320000	0	17060000
Firing Cost	0	976562.5	0	10000	0	10000	0	10000	0	10000	0	10000	1026562.5
Holding Cost	27500	0	37500	0	55000	0	60000	0	40000	0	20000	0	240000
Shipping Cost	20000	0	26000	3.55271E-14	36000	3.553E-14	50000	3.553E-14	40000	3.553E-14	24000	3.55271E-14	196000
Total	16629063	976562.5	19657875	10000	29906000	10000	41527500	10000	33210000	10000	19914000	10000	161871000

These are the constraint considered

Set Objective:

To:
☐ Max
☒ Min
☐ Value Of:

By Changing Variable Cells:

Subject to the Constraints:

\$B\$22:\$M\$22 <= \$B\$23:\$M\$23  
\$B\$29:\$M\$29 <= \$B\$26:\$M\$26  
\$B\$29:\$M\$29 <= \$B\$34:\$M\$34  
\$B\$30:\$M\$30 >= \$B\$31:\$M\$31  
\$B\$32:\$M\$32 <= \$B\$33:\$M\$33

Add  
Change  
Delete  
Reset All  
Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Simplex LP

Options

The cost of LP is ; 161871000



## Time flexibility; high levels of workforce or capacity

	Jan 20	Feb 20	Mar 22	Apr 20	May 22	Jun 21	Jul 20	Aug 22	Sep 22	Oct 20	Nov 21	Dec 20	Total
Working days													
Demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Hours Required Per Unit	312.5	312	312	312	312	312	312	312	312	312	312	312	
Regular hours per month per worker	160	160	160	160	160	160	160	160	160	160	160	160	
Over time hours per month per workers	40	40	40	40	40	40	40	40	40	40	40	40	
Regular monthly wage per worker	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	
Over time wage per hour	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	
Hiring Cost per worker	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
Lay off Cost per worker	500	500	500	500	500	500	500	500	500	500	500	500	
Holding Cost	25	25	25	25	25	25	25	25	25	25	25	25	
Beginning workers	20	20	20	20	20	20	20	20	20	20	20	20	
Cumulation hours	200	200	200	200	200	200	200	200	200	200	200	200	
Beginning workers	20	20	20	20	20	20	20	20	20	20	20	20	
Workers Hired	1933.125	2125	2515	2905	3490	4270	4855	4660	3880	3100	2320	1540	
Workers laid off	0	0	0	0	0	0	0	0	0	0	0	0	
Workers Available	1953.125	2145	2535	2925	3510	4290	4875	4680	3900	3120	2340	1560	
Regular hours available	312500	343200	405600	468000	561600	686400	780000	748800	624000	499200	374400	249600	
Over time hour used	0	0	0	0	0	0	0	0	0	0	0	0	
Maximum over time hours	78125	85800	101400	117000	140400	171600	195000	187200	156000	124800	93600	62400	
Available hour for production	312500	343200	405600	468000	561600	686400	780000	748800	624000	499200	374400	249600	
Production capacity per unit	1000	1100	1300	1500	1800	2200	2500	2400	2000	1600	1200	800	
Beginning of Inventory	0	0	0	0	0	0	0	0	0	0	0	0	
Units Produced	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Available to meet the demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Demand	1,000	1,100	1,300	1,500	1,800	2,200	2,500	2,400	2,000	1,600	1,200	800	
Ending Inventory	0	0	0	0	0	0	0	0	0	0	0	0	
Maximum Inventory capacity	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000	
Shipping Capacity	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	
Cost													
Regular Labour cost	14648437.5	16087500	19012500	21937500	26325000	32175000	36562500	35100000	29250000	23400000	17550000	11700000	283748438
Over time labour cost	0	0	0	0	0	0	0	0	0	0	0	0	0
Hiring Cost	1933125	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1944125
Firing Cost	0	0	0	0	0	0	0	0	0	0	0	0	0
Holding Cost	0	0	0	0	0	0	0	0	0	0	0	0	0
Shipping Cost	20000	22000	26000	30000	36000	44000	50000	48000	40000	32000	24000	16000	388000
<b>Total</b>	<b>16601562.5</b>	<b>16110500</b>	<b>19039500</b>	<b>21968500</b>	<b>26362000</b>	<b>32220000</b>	<b>36613500</b>	<b>35149000</b>	<b>29291000</b>	<b>23433000</b>	<b>17575000</b>	<b>11717000</b>	<b>286080563</b>

These are the constraint we have considered

Set Objective:

\$N\$43

To:
☐ Max
☒ Min
☐ Value Of:

0

By Changing Variable Cells:

\$B\$18:\$M\$18,\$B\$19:\$M\$19,\$B\$22:\$M\$22,\$B\$29:\$M\$29,\$B\$32:\$M\$32

Subject to the Constraints:

\$B\$18:\$M\$18 <= \$B\$20:\$M\$20  
\$B\$22:\$M\$22 <= \$B\$23:\$M\$23  
\$B\$29:\$M\$29 <= \$B\$26:\$M\$26  
\$B\$29:\$M\$29 <= \$B\$34:\$M\$34  
\$B\$30:\$M\$30 >= \$B\$31:\$M\$31  
\$B\$32:\$M\$32 <= \$B\$33:\$M\$33

Add  
Change  
Delete  
Reset All  
Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Simplex LP

Options

The cost of mixed plan is : 286080563

## 4. Comparison

Comparison between the three plans and recommend the most attractive option based on minimizing total costs. We arrive that Level plan is showing less cost comparing to other two plans

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Mixed																
Regular Labour cost	14648438	1.6E+07	1.9E+07	2.2E+07	2.6E+07	3.2E+07	3.7E+07	3.5E+07	2.9E+07	2.3E+07	1.8E+07	1.2E+07	283748438			
Over time labour cost	0	0	0	0	0	0	0	0	0	0	0	0	0			
Hiring Cost	1933125	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1944125			
Firing Cost	0	0	0	0	0	0	0	0	0	0	0	0	0			
Holding Cost	0	0	0	0	0	0	0	0	0	0	0	0	0			
Shipping Cost	20000	22000	26000	30000	36000	44000	50000	48000	40000	32000	24000	16000	388000			
Total	16601563	1.6E+07	1.9E+07	2.2E+07	2.6E+07	3.2E+07	3.7E+07	3.5E+07	2.9E+07	2.3E+07	1.8E+07	1.2E+07	286080563			
LP																
Regular Labour cost	14648438	0	1.9E+07	0	2.6E+07	0	3.7E+07	0	2.9E+07	0	1.8E+07	0	143348438			
Over time labour cost	0	0	0	0	0	0	0	0	0	0	0	0	0			
Hiring & Training Cost	1933125	0	581875	0	3490000	0	4855000	0	3880000	0	2320000	0	17060000			
Firing Cost	0	976562	0	10000	0	10000	0	10000	0	10000	0	10000	1026562.5	MP	286080563	
Holding Cost	27500	0	37500	0	55000	0	60000	0	40000	0	20000	0	240000	LP	161871000	
Shipping Cost	20000	0	26000	3.6E-14	36000	3.6E-14	50000	3.6E-14	40000	3.6E-14	24000	3.6E-14	196000	CP	321729563	
Total	16629063	976562	2E+07	10000	3E+07	10000	4.2E+07	10000	3.3E+07	10000	2E+07	10000	161871000			
CP																
Regular Labour cost	14648438	1.6E+07	1.9E+07	2.2E+07	2.6E+07	3.2E+07	3.7E+07	3.5E+07	2.9E+07	2.3E+07	1.8E+07	1.2E+07	283748438			
Over time labour cost	0	0	0	0	0	0	0	0	0	0	0	0	0			
Hiring Cost	1933125	2125000	2515000	2905000	3490000	4270000	4855000	4660000	3880000	3100000	2320000	1540000	37593125			
Firing Cost	0	0	0	0	0	0	0	0	0	0	0	0	0			
Holding Cost	0	0	0	0	0	0	0	0	0	0	0	0	0			
Shipping Cost	20000	22000	26000	30000	36000	44000	50000	48000	40000	32000	24000	16000	388000			
Total	16601563	1.8E+07	2.2E+07	2.5E+07	3E+07	3.6E+07	4.1E+07	4E+07	3.3E+07	2.7E+07	2E+07	1.3E+07	321729563			

Mixed							
Cost	Regular Labour cost	Over time labour cost	Hiring Cost	Firing Cost	Holding Cost	Shipping Cost	Total
	14648437.5	0	1933125	0	0	20000	16601562.5
	16087500	0	1000	0	0	22000	16110500
	19012500	0	1000	0	0	26000	19039500
	21937500	0	1000	0	0	30000	21968500
	26325000	0	1000	0	0	36000	26362000
	32175000	0	1000	0	0	44000	32220000
	36562500	0	1000	0	0	50000	36613500
	35100000	0	1000	0	0	48000	35149000
	29250000	0	1000	0	0	40000	29291000
	23400000	0	1000	0	0	32000	23433000
	17550000	0	1000	0	0	24000	17575000
	11700000	0	1000	0	0	16000	11717000
	283748437.5	0	1944125	0	0	388000	286080562.5
LP							
Cost	Regular Labour cost	Over time labour cost	Hiring & Trai	Firing Cost	Holding Cost	Shipping Cost	Total
	14648437.5	0	1933125	0	27500	20000	16629062.5
	0	0	0	976562.5	0	0	976562.5
	19012500	0	581875	0	37500	26000	19657875
	0	0	0	10000	0	3.55271E-14	10000
	26325000	0	3490000	0	55000	36000	29906000
	0	0	0	10000	0	3.55271E-14	10000
	36562500	0	4855000	0	60000	50000	41527500
	0	0	0	10000	0	3.55271E-14	10000
	29250000	0	3880000	0	40000	40000	33210000
	0	0	0	10000	0	3.55271E-14	10000
	17550000	0	2320000	0	20000	24000	19914000
	0	0	0	10000	0	3.55271E-14	10000
	143348437.5	0	17060000	1026562.5	240000	196000	161871000
CP							
Cost	Regular Labour cost	Over time labour cost	Hiring Cost	Firing Cost	Holding Cost	Shipping Cost	Total
	14648437.5	0	1933125	0	0	20000	16601562.5
	16087500	0	2125000	0	0	22000	18234500
	19012500	0	2515000	0	0	26000	21553500
	21937500	0	2905000	0	0	30000	24872500
	26325000	0	3490000	0	0	36000	29851000
	32175000	0	4270000	0	0	44000	36489000
	36562500	0	4855000	0	0	50000	41467500
	35100000	0	4660000	0	0	48000	39808000
	29250000	0	3880000	0	0	40000	33170000
	23400000	0	3100000	0	0	32000	26532000
	17550000	0	2320000	0	0	24000	19894000
	11700000	0	1540000	0	0	16000	13256000
	283748437.5	0	37593125	0	0	388000	321729562.5

## 5. Sensitivity analysis

A sensitivity analysis determines how different values of an independent variable impact a particular dependent variable under a given set of assumptions.





Microsoft Excel 16.0 Sensitivity Report  
Worksheet: [Green mill Aggregate planning.xlsx]sensitivity analysis  
Report Created: 10-11-2019 20:37:14

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
\$B\$18	Workers Hired Jan	1933.125	0	16250	2500	1750
\$C\$18	Workers Hired Feb	191.875	0	8750	1250	500
\$D\$18	Workers Hired Mar	2535	0	8750	500	1750
\$E\$18	Workers Hired Apr	0	500	8750	1E+30	500
\$F\$18	Workers Hired May	3490	0	8750	500	1750
\$G\$18	Workers Hired Jun	0	500	8750	1E+30	500
\$H\$18	Workers Hired Jul	4855	0	8750	500	1750
\$I\$18	Workers Hired Aug	0	500	8750	1E+30	500
\$J\$18	Workers Hired Sep	3880	0	8750	500	1750
\$K\$18	Workers Hired Oct	0	500	8750	1E+30	500
\$L\$18	Workers Hired Nov	2320	0	8750	500	1750
\$M\$18	Workers Hired Dec	0	1750	8750	1E+30	1750
\$B\$19	Workers laid off Jan	0	1750	-14500	1E+30	1750
\$C\$19	Workers laid off Feb	0	500	500	1E+30	500
\$D\$19	Workers laid off Mar	0	1750	-7000	1E+30	1750
\$E\$19	Workers laid off Apr	20	0	500	8244.230769	500
\$F\$19	Workers laid off May	0	1750	-7000	1E+30	1750
\$G\$19	Workers laid off Jun	20	0	500	8244.230769	500
\$H\$19	Workers laid off Jul	0	1750	-7000	1E+30	1750
\$I\$19	Workers laid off Aug	20	0	500	8244.230769	500
\$J\$19	Workers laid off Sep	0	1750	-7000	1E+30	1750
\$K\$19	Workers laid off Oct	20	0	500	8244.230769	500
\$L\$19	Workers laid off Nov	0	1750	-7000	1E+30	1750
\$M\$19	Workers laid off Dec	20	0	-7000	6994.230769	1750
\$B\$22	Over time hour used Jan	0	15.625	62.5	1E+30	15.625
\$C\$22	Over time hour used Feb	0	7.8125	62.5	1E+30	7.8125
\$D\$22	Over time hour used Mar	0	7.8125	62.5	1E+30	7.8125
\$E\$22	Over time hour used Apr	0	268.5697115	62.5	1E+30	268.5697115
\$F\$22	Over time hour used May	0	7.8125	62.5	1E+30	7.8125
\$G\$22	Over time hour used Jun	0	268.5697115	62.5	1E+30	268.5697115
\$H\$22	Over time hour used Jul	0	7.8125	62.5	1E+30	7.8125
\$I\$22	Over time hour used Aug	0	268.5697115	62.5	1E+30	268.5697115
\$J\$22	Over time hour used Sep	0	7.8125	62.5	1E+30	7.8125
\$K\$22	Over time hour used Oct	0	268.5697115	62.5	1E+30	268.5697115
\$L\$22	Over time hour used Nov	0	7.8125	62.5	1E+30	7.8125
\$M\$22	Over time hour used Dec	0	237.3197115	62.5	1E+30	237.3197115
\$B\$29	Units Produced Jan	1000	0	20	1E+30	14668.4375
\$C\$29	Units Produced Feb	1100	0	20	1E+30	17082.5
\$D\$29	Units Produced Mar	1300	0	20	1E+30	17082.5
\$E\$29	Units Produced Apr	1.77636E-15	0	20	11.25	16076.25
\$F\$29	Units Produced May	1800	0	20	1E+30	17082.5
\$G\$29	Units Produced Jun	1.77636E-15	0	20	11.25	16076.25
\$H\$29	Units Produced Jul	2500	0	20	1E+30	17082.5

## Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
\$B\$18	Workers Hired Jan	1933.125	0	0	1E+30	20
\$C\$18	Workers Hired Feb	191.875	0	0	1E+30	1953.125
\$D\$18	Workers Hired Mar	2535	0	0	1E+30	0
\$E\$18	Workers Hired Apr	0	0	0	1E+30	0
\$F\$18	Workers Hired May	3490	0	0	1E+30	20
\$G\$18	Workers Hired Jun	0	0	0	1E+30	0
\$H\$18	Workers Hired Jul	4855	0	0	1E+30	20
\$I\$18	Workers Hired Aug	0	0	0	1E+30	0
\$J\$18	Workers Hired Sep	3880	0	0	1E+30	20
\$K\$18	Workers Hired Oct	0	0	0	1E+30	0
\$L\$18	Workers Hired Nov	2320	0	0	1E+30	20
\$M\$18	Workers Hired Dec	0	0	0	1E+30	0
\$B\$22	Over time hour used Jan	0	0	0	1E+30	78125
\$C\$22	Over time hour used Feb	0	0	0	1E+30	85800
\$D\$22	Over time hour used Mar	0	0	0	1E+30	101400
\$E\$22	Over time hour used Apr	0	-206.1057692	0	0	800
\$F\$22	Over time hour used May	0	0	0	1E+30	140400
\$G\$22	Over time hour used Jun	0	-206.1057692	0	0	800
\$H\$22	Over time hour used Jul	0	0	0	1E+30	195000
\$I\$22	Over time hour used Aug	0	-206.1057692	0	0	800
\$J\$22	Over time hour used Sep	0	0	0	1E+30	156000
\$K\$22	Over time hour used Oct	0	-206.1057692	0	0	800
\$L\$22	Over time hour used Nov	0	0	0	1E+30	93600
\$M\$22	Over time hour used Dec	0	-174.8557692	0	0	800
\$B\$29	Units Produced Jan	1000	-14648.4375	0	989.76	98.24
\$C\$29	Units Produced Feb	1100	-17062.5	0	98.3974359	1E+30
\$D\$29	Units Produced Mar	1300	-17062.5	0	1300	1E+30
\$E\$29	Units Produced Apr	1.77636E-15	-11.25	0	1500	1.77636E-15
\$F\$29	Units Produced May	1800	-17062.5	0	1789.74359	1E+30
\$G\$29	Units Produced Jun	1.77636E-15	-11.25	0	2200	1.77636E-15
\$H\$29	Units Produced Jul	2500	-17062.5	0	2489.74359	1E+30
\$I\$29	Units Produced Aug	1.77636E-15	-11.25	0	2400	1.77636E-15
\$J\$29	Units Produced Sep	2000	-17062.5	0	1989.74359	1E+30
\$K\$29	Units Produced Oct	1.77636E-15	-11.25	0	1600	1.77636E-15
\$L\$29	Units Produced Nov	1200	-17062.5	0	1189.74359	1E+30
\$M\$29	Units Produced Dec	1.77636E-15	-11.25	0	800	1.77636E-15
\$B\$30	Available to meet the demand J	1000	14668.4375	1000	98.24	989.76
\$C\$30	Available to meet the demand F	1100	17082.5	1100	148900	98.3974359
\$D\$30	Available to meet the demand H	1300	17082.5	1300	148700	1300
\$E\$30	Available to meet the demand A	1500	31.25	1500	2998500	1500
\$F\$30	Available to meet the demand H	1800	17082.5	1800	148200	1789.74359

Above shows final output of values for the variable, there are two variables are lay off workers shown negative coefficient and monthly product units are impacted

## 6. Appendix



Green mill Aggregate  
planning.xlsx