Cellular Manufacturing Systems Planning Game©

Consider yourself to be working in a factory operating in a cellular manufacturing framework consisting of three cells. Raw materials are procured and issued from a centralised stores on request from the individual cells. The sub-assemblies have been grouped into three distinct product families and associated machine groups. The sub-assemblies are manufactured in the cells and then sent to the assembly shop. The assembled final product is sent for despatch. Figure 1 gives a schematic view of the proposed system.

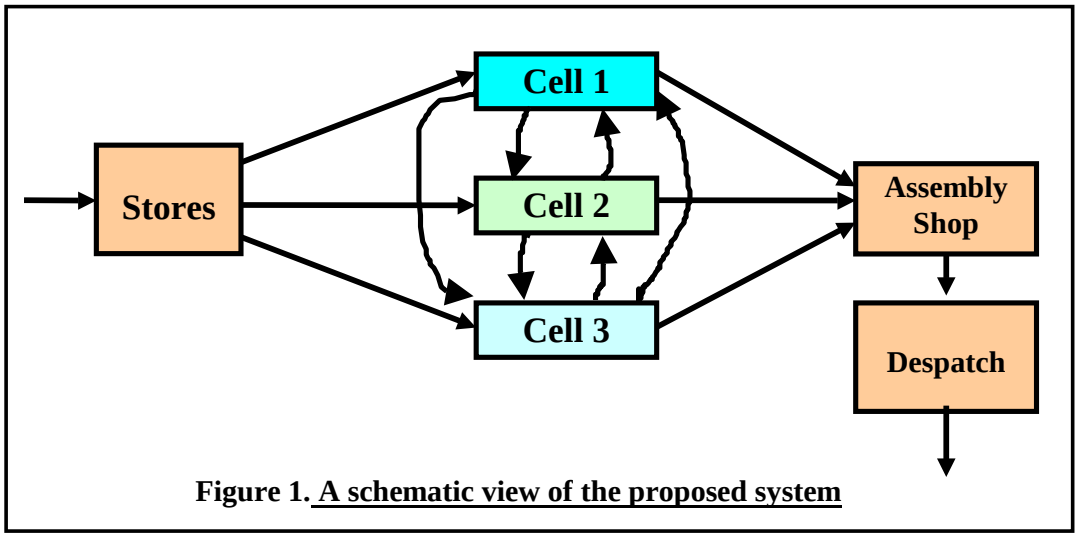

Figure 1. A schematic view of the proposed system

The three sub-assembly product families are designated as product family A (**PFA**), product family B (**PFB**), and product family C (**PFC**). The product families are assumed to be sufficiently homogeneous. Further assume that one unit each of PFA, PFB, and PFC will be assembled to make one unit of the final product X (**FPX**).

Processing details

As mentioned earlier, raw materials are issued from the stores to all the three cells on request. Each cell has been designed in such a manner that most of the processing is done within that cell. However, there are a few instances of jobs requiring processing in other cells. This has been due to non-duplication of resources for reasons of poor utilisation, high cost or health hazard. For example, for all requirements of anodising, phospating, and sand blasting, the jobs have to visit cell 3, since the facility is available only in that cell. Similarly, cell 2 has a high capacity press (1000 Tons) which is visited by the jobs in the other two cells. Cell 1 has certain special purpose machines, which are used by the jobs in the other two cells.

Thus, ***inter-cell movement*** of jobs has been minimised, although not eliminated altogether. At the time of locating the unique facilities, care was taken to ensure that they were placed in the cells where they were needed the most. Since the parts in each part family are homogeneous, assume that the machining time requirements are quite similar with in a group. Table 1 has some relevant data for the part families and the machine groups.

As seen from the table, although for the part family PFC, 89% of the total processing is done in cell 3, it still requires 6% of it's processing to be done in cell 1 and 5% of the processing in cell 2. The capacity requirement in the various cells is obtained from the total processing time per unit. For example, if the demand for PFA in a future period is 100, then the total processing time required is 100 hours (6000 minutes), out of which, 82 hours will be required in cell 1, 10 hours in cell 2 and 8 hours in cell 3.

Table 1
Total processing time and degree of processing in the cells

Degree of processing

	Cell 1	**Cell 2**	**Cell 3**	**Total processing time (min) per unit**
PFA	82%	10%	8%	60
PFB	7%	84%	9%	90
PFC	6%	5%	89%	45

Capacity issues

The system works for five days in a week with a single shift of 8 hrs each. A normal month is supposed to consist of four weeks and hence a maximum capacity of 160 Hrs per machine available. The available capacity in each of the cells is a function of several things. These include the number of machines of each type available, the breakdown pattern of these machines, the time lost in set-up time and so on. The cell capacity (in machine hours) has been estimated taking all these into consideration. Cells 1 and 3 have a maximum available capacity of 480 machine hours per month. Cell 2 has a maximum capacity of 640 machine hours.

While planning the production for a future period (say the next month), a realistic estimate of the capacity availability and the requirement from one's own cell and the other two cells is important. The available capacity in a cell has to be utilised for producing the sub-assemblies belonging to the cell. In addition, provisions will also have to be made for accommodating the requirements from the other two cells due to inter-cell movement.

When *commitments are made to process other cell requirements* it can not be easily altered. If the actual requirement of the other cells is less than the planned capacity, the excess capacity thus released may contribute for the cell's own planned production. If capacity is still available in excess it may go unutilised. Sudden

increase in the cell's production because extra capacity is available is not allowed, since the decision has its bearing on the capacity requirements in the other two cells also. If the demand from the other two cells is more than the capacity initially planned for, the excess capacity is provided to process the other cell requirements at an increased cost. The cost of providing extra capacity is borne by the cell that has made the request.

Unutilised capacity reflects the opportunity cost of not using the machines, the workers and a portion of the fixed factory overheads. Hence under utilisation of capacity will be penalised on a basis reflecting the above costs. However, the cell leader is free to produce more than the current requirement as indicated by the production controller in anticipation of the future requirements and the various uncertainties in his cell. In such a situation, there will be the cost of carrying inventory. Inventory carrying cost is valued at 24% per annum on the value of the sub-assembly, which is assumed to be Rs. 500 per unit.

If in the actual operation of the system, the capacity in the cells is found to be deficient to produce the planned quantities, the capacity is forced to be over utilised or other methods of augmenting the capacity will be resorted to, in order to complete the period requirements. Addition of excess capacity is normally done through adding over time or an extra shift. In extreme cases, the work may be sub-contracted to a remote place (to the other operating unit of the same organisation). All these increase the cost of operation. Hence over utilisation of capacity is penalised on a suitable basis, keeping in mind the above issues.

Set-up Time Reduction Initiatives

The machines in the cells are stopped whenever they need set-up. This results in loss of capacity. The estimate of the current cell capacity has taken this into consideration. However, the cell members are allowed to embark upon a set-up time reduction initiative. Usually, the bottleneck machine in the cell is identified and its set-up time brought down. Such an initiative invariably augments additional capacity to the cell.

Three types of set-up time reduction initiatives are possible. **Type I,** referred to as **Starter** will result in an increase in the cell capacity by 3%. It involves a cost of Rs. 4,000. **Type II** is **Modest**. The nature of efforts put in is much more than the starter and it will augment the capacity in the cell to the extent of 7%. However, the cost of this plan will be Rs. 10,000. The third type is the **Aggressive** one. Resorting to this type of set-up time reduction will demand more resources and will result in a 10% increase in the capacity. Due to the increased usage of organisational resources, the aggressive set-up time reduction initiative will cost Rs. 18,000.

Set-up time reduction initiatives are taken up in such a manner that the existing capacity of the cells will remain unaltered during the period such initiatives are undertaken. However, at the end of the set-up time reduction initiative, the capacity will increase. This would mean, for example, that if a set-up time initiative is taken up during period 1, the capacity will go up beginning period 2. The cost of the set-up time reduction exercise is however, charged to the period during which the initiative is taken.

Product demand

The demand of the finished product FPX has to be forecasted by the production controller on some basis. Table 2 gives the demand for FPX during the last three years. After taking into consideration the inventory of FPX and the three sub-assemblies available on hand, the production controller will decide on the quantity to be produced for the remaining stages of the planning period.

This becomes the basis for the cell leaders to take their decision with respect to the use of capacity and the quantity of sub-assemblies that they would like to produce in future periods. The actual demand for FPX during a period is the delivery commitments made by the marketing department in response to the prevailing market conditions. The actual demand has to be met with no matter what was the forecasted figure.

Table 2.
Demand for FPX in the last three years

	1991-92	**1992-93**	**1993-94**
April	200	241	203
May	245	227	204
June	202	216	175
July	230	274	211
August	265	273	207
September	266	302	190
October	223	264	183
November	228	230	197
December	294	285	206
January	260	296	281
February	318	268	332
March	366	270	282

If the stock on hand is more than the actual demand, the excess inventory is carried over to the future period at a carrying cost of 24% per annum of the value of the product FPX which is assumed to be Rs. 2000 per unit. If the demand is more than the stock, shortage cost is incurred. The shortage costs reflects the fire fighting operations initiated at the last minute to meet the delivery commitments. Shortage costs are assumed to be Rs.300 per unit.

Game structure

In order to play the game, two levels of decision making are involved. At the first level, designated as production planning, a production controller is expected to estimate the future demand for FPX. Taking into consideration any left over inventory from the previous period and the future demand, the quantity to be produced in the remaining stages of the planning period is decided and the information passed on to the individual cell leaders.

At the second stage, each cell leader will have to make the following decisions with respect to the capacity for the next period based on the information obtained from the production controller:

- Quantity of sub-assembly to be produced over and above the indicated requirements for the next period.
- The nature of set-up time reduction initiative to be taken up (if any)
- Capacity allocated for processing of other cell requirements
- Capacity allocated for processing the requirements of his own cell

Once the decisions are made, each cell leader will approach the production controller and intimate to him his requirements of capacity in the other two cells and his provisions for processing of the other two cells' requirements. The game facilitator will reveal the following information to the production controller:

- the actual demand for the product FPX

The production controller will in turn pass on the relevant information to the cell leaders. Discrepancies between the actual and the planned figure will be computed both at the cell level and at the final assembly level using the work sheets and the various penalties computed. Once again the game proceeds to the next period of the planning horizon by repeating the same process.

Details of various costs

When the planned requirements are not met with in the cells, it costs more to complete them. The cost incurred is related to the degree of completion. Table 3 lists the cost incurred per hour for various levels of completion in the cells. The costs apply to both unfinished jobs with in a cell and in the other cells.

The costs of under utilisation for the three cells are as follows:

Cell A: Rs. 40 per hour
Cell B: Rs. 25 per hour
Cell C: Rs. 65 per hour

Table 3.
Cost of non-completion of the planned requirements

Sl. No.	Degree of completion (%)	Cost (Rs. per Hour)
1	0	500
2	0.01 - 2.00	415
3	2.01 - 6.00	340
4	6.01 - 10.00	280
5	10.01 - 15.00	240
6	15.01 - 20.00	185
7	20.01 - 40.00	125
8	40.01 - 60.00	80
9	60.01 - 80.00	65
10	80.01 - 85.00	58
11	85.01 - 90.00	47
12	90.01 - 92.00	38
13	92.01 - 94.00	30
14	94.01 - 96.00	24
15	96.01 - 98.00	17
16	98.01 - 99.99	12
17	100	0

Make the following assumptions while playing the game

- There is no left over inventory at the beginning of the game in any of the cells and in the assembly area.
- The lead time is such that requirements for a period could be met within the same period
- Material shortages do not affect the production activities adversely

Form C11

Cell level performance measurement sheet - Cell 1

Planned production and the degree of completion for PFA

Period

	Description	**1**	**2**	**3**	**4**	**5**	**6**
X:	Requirement from PPC (units)						
Y:	Additional production as excess inventory (units)						
A:(X+Y)	Planned production. (units)						
B:(0.82*A*1.0)	Hours required in cell 1						
C	Actual hours available for own use						
D:(B-C or 0)	Number of deficit hours in cell 1						
E:(C/B)*100	Degree of completion in cell 1 (%)						
F:(0.10*A*1.0)	Hours required in cell 2						
G:	Actual hours provided by cell 2						
H:(F-G or 0)	Number of deficit hours in cell 2						
I:(G/F)*100	Degree of completion in cell 2 (%)						
J:(0.08*A*1.0)	Hours required in cell 3						
K:	Actual hours provided by cell 3						
L:(J-K or 0)	Number of deficit hours in cell 3						
M:(K/J)*100	Degree of completion in cell 3 (%)						

Form C12

Cell Level Capacity Planning Sheet - Cell 1

Period

	Description	1	2	3	4	5	6
	Set-up time reduction initiatives (1 or 2 or 3 or none)						
A: **	Maximum available capacity (hrs)	480					
B:	Capacity allocated for cell 2						
C:	Capacity requested by cell 2						
D:(B-C or 0)	Excess capacity allocated to cell 2						
E:	Capacity allocated for cell 3						
F:	Capacity requested by cell 3						
G:(E-F or 0)	Excess capacity allocated to cell 3						
H:	Planned capacity for own requirements						
I:(A-B-E+ D+G)	Actual capacity available for own use						
J:(I-H or 0)	Unutilised capacity in the cell						
K:(H-I or 0)	Deficit capacity in the cell						

** - If the previous period set-up time reduction initiative is

none : - maximum capacity of previous period
Type 1 : - maximum capacity of previous period * (1.03)
Type 2 : - maximum capacity of previous period * (1.07)
Type 3 : - maximum capacity of previous period * (1.10)

Form C13

Cell Level Performance Measurement Sheet- Cell 1

Cost consequences of the decisions made

Period

	Description	1	2	3	4	5	6
E:&	Degree of completion in cell 1						
1:$	Cost per hr of non-completion						
D:&	Deficit hours in cell 1						
2:(1xD)	Cost of non-completion in cell 1						
I:&	Degree of completion in cell 2						
3:$	Cost per hr of non-completion						
H:&	Deficit hours in cell 2						
4:(3xH)	Cost of non-completion in cell 2						
M:&	Degree of completion in cell 3						
5:$	Cost per hr of non-completion						
L:&	Deficit hours in cell 3						
6:(5xL)	Cost of non-completion in cell 3						
L:#	Unutilised capacity in own cell						
7:(Lx40)	Cost of under utilisation						
8: @	Cost of set-up time reduction initiatives						
Y:&	Excess inventory for the period						
9:(Yx10)	Cost of carrying inventory						
10:(2+4+ 6+7+8+9)	Total cost for the period decisions						
	Cumulative cost (current period)						

Note: $ - Read data from the write up about the game
& - Copy data from form c11
# - Copy data from form c12
@ - Type 1: Rs. 4,000, Type 2: Rs. 10,000, Type 3: Rs. 18,000.

Form C21

Cell level performance measurement sheet - Cell 2

Planned production and the degree of completion for PFB

Period

	Description	**1**	**2**	**3**	**4**	**5**	**6**
X:	Requirement from PPC (units)						
Y:	Additional production as excess inventory (units)						
A:(X+Y)	Planned production. (units)						
B:(0.07*A*1.5)	Hours required in cell 1						
C	Actual hours provided by cell 1						
D:(B-C or 0)	Number of deficit hours in cell 1						
E:(C/B)*100	Degree of completion in cell 1 (%)						
F:(0.84*A*1.5)	Hours required in cell 2						
G:	Actual hours available for own use						
H:(F-G or 0)	Number of deficit hours in cell 2						
I:(G/F)*100	Degree of completion in cell 2 (%)						
J:(0.09*A*1.5)	Hours required in cell 3						
K:	Actual hours provided by cell 3						
L:(J-K or 0)	Number of deficit hours in cell 3						
M:(K/J)*100	Degree of completion in cell 3 (%)						

Form C22

Cell Level Capacity Planning Sheet - Cell 2

Period

	Description	1	2	3	4	5	6
	Set-up time reduction initiatives (1 or 2 or 3 or none)						
A: **	Maximum available capacity	640					
B:	Capacity allocated for cell 1						
C:	Capacity requested by cell 1						
D:(B-C or 0)	Excess capacity allocated to cell 1						
E:	Capacity allocated for cell 3						
F:	Capacity requested by cell 3						
G:(E-F or 0)	Excess capacity allocated to cell 3						
H:	Planned capacity for own requirements						
I:(A-B-E+ D+G)	Actual capacity available for own use						
J:(I-H or 0)	Unutilised capacity in the cell						
K:(H-I or 0)	Deficit capacity in the cell						

** - If the previous period set-up time reduction initiative is

none : - maximum capacity of previous period
Type 1 : - maximum capacity of previous period * (1.03)
Type 2 : - maximum capacity of previous period * (1.07)
Type 3 : - maximum capacity of previous period * (1.10)

Form C23

Cell Level Performance Measurement Sheet- Cell 2

Cost consequences of the decisions made

Period

	Description	1	2	3	4	5	6
E:&	Degree of completion in cell 1						
1:$	Cost per hr of non-completion						
D:&	Deficit hours in cell 1						
2:(1xD)	Cost of non-completion in cell 1						
I:&	Degree of completion in cell 2						
3:$	Cost per hr of non-completion						
H:&	Deficit hours in cell 2						
4:(3xH)	Cost of non-completion in cell 2						
M:&	Degree of completion in cell 3						
5:$	Cost per hr of non-completion						
L:&	Deficit hours in cell 3						
6:(5xL)	Cost of non-completion in cell 3						
L:#	Unutilised capacity in own cell						
7:(Lx25)	Cost of under utilisation						
8: @	Cost of set-up time reduction initiatives						
Y:&	Excess inventory for the period						
9:(Yx10)	Cost of carrying inventory						
10:(2+4+ 6+7+8+9)	Total cost for the period decisions						
	Cumulative cost (current period)						

Note: $ - Read data from the write up about the game
& - Copy data from form c21
# - Copy data from form c22
@ - Type 1: Rs. 4,000, Type 2: Rs. 10,000, Type 3: Rs. 18,000.

Form C31

Cell level performance measurement sheet - Cell 3

Planned production and the degree of completion for PFC

Period

	Description	**1**	**2**	**3**	**4**	**5**	**6**
X:	Requirement from PPC (units)						
Y:	Additional production as excess inventory (units)						
A:(X+Y)	Planned production. (units)						
B:(0.06*A*0.75)	Hours required in cell 1						
C	Actual hours provided by cell 1						
D:(B-C or 0)	Number of deficit hours in cell 1						
E:(C/B)*100	Degree of completion in cell 1 (%)						
F:(0.05*A*0.75)	Hours required in cell 2						
G:	Actual hours provided by cell 2						
H:(F-G or 0)	Number of deficit hours in cell 2						
I:(G/F)*100	Degree of completion in cell 2 (%)						
J:(0.89*A*0.75)	Hours required in cell 3						
K:	Actual hours available for own use						
L:(J-K or 0)	Number of deficit hours in cell 3						
M:(K/J)*100	Degree of completion in cell 3 (%)						

Form C32

Cell Level Capacity Planning Sheet - Cell 3

Period

	Description	1	2	3	4	5	6
	Set-up time reduction initiatives (1 or 2 or 3 or none)						
A: **	Maximum available capacity	480					
B:	Capacity allocated for cell 1						
C:	Capacity requested by cell 1						
D:(B-C or 0)	Excess capacity allocated to cell 1						
E:	Capacity allocated for cell 2						
F:	Capacity requested by cell 2						
G:(E-F or 0)	Excess capacity allocated to cell 2						
H:	Planned capacity for own requirements						
I:(A-B-E+ D+G)	Actual capacity available for own use						
J:(I-H or 0)	Unutilised capacity in the cell						
K:(H-I or 0)	Deficit capacity in the cell						

** - If the previous period set-up time reduction initiative is

none : - maximum capacity of previous period
Type 1 : - maximum capacity of previous period * (1.03)
Type 2 : - maximum capacity of previous period * (1.07)
Type 3 : - maximum capacity of previous period * (1.10)

Form C33

Cell Level Performance Measurement Sheet- Cell 3

Cost consequences of the decisions made

Period

	Description	1	2	3	4	5	6
E:&	Degree of completion in cell 1						
1:$	Cost per hr of non-completion						
D:&	Deficit hours in cell 1						
2:(1xD)	Cost of non-completion in cell 1						
I:&	Degree of completion in cell 2						
3:$	Cost per hr of non-completion						
H:&	Deficit hours in cell 2						
4:(3xH)	Cost of non-completion in cell 2						
M:&	Degree of completion in cell 3						
5:$	Cost per hr of non-completion						
L:&	Deficit hours in cell 3						
6:(5xL)	Cost of non-completion in cell 3						
L:#	Unutilised capacity in own cell						
7:(Lx65)	Cost of under utilisation						
8: @	Cost of set-up time reduction initiatives						
Y:&	Excess inventory for the period						
8:(Yx10)	Cost of carrying inventory						
9:(2+4+6 +7+8)	Total cost for the period decisions						
	Cumulative cost (current period)						

Note: $ - Read data from the write up about the game
& - Copy data from form c31
# - Copy data from form c32
@ - Type 1: Rs. 4,000, Type 2: Rs. 10,000, Type 3: Rs. 18,000.

Form P1

Production Planning for the final product (FPX)

	Period	**1**	**2**	**3**	**4**	**5**	**6**
A	Forecasted demand						
B	Beginning inventory	0					
C	Planned Production						
D	Actual Demand						
E	Actual Production						
F:(D-E-B)	Demand not met						
G:(Fx300)	Penalty for demand not met						
H:(B+E-D)	Ending inventory @						
I:(B+H)/2	Average Inventory						
J:(I*.02*2000)	Inventory carrying cost						
K:(G+J)	Total cost						
	Cumulative cost						

@ If this quantity becomes negative please enter zero

Form P2

Monitoring the production of the sub-assemblies

	Period	1	2	3	4	5	6
1:	PFA begin inventory	0					
2:	PFA requirement						
3:(2-1)	PFA planned Production.						
4:	PFA actual Production						
5:(1+4)	PFA available for assembly						

6:	PFB begin inventory	0					
7:	PFB requirement						
8:(7-6)	PFB planned Production						
9:	PFB actual Production						
10:(6+9)	PFB available for assembly						

11:	PFC begin inventory	0					
12:	PFC requirement						
13:(12-11)	PFC planned production						
14:	PFC actual production						
15:	PFC available for assembly						

16:(min of 5,10,15)	Actual FPX production						

Note: 2,7,12: Copy item C from Form P1.
4,9,14: Information received from respective cell leaders.