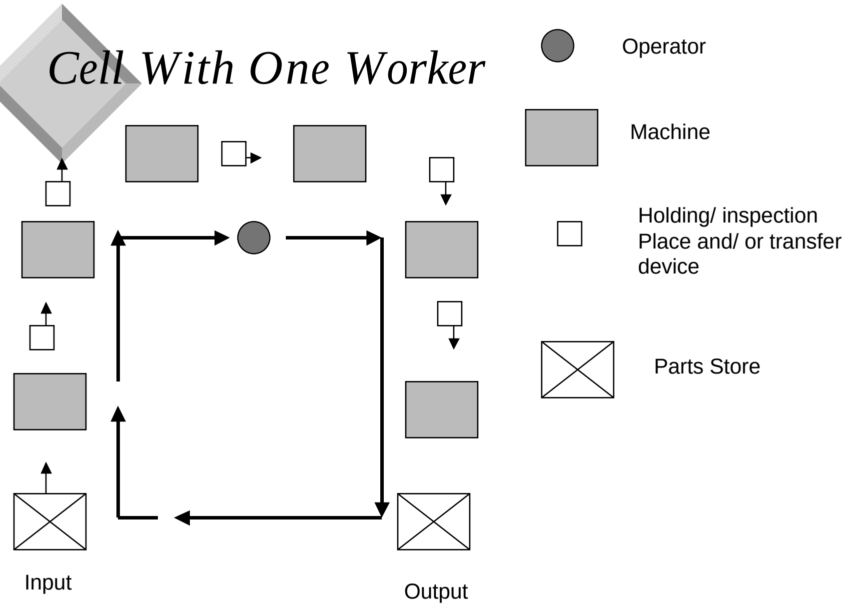
Work Cells and Cellular Manufacturing

Improving the fitness of the factory

Cellular Manufacturing

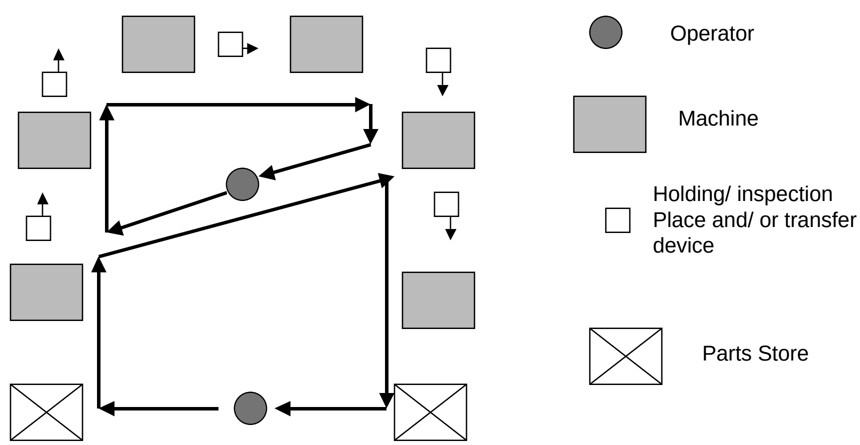
- Concept of performing all of the necessary operations to make a component, subassembly, or finished product in a work cell.
- Basic assumption is that product or part families exist and that the combined volume of products in the family justifies dedicating machines and workers to focused work-cells.
- Basic building blocks of cells
  - Workstations
  - Machines
  - Workers
  - Tools, gages, and fixtures
  - POU materials storage
  - Materials handling between work stations

Cell With One Worker

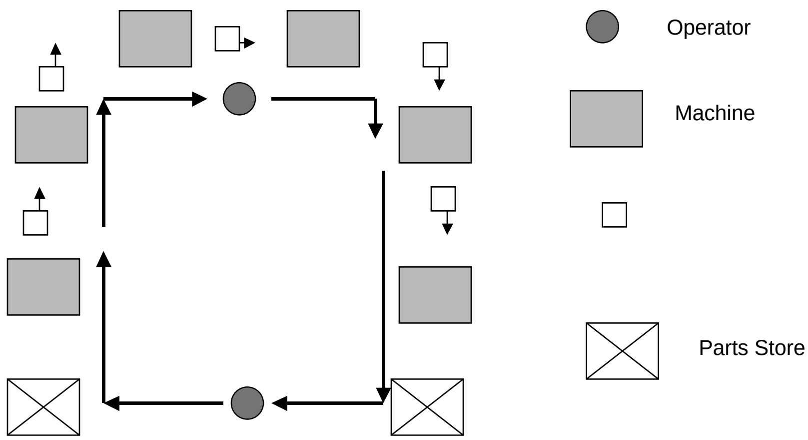


Assumption: Single operator can operate all machines and meet demand.

Cell With Two Workers



Two Workers - Rabbit Chase



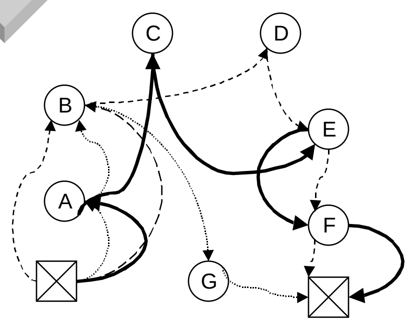
Work Cell Applications

- Work cells are more applicable for products (subassemblies) that are not extremely complex.

  Skills and abilities of the workers must fit the range of tasks required.

- Large work cells have a negative impact on teamwork.
- A workgroup of between 5 and 7 people is optimal- cells with 10 or more work stations are less common.
- If the products are very complex, a multi-station assembly line is typically used, with work cells potentially acting as feeder cells.

Work Cells For Multiple Product Families



Product Family	Routing sequence
X	A-C-E-F
Y	B-D-E-F
Z	A-B-G

- Note that all three product families have similar routings.
- Some families skip selected operations.
- Could deploy a lighting scheme to identify which operations are used for a given product family now being produced.

Linked Work Cells and Sub-cells

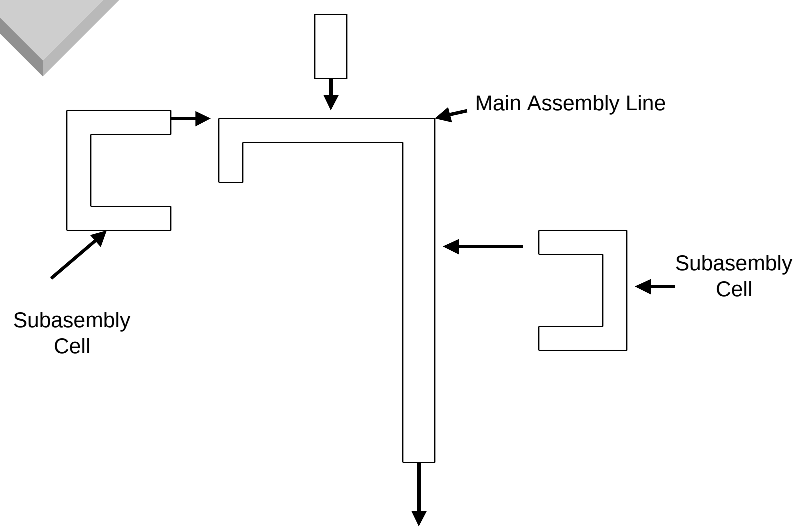
❖ Products with several assembly steps and made from parts that also require several fabrication steps can also be make in cells.

❖ All the operations are divided into logical work cells, and then the work cells are linked so parts and assemblies flow in a coordinated manner.

❖ The material handling between cells can be via conveyors (not best choice) or mechanical feeders, handcarts, or fork lifts

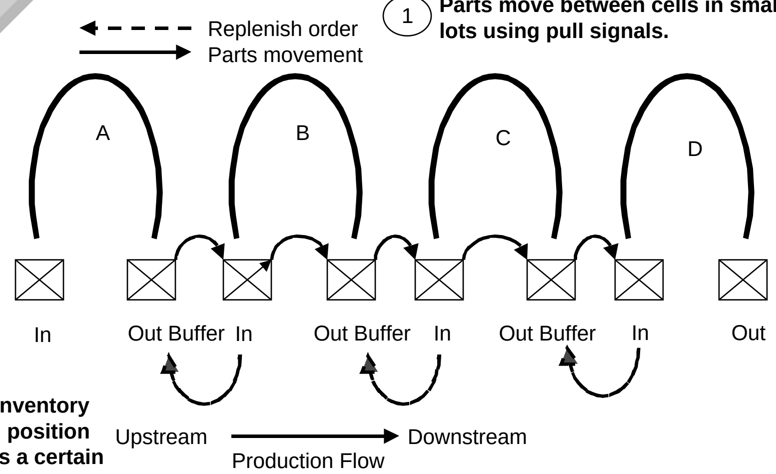
❖ Material transfer is authorized by kanban.

Facility of Linked Work Cells



Linked Cell

(1) **Parts move between cells in small lots using pull signals.**



(2) **When inventory at "in" position reaches a certain level, pull is initiated**

(3) **Enough stock is held in the "Out Buffer" to make sure no downstream cell is starved during replenishment.**

Linked Cell

- Linked cell system just described is a classic pull production system, but uses the level of inventory in the containers as the signal for replenishment.
- Each cell produces only enough to bring its outbound inventory up to the maximum number of containers.
- The output of the final cell in the chain depends on the output rate of the bottleneck cell (cells are supposed to be balanced, but they may not be).

Work Cell Design

- Assembly Cells
  - work tasks are entirely or mostly manual
  - work tasks are usually difficult or costly to automate (welding, testing of multiple components, hand assembly, etc.)
- Machining cells
  - work tasks are usually simpler, more-easily automated, and largely or entirely performed by machines
  - products are single-piece items that require little or no manual assembly
  - process involves a series of machining operations on a piece of metal, wood, plastic, or other material

Cycle Time Concept

- Cycle Time - The time between when units are completed in a process (time per unit)

- Cycle time is the inverse of the production rate (units per period of time)

- Required cycle time is sometimes called Takt time - Takt time is computed by determining the available time per day and dividing that by required customer demand.

  Assume that seven products totaling 80 units per day are to be placed into a cell that has 450 minutes available per day (one shift less 30 minutes lunch and relief.

$$\text{Takt Time} = \frac{450 \text{ minutes}}{80 \text{ units}} = 5.63 \text{ units/minute}$$

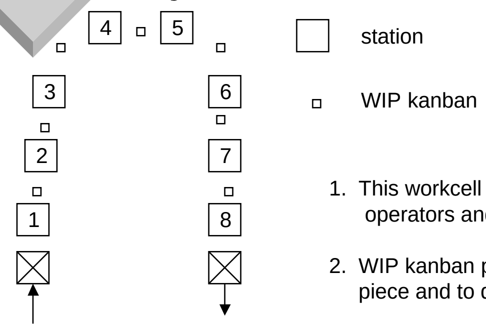
Further Definitions

- Note that Takt time does not take into consideration the time to produce a given product (demand for all products are added together to form a sum of total demand).

- Actual cycle time should represent demonstrated capacity. It is determined by physical conditions such as:
  - time to perform manual or automatic operations
  - machine time
  - time to walk around in the cell
  - changeover time
  - unplanned downtime
  - defective product
  - etc.

- Objective -- Cycle Time < Takt Time

Assembly Cells



1. This workcell can be operated by as many as 8 operators and as few as one.

2. WIP kanban provides a place to put a completed piece and to decouple adjacent stations.

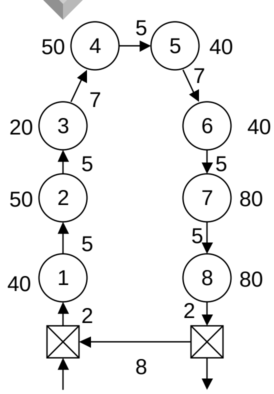
3. In an assembly cell the cycle time is determined totally by the manual time and is made up of manual operation (tasks) times and the time to move between stations.

4. If one person is in the cell then:

$$\text{Cell CT}_a = \sum \text{Operation Times} + \sum \text{Walk Times}$$

$$\text{Given the actual cycle time, the capacity of the cell is then } = \frac{\text{Time Available}}{\text{Cell CT}_a}$$

Work Cell Cycle Time and Capacity



Example 1: Work Cell CT and Capacity

Suppose the cell at the left is operated by one worker who walks from station to station. The number next to each station is the time required for the worker to perform the operation. The number by each arrow is the time to walk between locations (including the time To pick and place items at the locations.

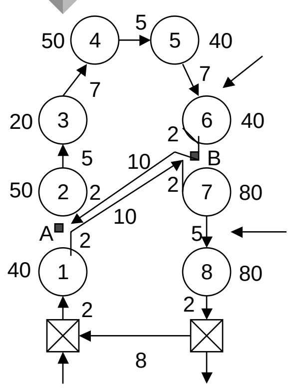
$$\text{Cell CT}_a = \sum \text{operation times} + \sum \text{walk times}$$

$$= 400 + 51 = 451 \text{ sec/unit}$$

Assuming an 8-hr workday

$$\text{Cell Capacity} = \frac{8 \text{ hours x } 60 \text{ min x } 60 \text{ sec}}{451 \text{ seconds / unit}} = 63.9 \text{ units per day}$$

Two Worker Assembly Cell



OP #1-2, 3, 4, 5, 6
CT_1 = 238 sec*

Controlling Cycle Time.

OP#2 - 1, 7, 8
input
output
CT_2 =231 sec

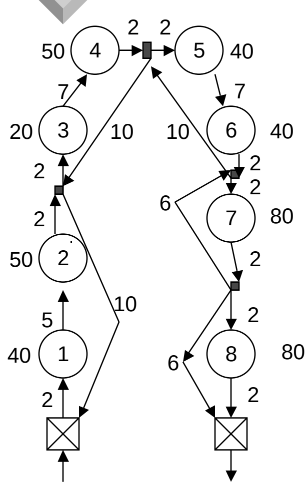
Operator #1 picks up the piece at area A and carries it to operations 2, 3, 4, 5, and 6 and puts it down in holding area B.

Example 2

Two workers now work in the cell shown at the left. The first worker Has operations 2, 3, 4, 5, and 6. The second worker has operations 1, 7, 8 and the input and output areas. The sum of the operation times and walk times are shown for each worker. Note the holding units shown by a black square.

After completing a piece at operation 1 the second worker drops a piece off at holding area A and proceeds to the piece located at area B. He/she then completes the work on that unit at operations 7 and 8 and places the unit In the out area.

Five Person Cell



Worker	Station	CT (sec)
1	1, 2	**109**
2	3, 4	91
3	5, 6	101
4	7	90
5	8	90

CT_a = 109 sec / unit

$$\text{Cell Capacity} = \frac{8 \text{ hr} \times 60 \text{ min} \times 60 \text{ sec}}{109 \text{ sec / unit}} = 264 \text{ units / day}$$

Total Idle Time = 18 + 8 + 19 + 19 = 64 seconds/unit

Rabbit Chase to Increase Capacity

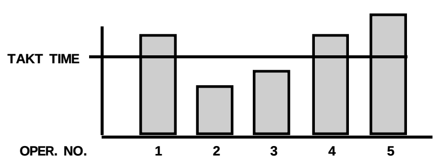
- One person follows another person around the cell, performing all operations to produce the part.
- Slowest worker will set the pace for the total cell.
- Every worker must be capable of performing all operations.
- Results in more walking time per worker.
- When cycle times are longer and tasks are more challenging, this approach can actually increase worker alertness and productivity over simply performing stationary work.
- Could also rotate jobs to increase alertness.

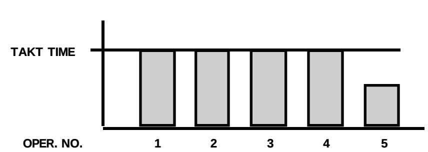
Line Balance

The objective of standard work is to achieve line balance.

BAD SITUATION: Each worker performs an individual cycle time at each work station.

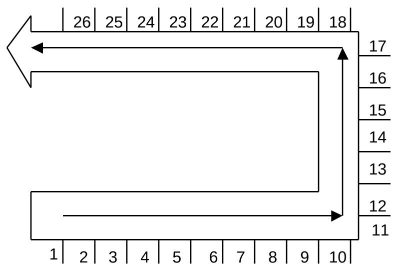
GOOD SITUATION: Workers share tasks and flex between work stations to balance output to demand.

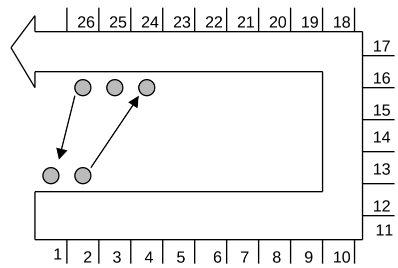




*REMEMBER: *Takt time changes as demand changes. Standard work must change with demand!*

Task Sequence Versus Standard Work





The individual tasks must be performed in sequence because of precedence relationships.

The sequence of task represents product Flow.

Standard work can be made up of some combination of tasks such that the sum of the task times is less than Takt time.

Machining Work Cells

- Operations are done by machines, with one or more machines located at every workstation.
- Machines are often automatic, single-cycle machines that stop after the machining operation has been completed.
- Stations and machines are connected to one another using a variety of devices called de-couplers.

  These allow machines in a sequence to operate somewhat independently of each other.

  In essence, this serves as a WIP kanban.

De-couplers

- WIP control; machine automatically stops when WIP reaches a certain level.
- Automatically transfer parts from operation to operation (e. g., gravity chutes, slides, or mechanical conveyors).
- With de-couplers, workers can move in any direction around the cell, even counter to the product flow.
- Automatic inspection is possible, even to the point of sensing some characteristic about the part that allows it to be routed to the appropriate downstream operation

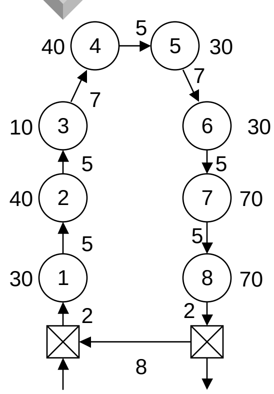
De-couplers (Cont.)

- Part manipulation: reorients the part so it is ready for insertion into the next machine.
- Skip operation: Identifies certain types of parts, so that subsequent operations can be bypassed.
- Enables multiple machines to feed into a single machine or a single machine to branch into multiple machines.

Other Characteristics

- Material is generally fed into one end of the cell and departs the other end (in contrast to material at point-of-use with assembly).
- Actual cycle times are based on the CTs of the machines in the cell and the manual task times of workers.
- For a cell that has a single-cycle automatic machine, the machine CT is the time per unit to set up the machine (unload, changeover, and load) and for the machine to perform its operation.
- The worker CT is the time for the operator to perform all activities to set up the machine and walk from one operation to another as required.

Machining Cells



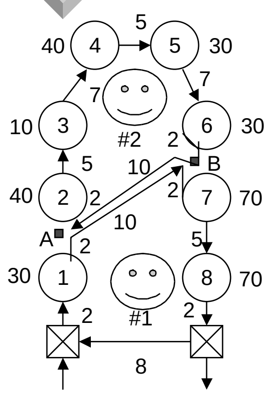
Example 3: The numbers beside the arrows is the walk time between stations. The numbers beside the circles is the machine time for the station. The task time per station is 10 seconds (unload, load, start).

With one operator:

Cell CT = Max (Worker CT, Longest machine CT)
Worker CT = 8 (10) + 51 = 131 sec / unit
Longest machine CT = 70 sec / unit + 10 sec / unit
= 80 sec / unit
Cell CT = Max (131, 80) = 131 sec / unit

$$\text{Cell Capacity} = \frac{8 \text{ hr x } 60 \text{ min x } 60 \text{ sec}}{131 \text{ sec / unit}} = 219.8 \text{ units per day}$$

Two Worker Machine Cell



Sub-cell 1: CT = 3 (10) + 31 = 61 sec / unit

Sub-cell 2: CT = 5 (10) + 38 = 88 sec /' unit

CT_m = Max (longest worker CT, longest machine CT)

= Max (88, 80) se¢ unit = 88 sec / unit

Capacity =(8 x 60 x 60) / 88 = 327 units / day

Creating a Lean Production Process

Capacity Planning and Takt Time

- Estimated capacity for each work center to be included in the cell.

$$\mathbf{Takt_{DC}} = \frac{\text{(HRS/SHIFT)*(NO. SHIFTS)}}{\text{DAILY DEMAND AT DESIGN CAPACITY FOR ALL PRODUCTS}}$$

Machining Cell Capacity Analysis (Example)

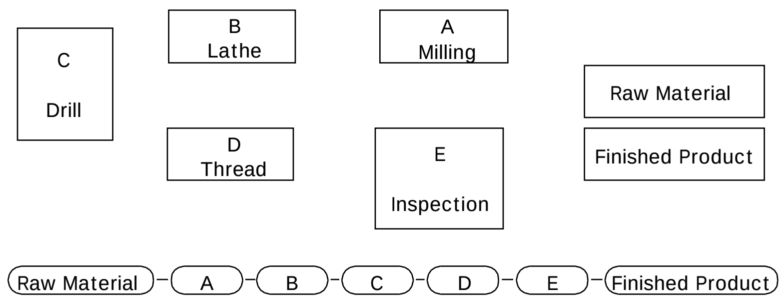
Part Number: 69242

Part Name: Master Cylinder

Regular Work Day: 420 Minutes

Required Daily Output: 450 Units

1) Machine Layout Diagram



Machining Cell Capacity Analysis (Example) [Cont.]

2) Processing Sequence and Times

Type of Processing		Mounting Surface Cut (A)	O.D. Cut (B)	Drill Hole (C)	Thread (D)	Check Thread Diameter (E)	
Manual Task Time (sec.)	3"	4"	5"	4"	3"	6"	3"
Automatic Run Time (sec.)		27"	30"	28"	12"		

Machining Cell Capacity Analysis (Example) [Cont.]

3) Tool Changes and Times

   a) Tools on machine A are changed in 60 seconds once every 100 parts.
   b) Tools on machine B are changed in 50 seconds once every 200 parts.
   c) Tools on machine C are changed in 100 seconds once every 300 parts.
   d) Tools on machine D are changed in 30 seconds once every 400 parts.

4) Miscellaneous

   a) 3 seconds walking time between machine.
   b) 3 seconds manual task time each for picking up raw material and putting down finished product.

Machining Cell Capacity Analysis (Example) [Cont.]

NEW/REV ____ /____ /____

SECTION HEAD	SUPERVISOR		TABLE OF PRODUCTION CAPACITY BY PROCESS	PART NO.		LINE NAME	Master Cylinder Processing		CURRENT OUTPUT PERSON/DAY
Fisher	Jones	Davis		PART NAME	Master Cylinder	MAX. OUTPUT-DAY		WORKERS NEEDED	

STEP NUMBER	PROCESS DESCRIPTION	MACHINE NUMBER	BASE TIME: WALKING TIME	BASE TIME: MANUAL TASK TIME	BASE TIME: AUTO RUN TIME	BASE TIME: TIME TO COMPLETE	TOOLS: # OF PIECES TO CHANGE	TOOLS: TIME TO CHANGE	TOOLS: TIME/PIECE	PROCESSING CAPACITY	REMARKS/ TIME INDICATED (Manual ——— Automatic - - - - Walking ∿∿∿)
1	Pick up raw material	-	3"	3"	"	3"					
2	Cut mounting surface	A	3	4	27	31	100	60	0.6	797	◄— 420 x 60 / 31.6
3	Cut O.D.	B	3	5	30	35	200	50	0.25	715	
4	Drill hole	C	3	4	28	32	300	100	0.34	779	
5	Thread	D	3	3	12	15	400	30	0.075	1672	
6	Quality check (thread diameter check)	-	3	6		6					
7	Put down finished product	-	3	3		3					
		TOTALS	21	28							
		GRAND TOTAL	49								

Required Output = 450 pcs

Takt Time = 56 sec

Operators Needed = 1.00

NOTE: REVISE TIMES EVERY TIME KAIZEN HAS SHORTENED THEM AND WRITE THE REASON FOR THE NEW TIMES IN THE "REMARKS" COLUMN.

Demonstrated Capacity

- Demonstrated capacity is estimated by considering the performance of a given piece of equipment over the recent past.
- Performance can be negatively influenced by several factors, including the following:
  - changeover times
  - defective parts
  - unplanned downtime
- If these non-value added activities are active, then the cycle time achieved when the equipment is running will must be <u>less</u> (lower time per unit) in order for the adjusted cycle time to be less than Takt time.

Capacity Planning with Multiple Models and Multiple Families

<u>Forming Product Families</u>

Product Name	Unit Volume	Activity (Process): Saw	Lathe	Grinder	Mill
03056	2000	(1) →		(2) →	(3)
06342	1000	(1) →		(2) →	(3)
03050	2750	(1) →	(2) →	(3) →	(4)
04922	1450		(1) →	(2) →	(3)
05021	850		(1) →	(2) →	(3)
05624	1240		(1) →		(2)

Capacity Planning with Multiple Models and Multiple Families (Cont.)

Remember:

$$\text{Takt Time} = \frac{\text{Total Time Available per Day}}{\text{Total Customer Demand per Day}} = \text{Time/Unit}$$

Average Cycle Time

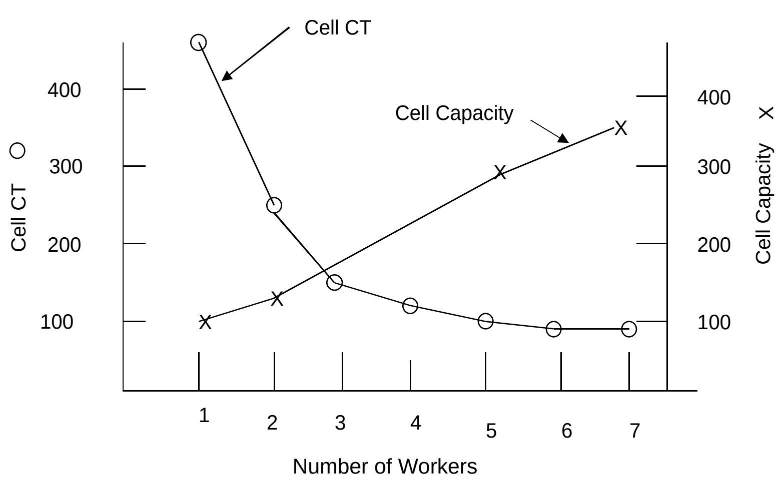
$$= \sum_{i=1}^{n} (\text{cycle time model}_i \times \text{model}_i \text{ percent total})$$

where n = number of models to be run in the cell

Model	% Total	Cycle Time
A	30	1.3
B	50	1.0
C	20	1.5

Average Cycle Time $= 0.30(1.3) + 0.50(1.0) + 0.20(1.5)$
$= 1.19$

AVERAGE CYCLE TIME MUST BE < TAKT TIME



Cost/Capacity Trade-off Analysis-Example 5

Consider again the eight-station assembly cell and the four staffing levels investigated Earlier. Reviewing the results,

No. Workers	Cell CT (sec)	Output = 60 sec x 60 min/ cell CT (units/hr)
1	451	7.98
2	238	15.13
5	109	33.03
8	84	42.86

Suppose the machine operating cost of the cell is $80/hr, and the labor rate per worker is $10/hr. The total direct labor cost is then $10/hr x no.of workers, and total unit manufacturing Costs is:

No. of workers	Direct labor cost (($/hr) A	Machine Operating cost ($/hr) B	Unit cost (A+B)/ Output ($ / unit)
1	10	80	90 / 7.98 = 11.28
2	20	80	100 / 15.13 = 6.61
5	50	80	130 / 33.03 = 3.94
8	80	80	160 / 42.86 = 3.73

Cost/Capacity Trade-off Analysis

- Increasing rates of output from additional workers more than offset increasing direct labor costs when the labor rates are low relative to the other cell costs. Note what happens below when the labor rate goes from $10 to $20 per hour.

The labor rate per worker is now $20/hr and the other cell costs are still $80 per hour. The total direct labor cost is then $20/hr x no.of workers, and total unit manufacturing costs are:

No. of workers	Direct labor cost (($/hr) A	Machine Operating cost ($/hr) B	Unit cost (A+B)/ Output ($ / unit)
1	20	80	100 / 7.98 = 11.28
2	40	80	150 / 15.13 = 7.93
5	100	80	180 / 33.03 = 5.45
8	160	80	160 / 42.86 = 5.60

- The lowest costs now occur at 5 workers and may be at four or six workers.

Cost/Capacity Trade-off

- In situations where cells process many small jobs of different products with frequent changeovers, the number of workers is determined more by the required cycle time (demand) than by manufacturing costs.
- Cross-trained workers can be shifted from cell to cell as needed by demand.
- Adding or deleting workers at a particular cell represents no net change of employees to the company.
- Issue - how often do we change the crew size in a cell when we move from one product to another?

  - Is it easier to let the crew remain the same if sufficient capacity is available?

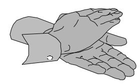
Sequential Changeover of Machines

	Machine				
Cycle	1	2	3	4	5
1	Change	X	X	X	X
2	Y	Change	X	X	X
3	Y	Y	Change	X	X
4	Y	Y	Y	Change	X
5	Y	Y	Y	Y	Change

1. Product is on X and wants to move to Y.
2. First cycle around operator changes machine 1 to Y.
3. Next cycle operator changes machine 2 to Y.
4. Will take five cycles to change the cell over, but it is not terribly disruptive.

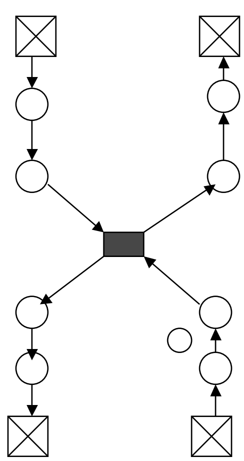
Productivity Improvement

- Emphasis is on reducing the number of people to produce at Takt time, not reducing the cycle time (reducing cycle time would result in over-production).
- If you are able to reduce the number of people, the first one to go should be the most highly skilled worker.



- It is easier to reassign the most skilled person and it is looked on as a reward for good performance, not a penalty for poor performance.
- Also want to work on trying to achieve about the same cycle time for every item within a product family; avoid changing crew sizes every time a product is changed.

Shared Machines



1. Machine located between two adjacent cells.
2. Theoretically it resides in both.
3. What would be some of the problems associated with this arrangement?
4. As a manager, what would you have to do in order to make it work?

You could also have a scenario where the shared machine is a monument (difficult or very expensive to move). Material flows to it from all over the facility. Has same disadvantages as the one to the left, but also has serious distances that must be traveled.

When cells share machines, the advantages of cellular manufacturing are diminished.

Machine Acquisition

- Must rethink the types of machines we buy.
- Rather than costly, multipurpose or special order machines, we need to think about purchasing inexpensive, slower, and fewer-purpose machines (but many of them).
- Conventional machines are typically simpler for workers to operate and less costly to maintain.
- To foster reconfiguring cells often, machines and workstations should be small, mobile, and have simple utility hookups.

Planning and Control

- Organizations implementing work cells usually have centralized planning and control systems already in place.

  This is usually an MRP system where the focus is on order releases and completion dates for all individual components and higher level assemblies in a product.
- Focus in cellular manufacturing is what is going out of a cell. You move from planning and controlling all machines to planning and controlling the entire cell.

MRP Survey

- 57 companies that had implemented cellular manufacturing:
  - 75% had used MRP before implementation
  - 71% still used MRP systems after implementation
  - 33% of the 71% moved to kanban pull systems
  - Only 13% used kanban only systems and only 31% used MRP only
- Must use MRP systems for planning and pull systems for execution.
  - Pull systems have no forward looking capability
  - Must use MRP system for future planning (forecasting) and order entry

Adapting MRP Systems

- Centralized system must forecast demand, accumulate job orders, perform rough-cut capacity planning, and prepare and coordinate master production schedules.
- To adapt MRP systems for releasing orders to work cells, the product bills of material must be restructured.
- Once an order arrives at a work cell, all detailed job sequencing, scheduling and control are performed by work cell supervisors and operators.

Roles and Responsibilities

- In addition to their normal duties, operators usually take on added responsibilities:
  - Inspection
  - Basic maintenance and repair
  - Job prioritizing
  - Dispatching
- Primary function of staff shifts to supporting the workers.
  - training work cell operators
  - providing on-demand technical guidance
  - performing tasks that require high-level expertise (e.g., some maintenance tasks)
- Quality control staff does company quality audits, certifies suppliers, trains workers in inspection procedures, and does tests and inspections that require specialized skill / knowledge.

Time and Rate Standards

- Time standards are usually based upon one person performing a given set of tasks.

  They are usually not applicable in a cell environment where a team of workers perform a different set of tasks or perform them collectively.
- Motion patterns will also often change with one-piece flow.
- Labor standards will likely have to be developed after the cell is formed since they are used for capacity planning, product costing, work scheduling,and deriving gain-sharing baseline measurements

Attitudinal Issues

- Many staff people and supervisors will perceive the transfer of responsibility to the operators as a loss of power and prestige.
  - Supervisors, in particular may see their role as being redundant and unnecessary.
  - There are often no guarantees for supervisors about no layoffs.
  - There could also be additional work involved in training, coordinating, and problem solving for which there is no increased pay.

- Shop floor workers
  - Some will not want to broaden their base of skills
  - Problems with some union contracts
  - Pay for skills may help, but it is not the total solution

Management Issues

- The transition will require some capital outlay, as a general rule.

- The analysis to justify moving to work cells, cross-trained workers, etc. will require the use of multi-criteria methods of analysis that consider the intangible benefits of quality, flexibility, employee satisfaction, as well as the intangible risks (market and technology) of not adopting them.

- Cutting corners in not training people, not relocating equipment, will ultimately result in failure (or at best a minimum level of improvement over the prior condition).