The optimized net present value over the 10-years project time is $1697.6*10^8$$. Major results are listed in the following chart. Excerpts of run report and commentary to corresponding parts are also listed below, for detail run report please check the other file.

	Chemical 1 purchased (kton)	Chemical 2 purchased (kton)	Chemical 3 produced by process 2 (kton)	Chemical 3 produced by process 3 (kton)	Total chemical 3 (kton)
Period 1	6	20	20.824		20.824
Period 2	7.5	25.5		30.721	30.721
Period 3	8.6	30		35.95	35.95
	Expansion Strategy		Size of expansion (kton)	Investment ($)	NPV ($)
Period 1	Expand process 1		7.748	$9.5692*10^6$	$1.6976*10^8$
Period 2	Expand process 3		35.95	$2.0912*10^7$	
Period 3					

```
               S O L V E      S U M M A R Y

     MODEL   mod                 OBJECTIVE  npv
     TYPE    MIP                 DIRECTION  MAXIMIZE
     SOLVER  CPLEX               FROM LINE  182

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE             1697.6072

 RESOURCE USAGE, LIMIT          0.281      1000.000
 ITERATION COUNT, LIMIT       106    2000000000

IBM ILOG CPLEX   30.3.0 rc5da09e Released Mar 06, 2020 WEI x86 64bit/MS Window
*** This solver runs with a demo license. No commercial use.
Cplex 12.10.0.0

Space for names approximately 0.01 Mb
Use option 'names no' to turn use of names off
MIP status(101): integer optimal solution
Cplex Time: 0.20sec (det. 3.09 ticks)
Fixing integer variables, and solving final LP...
Fixed MIP status(1): optimal
Cplex Time: 0.08sec (det. 0.33 ticks)
Proven optimal solution.

MIP Solution:        1697.607221   (78 iterations, 0 nodes)
Final Solve:         1697.607221   (28 iterations)
```

y is a binary variable, with value either 1 or 0. In this context, “1” means to build a process. Process 1 is invested at the start of the project, while process 3 is invested at year2.

```
---- VAR y  build process p in period jp or not

            LOWER      LEVEL      UPPER    MARGINAL

year0.p1        .      1.000      1.000     -68.405
year0.p2        .          .      1.000     -58.747
year0.p3        .          .      1.000    2370.633
year2.p1        .          .      1.000     -47.279
year2.p2        .          .      1.000     -51.727
year2.p3        .      1.000      1.000     -78.853
year5.p1        .          .      1.000     111.057
year5.p2        .          .      1.000         EPS
year5.p3        .          .      1.000     147.612
```

The amount of capacity expanded.

```
---- VAR addCap  additional capacity for process p in period jp

            LOWER      LEVEL      UPPER    MARGINAL

year0.p1        .      7.748       +INF        .
year0.p2        .          .       +INF     -2.189
year0.p3        .          .       +INF        .
year2.p1        .          .       +INF        .
year2.p2        .          .       +INF     -2.031
year2.p3        .     35.950       +INF        .
year5.p1        .          .       +INF        .
year5.p2        .          .       +INF      EPS
year5.p3        .          .       +INF        .
```

Though p1 is expanded to 7.748kton at year0, it's not used to full capacity until year6 (due to lower availability for chemical1 in early periods). And after p3 is invested on year2, p2 is no longer used. Note that p2 already has a capability of 50 kton/yr in the beginning.

```
---- VAR prflow  product flows from process p in year j

            LOWER      LEVEL      UPPER    MARGINAL

year0 .p1       .          .       +INF      EPS
year0 .p2       .          .       +INF      EPS
year0 .p3       .          .       +INF      EPS
year1 .p1       .      5.405       +INF        .
year1 .p2       .     20.824       +INF        .
year1 .p3       .          .       +INF        .
year2 .p1       .      5.405       +INF        .
year2 .p2       .     20.824       +INF        .
year2 .p3       .          .       +INF        .
year3 .p1       .      6.757       +INF        .
year3 .p2       .          .       +INF     -1.955
year3 .p3       .     30.721       +INF        .
year4 .p1       .      6.757       +INF        .
year4 .p2       .          .       +INF     -1.777
year4 .p3       .     30.721       +INF        .
year5 .p1       .      6.757       +INF        .
year5 .p2       .          .       +INF     -1.615
year5 .p3       .     30.721       +INF        .
year6 .p1       .      7.748       +INF        .
year6 .p2       .          .       +INF     -0.050
year6 .p3       .     35.950       +INF        .
year7 .p1       .      7.748       +INF        .
year7 .p2       .          .       +INF     -1.605
year7 .p3       .     35.950       +INF        .
year8 .p1       .      7.748       +INF        .
year8 .p2       .          .       +INF     -1.459
year8 .p3       .     35.950       +INF        .
year9 .p1       .      7.748       +INF        .
year9 .p2       .          .       +INF     -1.326
year9 .p3       .     35.950       +INF        .
year10.p1       .      7.748       +INF        .
year10.p2       .          .       +INF     -1.206
year10.p3       .     35.950       +INF        .
```

Chemical1 and chemical2 are both purchased every year, meaning chemical2 is supplied by both direct purchase and manufacturing in line. Chemical3 sales amount is always lower than upper limit while chemical1 and 2 purchase amount are always at upper limit, indicating insufficient supply of raw materials.

---- VAR pur1 amount of chem 1 purchased year j

	LOWER	LEVEL	UPPER	MARGINAL
year0	.	.	.	EPS
year1	.	6.000	6.000	7.272
year2	.	6.000	6.000	6.611
year3	.	7.500	7.500	7.789
year4	.	7.500	7.500	7.081
year5	.	7.500	7.500	6.437
year6	.	8.600	8.600	4.483
year7	.	8.600	8.600	6.136
year8	.	8.600	8.600	5.578
year9	.	8.600	8.600	5.071
year10	.	8.600	8.600	4.610

---- VAR pur2 amount of chem 2 purchased year j

	LOWER	LEVEL	UPPER	MARGINAL
year0	.	.	.	EPS
year1	.	20.000	20.000	5.692
year2	.	20.000	20.000	5.174
year3	.	25.500	25.500	6.495
year4	.	25.500	25.500	5.905
year5	.	25.500	25.500	5.368
year6	.	30.000	30.000	4.598
year7	.	30.000	30.000	5.458
year8	.	30.000	30.000	4.962
year9	.	30.000	30.000	4.510
year10	.	30.000	30.000	4.100

---- VAR sel3 amount of chem 3 sold year j

	LOWER	LEVEL	UPPER	MARGINAL
year0	.	.	.	EPS
year1	.	20.824	65.000	.
year2	.	20.824	65.000	.
year3	.	30.721	75.000	.
year4	.	30.721	75.000	.
year5	.	30.721	75.000	.
year6	.	35.950	90.000	.
year7	.	35.950	90.000	.
year8	.	35.950	90.000	.
year9	.	35.950	90.000	.
year10	.	35.950	90.000	.

A summary on economical results (invest amount, sales amount, operating expenses, purchasing fee, working capital, taxable income, depreciation, net present value).

```
---- VAR inv  amount invested in jp

         LOWER     LEVEL     UPPER    MARGINAL

year0      .       95.692   200.000      .
year2      .      209.124   300.000      .
year5      .         .      400.000    -0.392

---- VAR sell  amount earned from the sale of chem3 in year j

          LOWER     LEVEL     UPPER    MARGINAL

year0       .         .        +INF       .
year1       .       545.591    +INF       .
year2       .       545.591    +INF       .
year3       .       897.045    +INF       .
year4       .       897.045    +INF       .
year5       .       897.045    +INF       .
year6       .      1265.448    +INF       .
year7       .      1265.448    +INF       .
year8       .      1265.448    +INF       .
year9       .      1265.448    +INF       .
year10      .      1265.448    +INF       .

---- VAR opex  operating expenses for year j

          LOWER     LEVEL     UPPER    MARGINAL

year0       .         .        +INF     -0.550
year1       .       14.657     +INF       .
year2       .       14.657     +INF       .
year3       .       21.811     +INF       .
year4       .       21.811     +INF       .
year5       .       21.811     +INF       .
year6       .       29.814     +INF       .
year7       .       29.814     +INF       .
year8       .       29.814     +INF       .
year9       .       29.814     +INF       .
year10      .       29.814     +INF       .
```

```
---- VAR wc  working capital put in at begining of period jp

         LOWER     LEVEL     UPPER    MARGINAL

year0      .       14.354     +INF       .
year2      .       31.369     +INF       .
year5      .         .        +INF     -0.235
```

---- VAR buy1 amount spent to purchase chem1 in year j

	LOWER	LEVEL	UPPER	MARGINAL
year0	.	.	+INF	-0.550
year1	.	24.000	+INF	.
year2	.	24.000	+INF	.
year3	.	39.300	+INF	.
year4	.	39.300	+INF	.
year5	.	39.300	+INF	.
year6	.	62.952	+INF	.
year7	.	62.952	+INF	.
year8	.	62.952	+INF	.
year9	.	62.952	+INF	.
year10	.	62.952	+INF	.

---- VAR buy2 amount spent to purchace chem2 in year j

	LOWER	LEVEL	UPPER	MARGINAL
year0	.	.	+INF	-0.550
year1	.	192.000	+INF	.
year2	.	192.000	+INF	.
year3	.	293.760	+INF	.
year4	.	293.760	+INF	.
year5	.	293.760	+INF	.
year6	.	405.600	+INF	.
year7	.	405.600	+INF	.
year8	.	405.600	+INF	.
year9	.	405.600	+INF	.
year10	.	405.600	+INF	.

---- VAR income taxable imcome year j

	LOWER	LEVEL	UPPER	MARGINAL
year0	.	.	+INF	.
year1	.	314.935	+INF	.
year2	.	314.935	+INF	.
year3	.	542.174	+INF	.
year4	.	542.174	+INF	.
year5	.	542.174	+INF	.
year6	.	767.082	+INF	.
year7	.	767.082	+INF	.
year8	.	767.082	+INF	.
year9	.	767.082	+INF	.
year10	.	767.082	+INF	.

---- VAR dep depriciation in year j

	LOWER	LEVEL	UPPER	MARGINAL
year0	.	.	+INF	.
year1	.	8.612	+INF	.
year2	.	8.612	+INF	.
year3	.	32.139	+INF	.
year4	.	32.139	+INF	.
year5	.	32.139	+INF	.
year6	.	32.139	+INF	.
year7	.	32.139	+INF	.
year8	.	32.139	+INF	.
year9	.	32.139	+INF	.
year10	.	32.139	+INF	.

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR npv	-INF	1697.607	+INF	.

  npv net present value